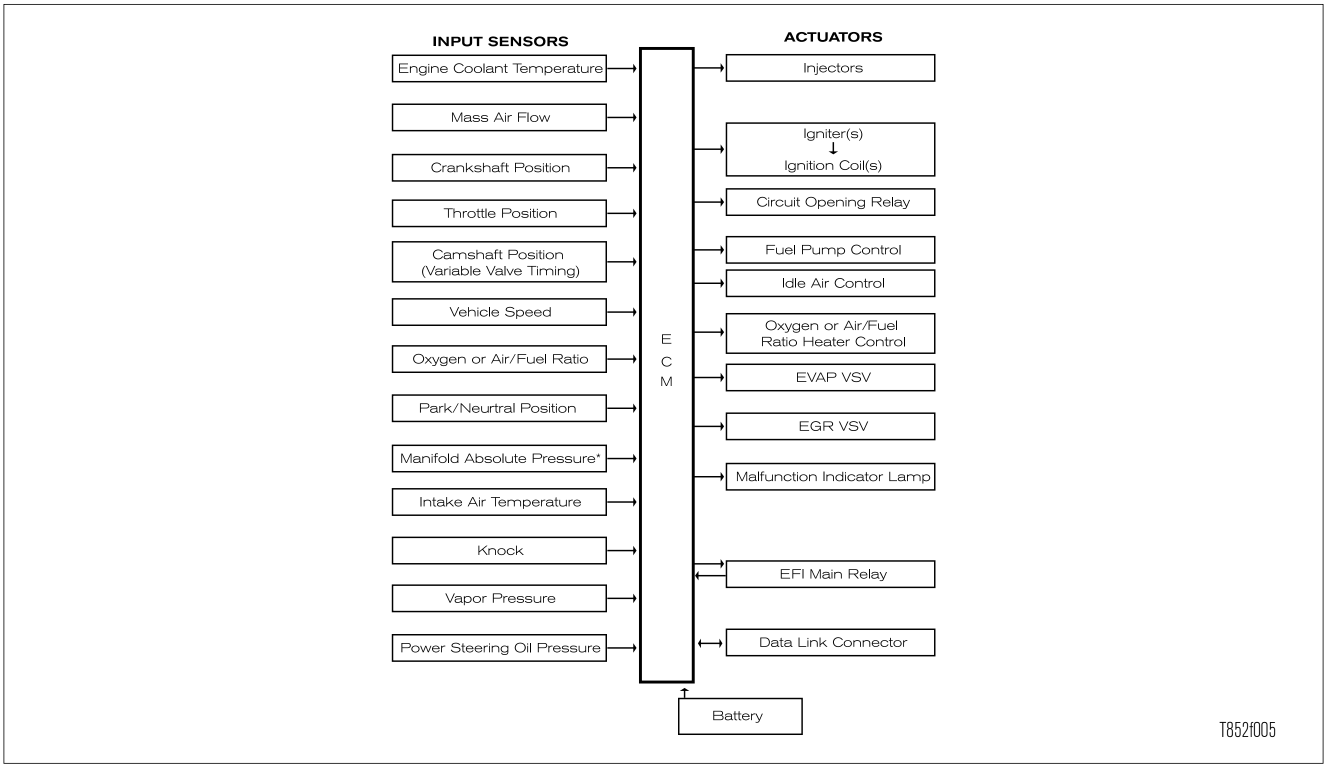
Section 1

Introduction to Engine Control Systems



Lesson Objectives

1. Identify major control systems/components
2. Locate needed engine control systems service information
3. Familiar with engine control systems terms

Notes

Section 1

Introduction to Engine Control Systems

Basic Engine Operation

The need to achieve high power output, high fuel economy, and the lowest amount of emission gases from today's engines has led to very sophisticated engine control systems. A computer, referred to as an Engine Control Module (ECM), manages a variety of engine systems. These systems are basically divided into the following areas:

- Air induction systems.
- Fuel system.
- Ignition system.
- Exhaust/Emission control system.

All the above and other systems are controlled or sensed by the ECM. The ECM with its sensors and actuators is often referred to as the electronic control system. It is important to keep in mind while diagnosing engine concerns that the fundamentals of engine operation (correct mixture of air and fuel sufficiently compressed and ignited at the proper time) are not different. The following is an overview of these systems.

Basic Air Induction System

The amount of air is measured and the air is controlled for efficient engine operation. The idle air control valve is not used on electronic throttle controlled systems. On some engines, an intake manifold pressure sensor is used in place of an air flow sensor.

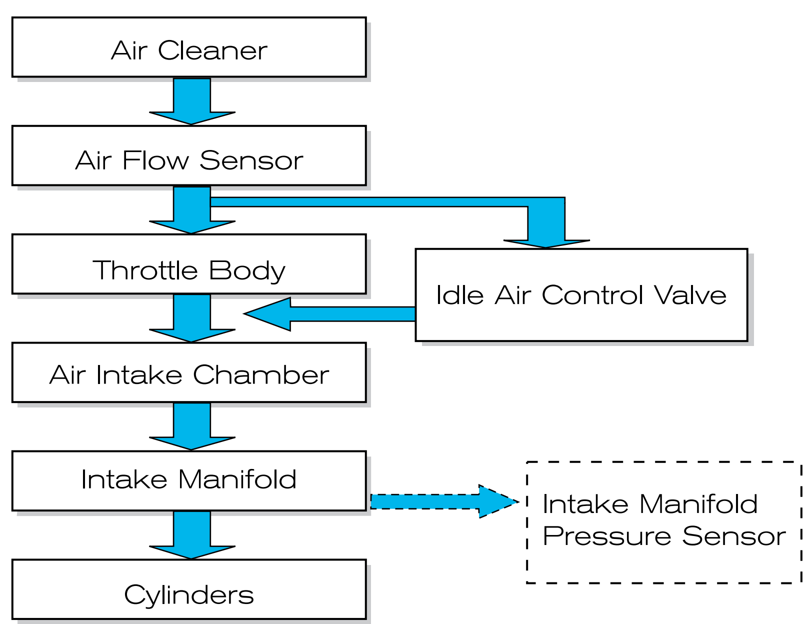


Fig. 1-01

T852f001

Air Induction System

Air filtered by the air cleaner is measured by the air flow sensor (commonly called the mass air flow sensor). The volume of air is regulated by the throttle valve. The idle air control valve regulates the amount of air bypassing the throttle valve to adjust idle speed. The air intake chamber and intake manifold are tuned for efficient engine operation.

There are many variations on the basic air induction system. The Acoustic Controlled Induction System (ACIS) modifies air intake runner length for greater efficiency. Some engines have turbochargers or superchargers to provide additional air.

Basic Fuel Injection System

Based on signals received, the ECM calculates how long and when to turn on the injectors to deliver the correct amount of fuel.

**The location of the pressure regulator varies with system. When excess fuel is returned to the fuel tank (return type) the pressure regulator is after the injectors. On the returnless fuel system, the pressure regulator is in the fuel tank.*

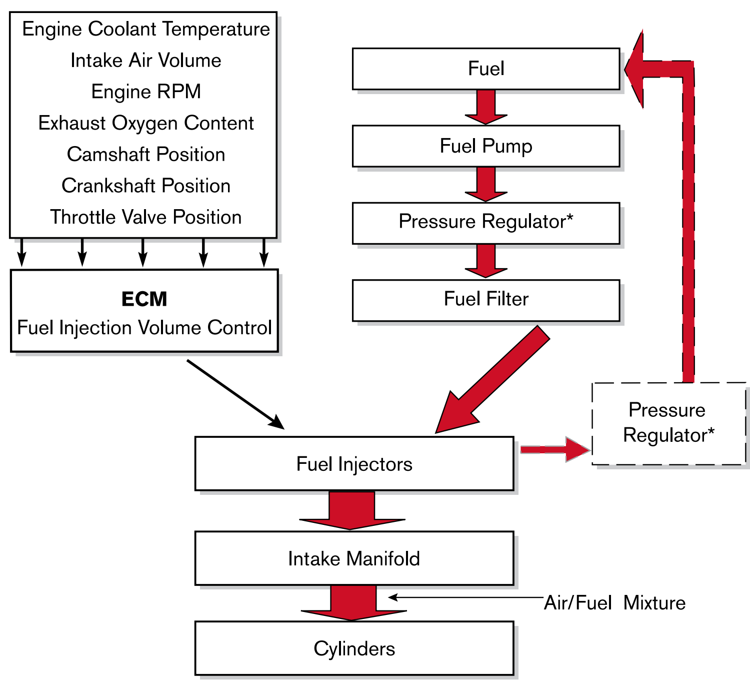


Fig. 1-02

T852f002

Fuel System

The fuel system needs to deliver the correct volume of fuel to the cylinders under a variety of conditions.

Fuel is pressurized by the fuel pump and flows to the fuel injectors. A pressure regulator, located in the fuel tank or after the injectors, regulates fuel pressure. The ECM controls when and how long the fuel injectors are on. The injectors, when on, allow fuel to flow into the intake manifold. The ECM calculates how much fuel to be injected based on a variety of parameters, primarily temperature and intake air volume.

There are other components used on a fuel injection system to modify its operation and are covered in the fuel system section.

Basic Ignition System

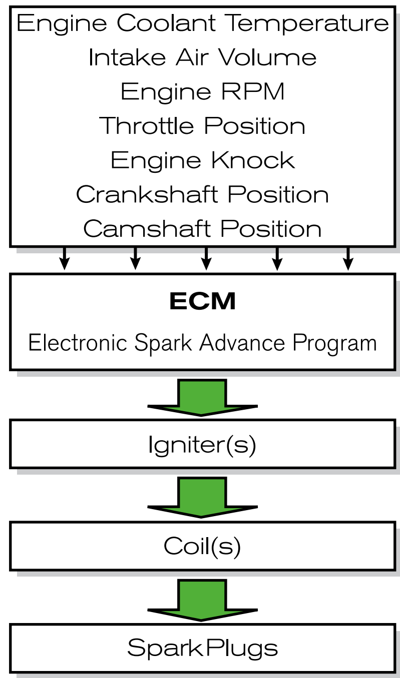


Fig. 1-03

T852f003

Ignition Systems

Based on engine operating conditions, the ECM determines when to ignite the air/fuel mixture according to its programming. The igniter turns the ignition coil(s) on and off based on a signal from the ECM. The high voltage needed to create the spark is generated in the coil(s).

Exhaust and Emission Systems

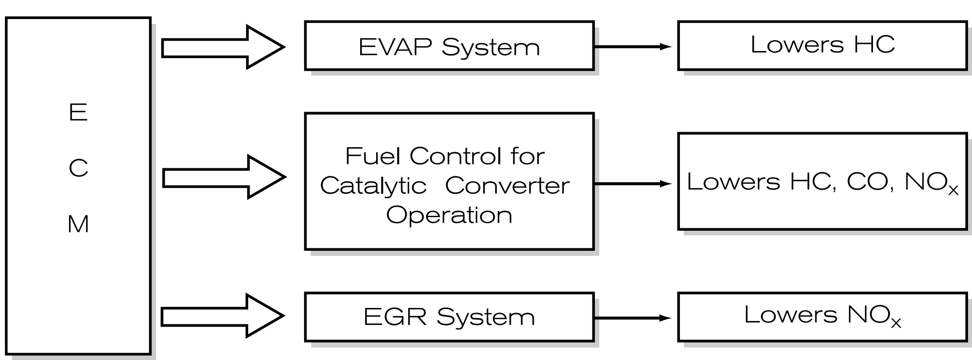


Fig. 1-04

T852f004

Exhaust and Emission Systems

The ECM manages systems and components to meet regulations. The evaporative system (EVAP) prevents gasoline vapors (HC) from entering the atmosphere. The fuel control program adjusts the air/fuel ratio so the catalytic converter runs at peak efficiency. This lowers hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). The exhaust gas recirculation system (EGR) also helps to lower NO_x.

Other Systems

Engine components that were once mechanically controlled are now electronically controlled. The goal is better engine efficiency and vehicle safety. Some of these systems are:

- Electronic Throttle Control-intelligent (ETCS-i) - the ECM adjusts throttle opening according to driver demand and vehicle conditions. This enhances vehicle performance and safety.

- Acoustic Control Induction System (ACIS) - the ECM will vary the effective intake runner length for better engine performance.

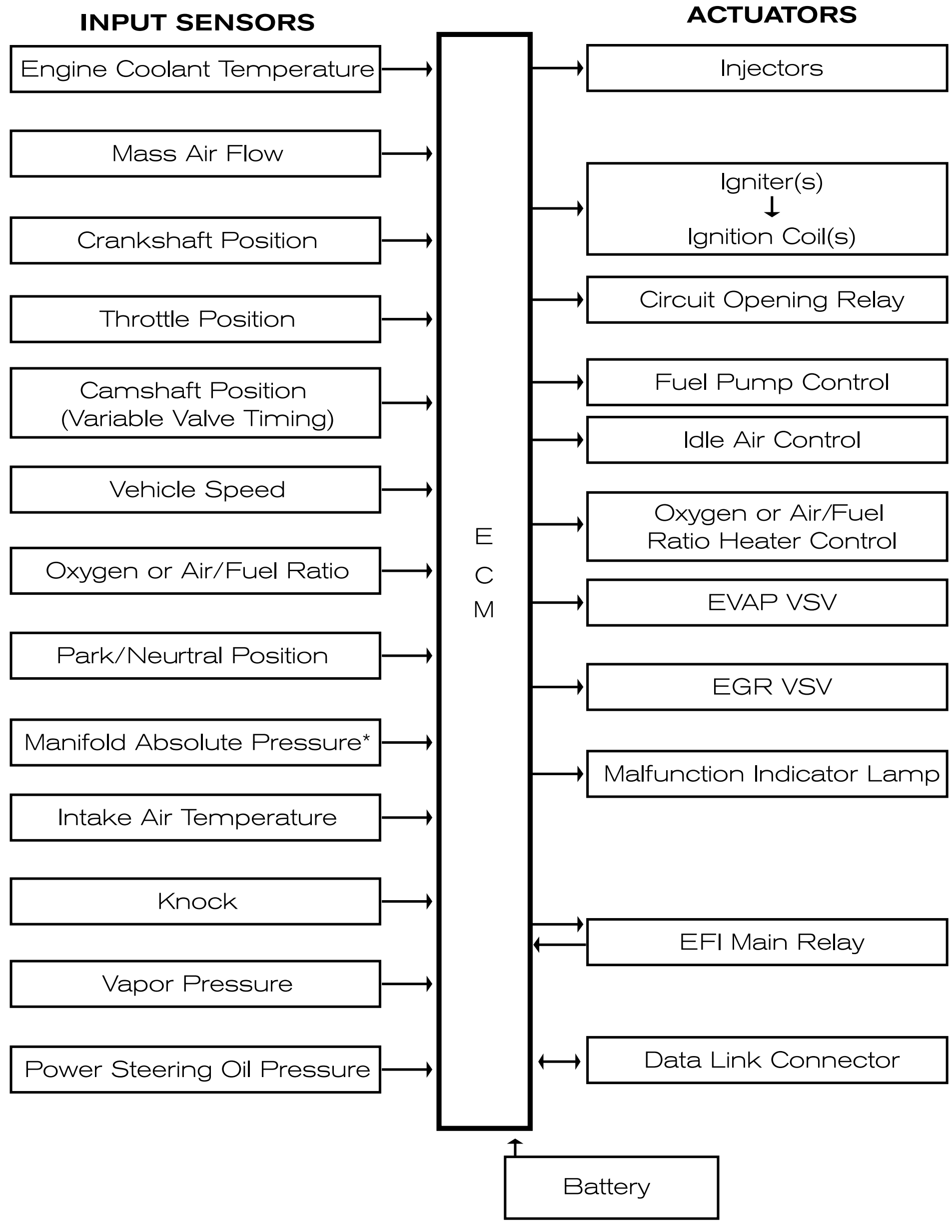
- Variable Valve Timing-intelligence (VVT-i) - the ECM adjusts when the valves open to provide better fuel economy, horsepower, and lower emissions.

There is no doubt that these systems will be modified and new systems added as new models are introduced.

Another significant trend is the integration of individual systems. For example, the ECM works in coordination with the Vehicle Stability Control system to provide better vehicle control in slippery conditions.

Basic Electronic Engine Control System

The following chart shows a basic electronic engine control system. Sensors provide the needed data. The ECM will will send the appropriate signal to the actuators.



**Manifold absolute pressure sensor equipped engines do not use a mass air flow sensor.*

Fig. 1-05

T852f005

Electronic Engine Control Systems

The electronic engine control system consists of sensors that detect various engine conditions, a computer called the Electronic Control Module (ECM), and numerous actuators that control a variety of engine components.

Accurate diagnosis of the electronic engine control system consists of several elements:

- fundamental knowledge of how the system works.
- finding the correct repair information.
- correctly interpreting data from the engine control system.
- performing the proper tests accurately.

To understand how the ECM controls various engine functions, the electronic control system is divided into three sections:

- input.
- process.
- output.

Electronic Control System

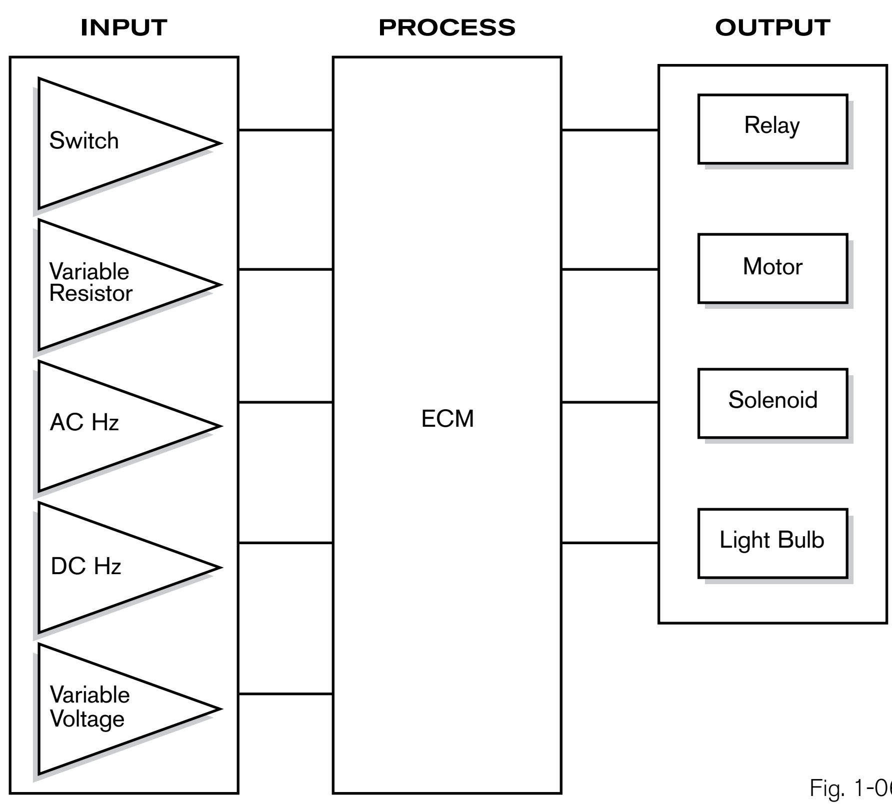


Fig. 1-06

T852f006

Inputs

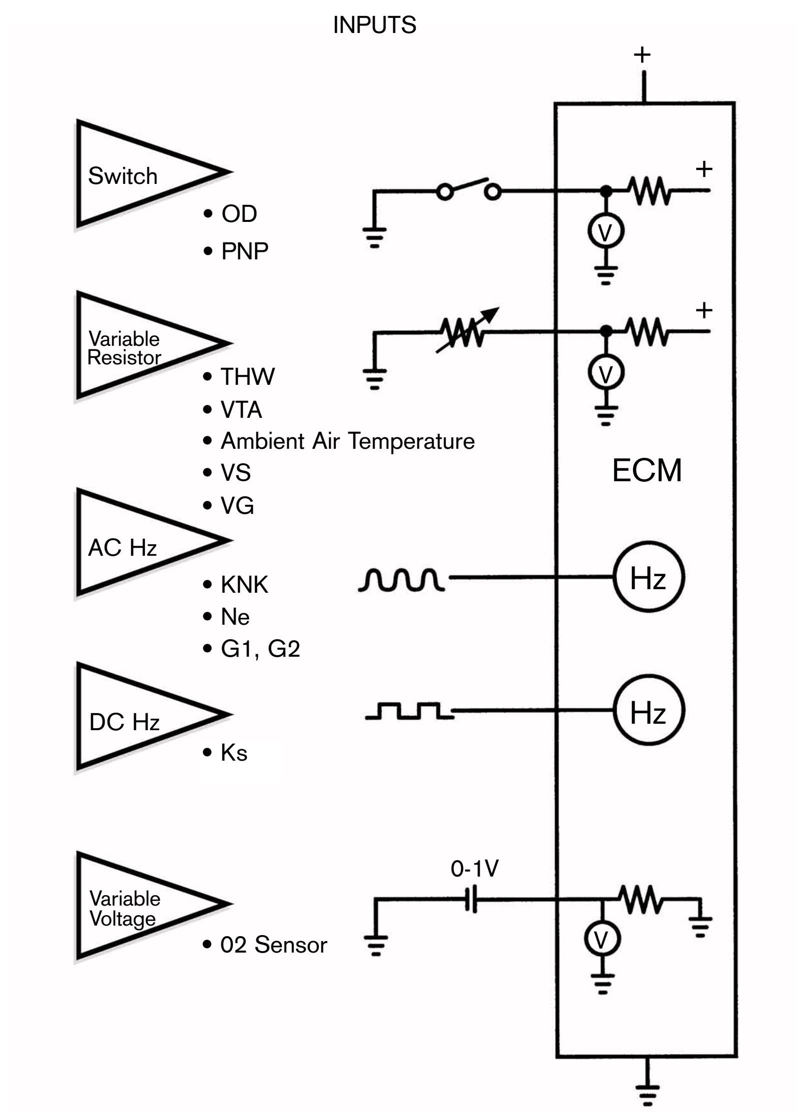


Fig. 1-07
T852f007

Inputs Sensors are used to convert engine operating conditions like temperature, rpm, throttle position, and other parameters into electrical signals which the ECM constantly monitors. Electronic circuits built into the ECM sense some circuits, (like the electrical load circuit) for proper operation. With this data, the ECM has sufficient information to run the programs that operate the engine and emission control systems.

ECM Processing Function

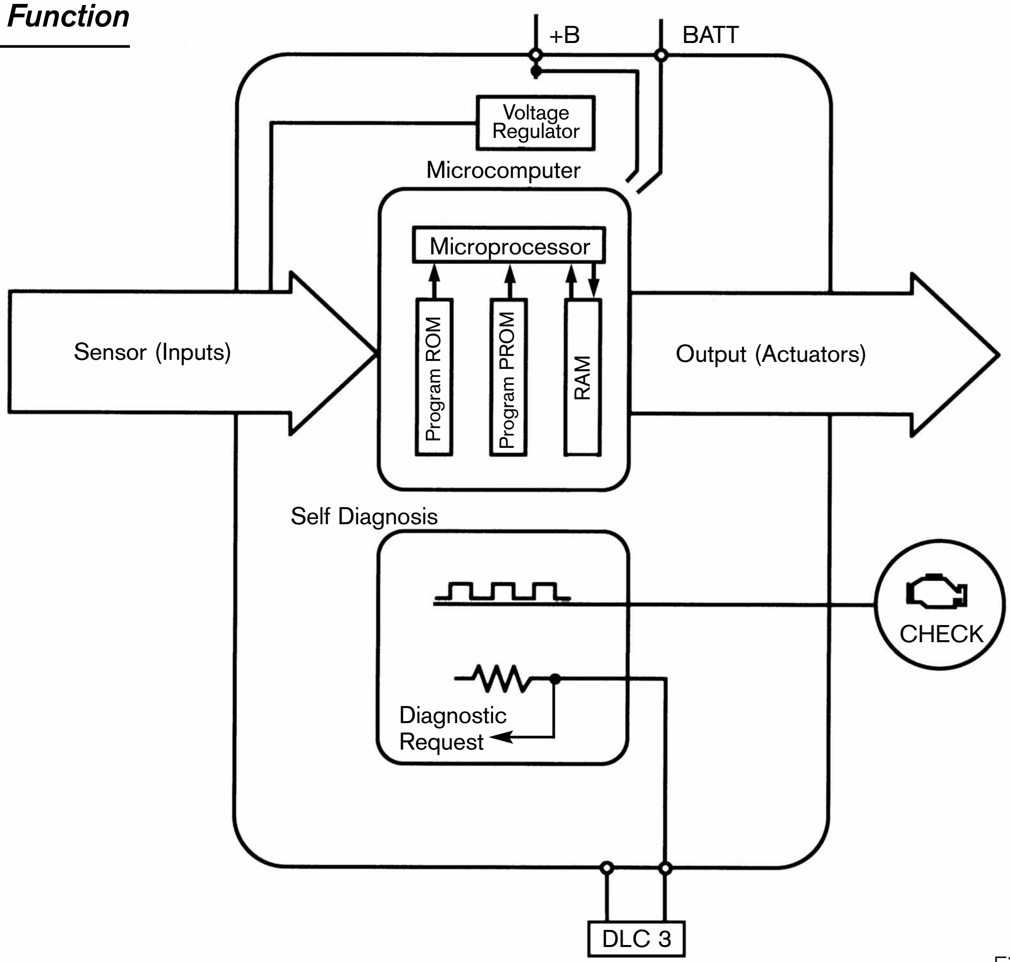


Fig. 1-08

T852f008

Engine Control Module (ECM)

The ECM processes the input signals, arrives at a decision based on its programming, and carries out the needed action. The ECM also stores in its memory vehicle/engine information to make certain the vehicle performs as prescribed, Diagnostic Trouble Codes (DTC) and other diagnostic information. The ECM may also control other functions such as transmission/transaxle control.

The latest ECMs also contain the vehicle information number (VIN), calibration identification (CAL ID), and calibration verification. This is done to insure the calibration settings are correct for that vehicle/engine.

ECMs should be handled with care. Electronic components are sensitive to electrostatic discharge (static electricity). Always follow the recommended procedures when handling these components.

Output Actuators and Devices

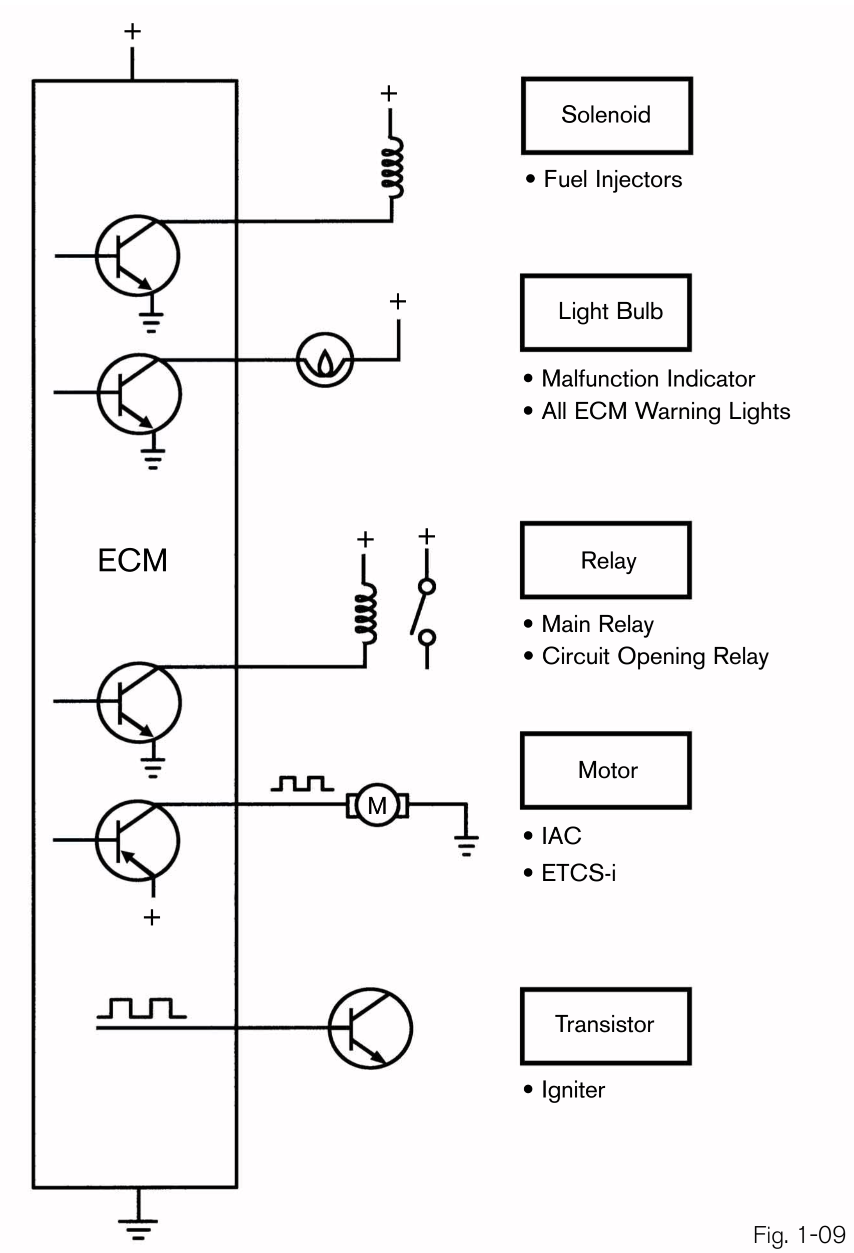


Fig. 1-09

T852f009

Outputs (Actuators)

Output commands are sent from the microprocessor inside the ECM to the various output driver transistors. The output drivers then turn on or off, causing the actuator (output) device to turn on or off.

Types of output actuators are:

- Solenoids - Fuel Injectors, Vacuum Switching Valves (VSV).
- Relays - Circuit Opening Relay.

- Transistors - Igniter.
- Lights - Malfunction Indicator Light (MIL).
- Motors - Electronic Throttle Control Motor.
- Heater(s) - Oxygen and Air/Fuel Ratio sensor heaters.
- Clutch - Electronic Throttle Control.

Power Distribution

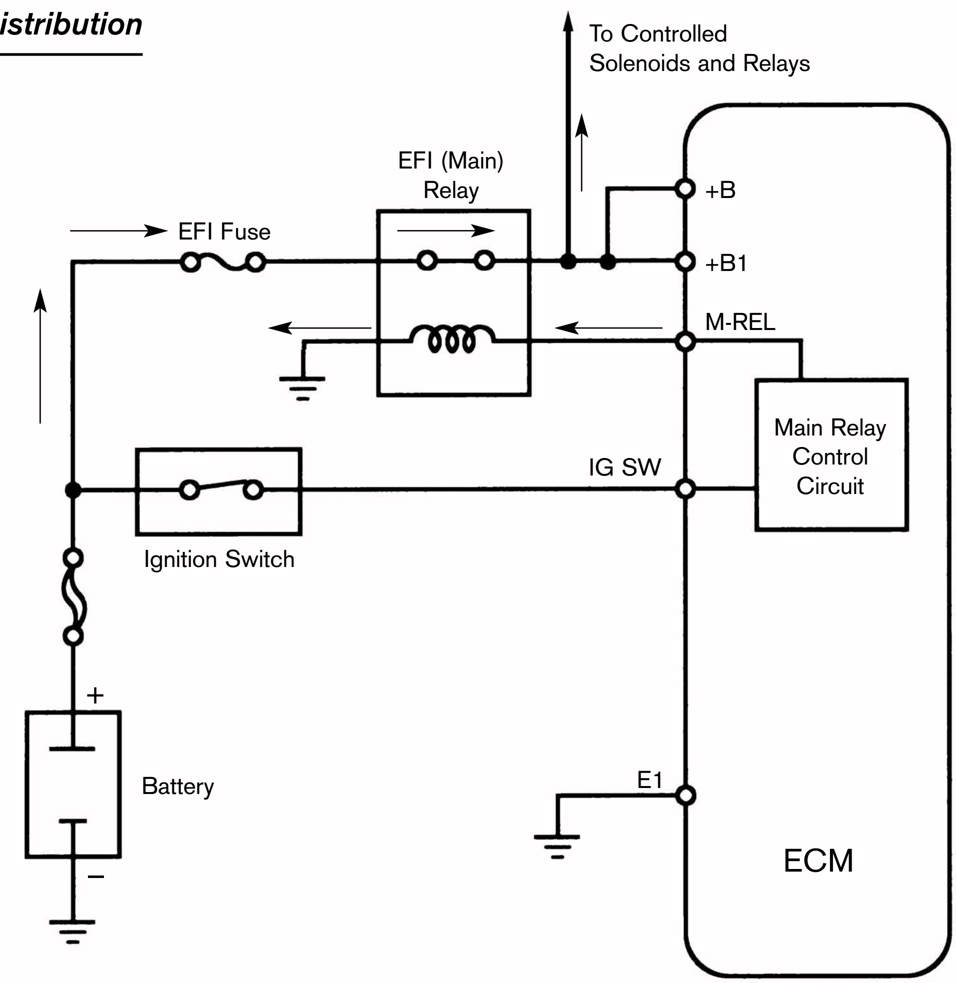


Fig. 1-10

T852f010

Power Distribution When the ignition switch is turned on, current is supplied to the ECM initializing the computer program, and supplying electrical current to all of the system controlled solenoids, relays, and motors. The current operating the ECM returns to ground through E1. Without a properly operating power distribution circuit, the ECM and engine will not function and there will be no communication with the Diagnostic Tester.

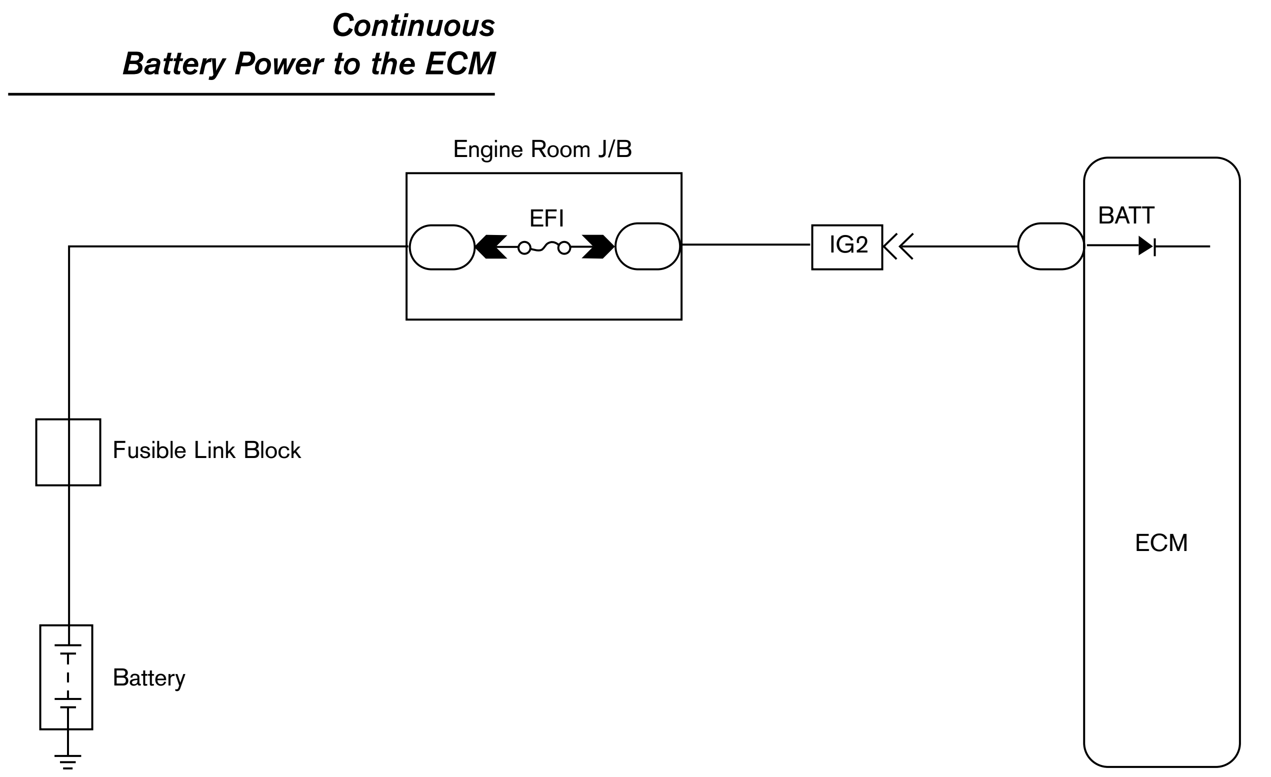


Fig. 1-11

T852f011

The ECM also has another battery power line used to store DTCs, ignition timing, fuel trim, and other values stored in memory. If there is no power at this terminal, DTCs and other stored memory values are erased.

Voltage Control Signal

The ECM sends out a regulated voltage of 5 volts on the voltage control (VC or VCC) signal line. This voltage is used for many sensors such as temperature sensors, position sensors, throttle position sensors, etc.

Ground Circuitry

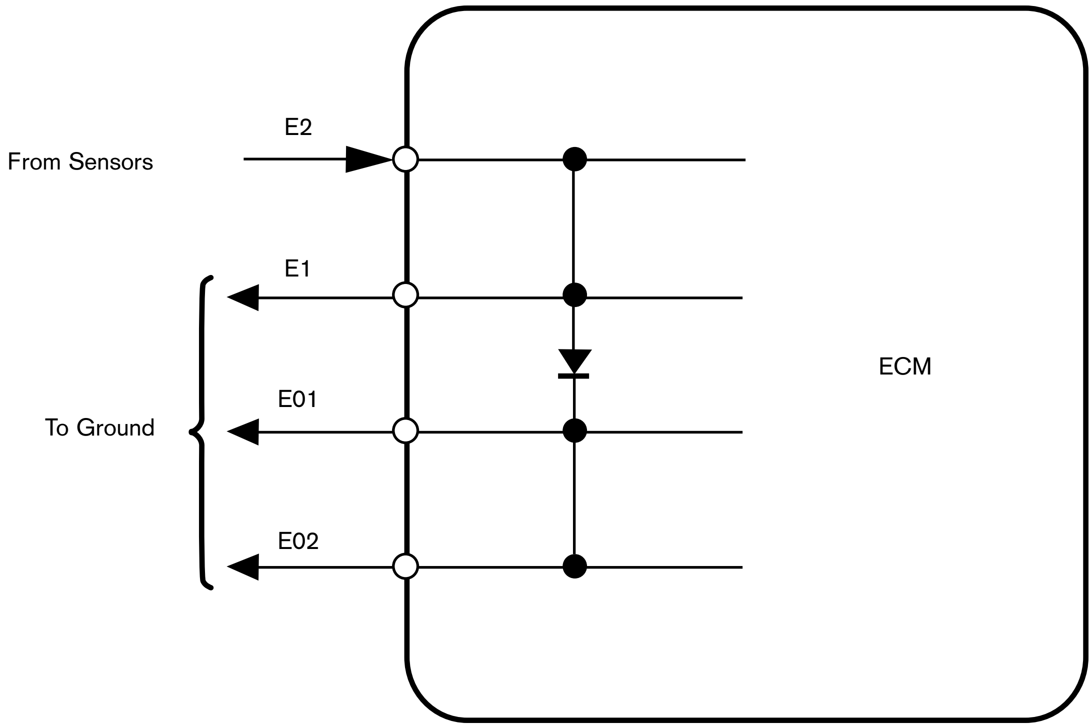


Fig. 1-12
T852f012

Ground Circuits

The ground circuit is equally as important as the power circuits. The ECM has multiple grounds, and is usually the ground path for sensors and actuators. The number of grounds will vary with engine and model year.

Ground circuits are often checked by measuring the voltage drop, and the wires are checked for continuity.

Despiking/ Clamping Circuits

When a circuit that carries a large current is suddenly turned off, a high voltage is induced in the coil windings found in relays and solenoids. This high voltage spike can damage the transistor in the ECM, generate a false signal in other circuits, or generate radio noise. A diode or resistor prevents these things from happening. The diode or resistor is connected in parallel to the coil winding limiting the high voltage spike. An ECM that is frequently being replaced for the same cause may have a damaged despiking diode/resistor in the circuit.

Despiking/Clamping Circuits

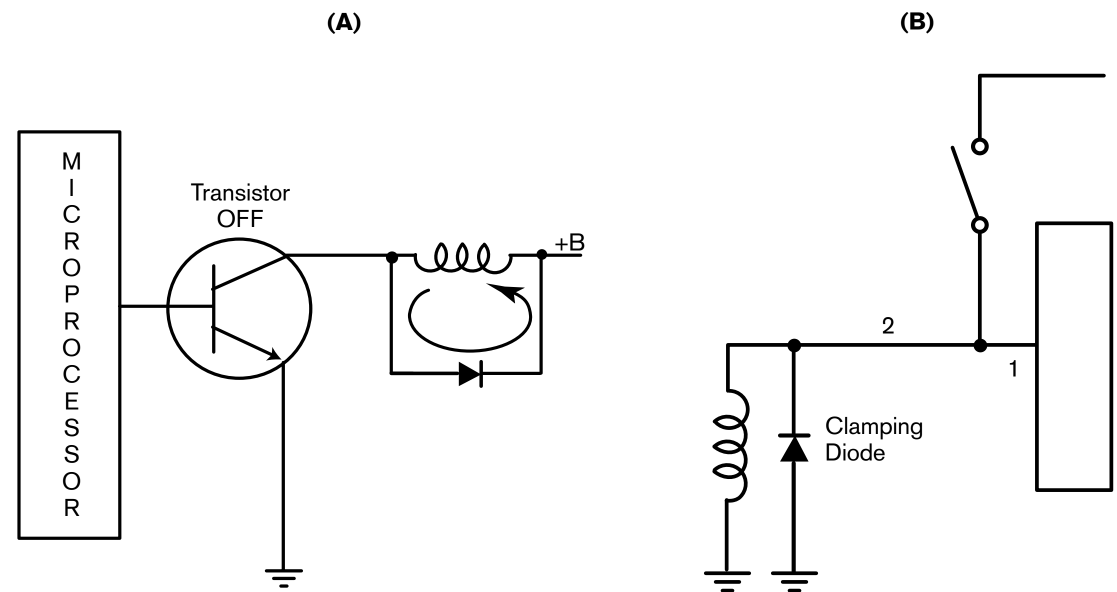


Fig. 1-13
T852f396/T852f014

Clamping Diode (A) During normal operation (circuit on) the diode is connected with a polarity that will not allow it to conduct. When the circuit is turned off, the collapse of the magnetic field across the coil induces a voltage in the opposite direction. The diode conducts this induced voltage preventing a voltage spike and damage to the ECM.

(B) With the switch closed, current flows in circuit 2 energizing the coil. Circuit 1 tells the ECM the circuit is on. The diode will not conduct current as this time.

When the switch is turned off the magnetic field around the coil collapses. This collapse generates a voltage in the coil with opposite polarity (top, negative, bottom: positive). This polarity is correct for the diode to conduct, so current will flow through the diode. This will prevent voltage from building on circuits B and A and prevent high voltage from damaging the ECM.

Resistor Clamping Circuit

A resistor can be used for the same purpose. The resistor has a very high resistance in relation to the circuit (400-600 Ohms). The resistor provides an alternative path preventing the high voltage spike

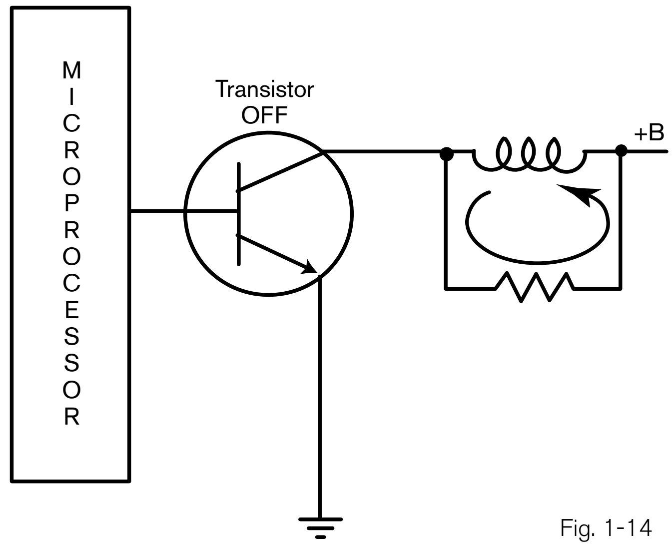


Fig. 1-14

T852f015

Diagnostic Link Connectors

Three types are shown here. DLC1 is found under the engine hood. DLC2 is found in the passenger compartment, drivers side. DLC3 is found within a foot (right or left) of the steering column.

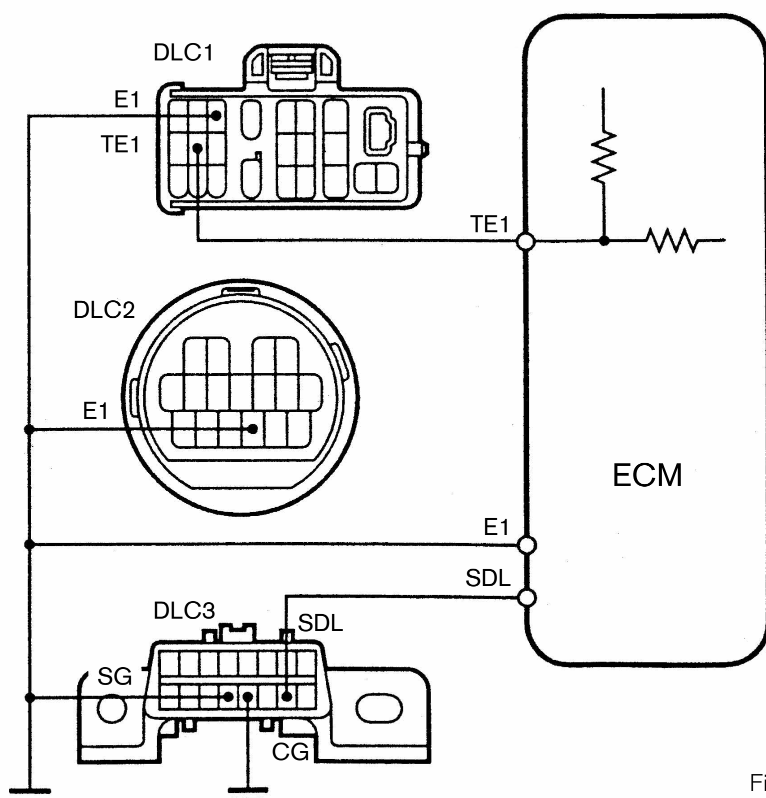


Fig. 1-15

T852f016

Diagnostic Link Connectors

The Diagnostic Link Connector (DLC) provides a way to communicate with the ECM and simplifies many diagnostic procedures.

Three types of DLCs have been used, and some years will have all three. OBD II regulations require a standard DLC for vehicles, and it is referred to as DLC3.

EngineControl System Diagnostic Information

Knowing where to find the information can save you time. The following is an explanation of the information resources are needed for accurate and timely repairs.

Repair Manual

The Repair Manual (RM) contains the following sections (note: this section follows the 1996 and newer format).

Introduction (IN)

This section contains how to troubleshoot ECU controlled systems, the abbreviations used and a glossary of terms. You will find the troubleshooting procedures and where to find more information.

Diagnostics (DI)

This part is the most used section for diagnosing engine control system concerns.

- **Pre-Check** contains an overview of obtaining DTCs and Freeze Frame. Also, it describes what to do if there is no communication between the ECM and Diagnostic Tester.
- The **Fail-Safe Chart** is used indicating ECM strategy when certain DTCs are set.
- The **Basic Inspection Section** is a fundamental check of air, fuel, and spark.
- **Engine Operating Condition** explains the items displayed on the Diagnostic Tester and show normal condition signals.
- The **Diagnostic Trouble Code Chart** displays all the applicable DTCs for that engine, possible trouble areas, and the page to turn to to diagnose the DTC.
- **Parts Location** shows a picture of the vehicle where the major components are found.
- **Terminals of the ECM** shows a view of the ECM and its connectors as you would view them. This view is NOT in the EWD. This is a very useful view for knowing which circuit to to find and test. You will also

find the wire colors, signal acronym and standard voltages at each terminal.

- **Problem Symptoms table** is used when there is no DTC displayed to direct you to the appropriate area.

- **Circuit Inspection** is where the DTCs are diagnosed. At the end of this section, after the last DTC diagnosis, you may find the Starter Signal Circuit, IACV Control Circuit, ECM Power Source Circuit and Fuel Pump Control Circuit diagnosis.

Emission Control (EC)

Shows component checks of emission system components such as the EVAP canister, EGR system, etc.

Sequential Fuel Injection (SFI)

This section contains the component check for the sensors and actuators of the fuel injection system. Here you will find how to remove and test components.

Ignition System (IG)

This section shows how to check ignition system components.

Electrical Wiring Diagram Manual (EWD)

The EWD manual provides you sections and overall view of the engine control system with power circuits, ground circuit, connectors and associated numbers, and a brief description of operation. Because the wires are provided in color, it is often easier to use the EWD to locate components and related signals by wire color, then use the ECM connector view in the DI section to determine where to connect a DVOM or oscilloscope.

Diagnostic Tester Manual

This manual comes when a Diagnostic Tester is purchased. Updates are provided when the software card is updated. This manual provides you with operation of the tester in a variety of modes.

Technical Service Bulletins (TSB)

These bulletins provide you with the latest solutions and corrections that are not provided in the Repair Manual.

Hotline Support

The hotline is for those problems when you need advice when all other methods did not lead to a solution. It is critical that you provide and record all DTCs, conditions when symptoms occur, and what has been done to repair the concern. Accurate information is vital - write it down.

Technical Information System (TIS)

This networked computer system will provide you with all the above information in one location. The significant advantages of TIS is that large quantities of the latest information can be retrieved from one source, and the information can be accessed by a variety of methods.

History of On-Board Diagnostics

This section is a summary of emission control regulations and will provide background on the regulations that relate to On Board Diagnostics. The emphasis is placed on the differences between On Board Diagnostics, generation 1 (OBD) and On Board Diagnostics, generation 2 (OBD II).

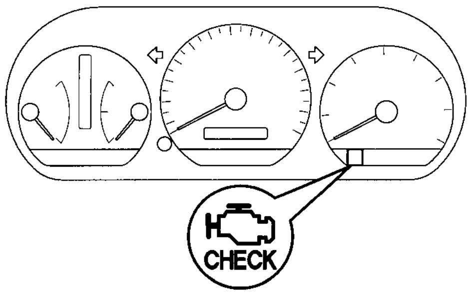
Federal and state efforts to improve air quality over the years have created regulations that influence the design of the emission and engine control systems on all vehicles. Standards are set to provide regulation, monitoring, and enforcement to achieve mandated goals. On Board Diagnostics (OBD) monitor the vehicle's systems and components and report failures through Diagnostic Trouble Codes (DTC). The state of California has been instrumental in setting emission standards. For this reason, systems have appeared on California vehicles before appearing on vehicles sold in other states (Federal Vehicles). Today federal and state standards may vary, but the equipment and monitoring systems are essentially the same.

OBD Objectives

The primary objective of OBD systems is to reduce vehicle emissions and the possibility of further damaging emission components by detecting and reporting a malfunction. To meet that objective:

- The driver is alerted of a malfunction in the emission control system by the Malfunction Indicator Lamp (MIL).
- All vehicles are certified to meet or exceed emission standards. OBD systems are designed to monitor and report malfunctions when emission output will exceed mandated standards.

OBD (On-Board Diagnostic System, Generation 1)



Current related checks (open or short)

Limited system monitoring (A/F & EGR)

Minimal use of rationality checks

Limited DTCs

Limited use of Serial Data

System and component names not standardized

DTCs not standardized

Fig. 1-16

T852f017

OBD (On-Board Diagnostic System, Generation 1)

In April 1985, the California Air Resources Board (CARB) approved On-Board Diagnostic system regulations, referred to as OBD. These regulations were phased in beginning in 1988 to include cars and light trucks marketed in the State of California. They required that the engine control module (ECM) monitor critical emission related components for proper operation and illuminate a Malfunction Indicator Lamp (MIL) on the instrument panel when a Malfunction was detected.

Although the OBD regulations initially apply to California emissions certified vehicles, some or all of the OBD system features are found on Federal emissions certified vehicles as well.

The OBD system uses Diagnostic Trouble Codes (DTC) and fault isolation logic charts in the repair manual to assist technicians in determining the likely cause of engine control and emissions system malfunctions.

The basic objectives of this regulation are twofold:

1. To improve in-use emissions compliance by alerting the vehicle operator when a malfunction exists.

2. To aid repair technicians in identifying and repairing malfunctioning circuits in the emissions control system.

OBD applies to systems that are considered most likely to cause a significant increase in exhaust emissions when a malfunction occurs. Commonly, this includes:

- All major engine sensors.
- The fuel metering system.
- Exhaust gas recirculation (EGR) function.

Components and circuits are monitored for continuity, shorts, and in some cases, normal parameter range. OBD systems were normally limited to the detection of an open or short in a sensor circuit.

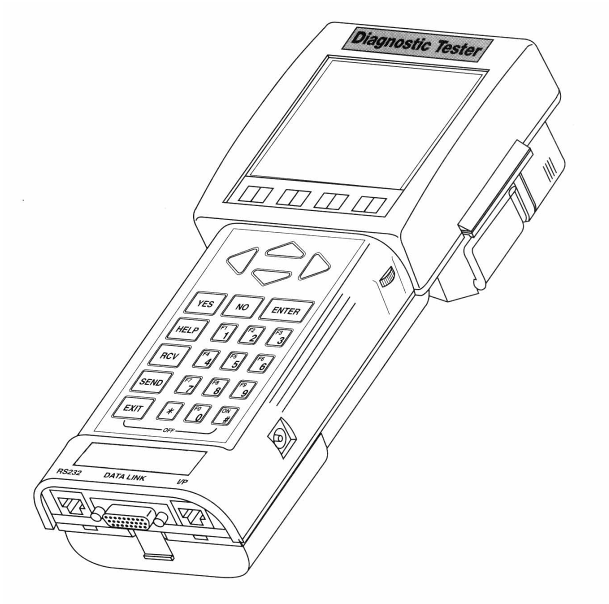
OBD Malfunction Indicator Light (MIL)

A Malfunction Indicator Lamp (MIL) is required to serve as a visual alert to the driver of a malfunction in the system. When a malfunction occurs, the MIL remains illuminated as long as the fault is detected and goes off once normal conditions return, leaving a Diagnostic Trouble Code (DTC) stored in the ECM memory.

OBD Diagnostic Trouble Codes (DTC)

Diagnostic Trouble Codes or DTCs are generated by the on-board diagnostic system and stored in the ECM memory. They indicate the circuit in which a fault has been detected. DTC information remains stored in the ECM long-term memory regardless of whether a continuous (hard) fault or intermittent fault caused the code to set. Toyota products with OBD store a DTC in the ECM long-term memory until power is removed from the ECM. In most cases, the EFI fuse powers this long term (keep alive) memory.

OBD II (On-Board Diagnostic System, Generation 2)



- Circuit continuity and out of range values monitored
- Systems monitored
- Rationality checks used (logic)
- Expanded DTCs
- Freeze Frame Data stored with DTC
- Serial Data required
- Active Tests
- Standards established

Fig. 1-17

T852f018

OBD II (On-Board Diagnostic System, Generation 2)

Although OBD supplies valuable information about a number of critical emissions related systems and components, there were several important items not incorporated into the OBD standard because of technical limitations at the time. Since the introduction of OBD, several technical breakthroughs have occurred and stricter emissions standards were mandated.

As a result of these technical breakthroughs and because existing Inspection and Maintenance Diagnostic programs proved less effective than desired in detecting critical emissions control system defects under normal operation, a more comprehensive OBD system was developed under the direction of CARB called OBD II.

OBD II, which was phased in the 1994 through 1996 model years, added catalyst efficiency monitoring, engine misfire detection, evaporative system monitoring, secondary air system monitoring, and

EGR system flow rate monitoring. Additionally, a serial data stream consisting of twenty basic data parameters and a common system of diagnostic trouble codes was adopted.

The goal of OBD II is to monitor the effectiveness of the major emission control systems and to turn on the Malfunction Indicator Light (MIL) when a malfunction is detected. For example, the ECM diagnostic system monitors the engine cylinder misfire. If the rate of cylinder misfire is out of range, the MIL will illuminate and a DTC will set. In addition, if the ECM detects misfire conditions severe enough to damage the catalytic converter the MIL will blink.

The ECM diagnostic system monitors malfunctions in the powertrain that either provides input to (directly or indirectly), or receives commands from the ECM. Components or systems are monitored that effect emissions output. These monitors are designed to detect malfunctions in the powertrain and report when there is a system or component failure.

OBD II Standardization

OBD regulations and technical standards have been developed with the cooperation of the automotive industry and the Society of Automotive Engineers (SAE). A number of applicable SAE J standards were developed to implement an OBD II plan that was acceptable to all manufacturers. The following list is an example of the areas of standardization:

- ISO 9141, (International Standards Organization) Serial Data Protocol
- J1850, Serial Data Protocol.
- J1930, Terms and Definitions.
- J1962, Standard OBD II Diagnostic Connector.
- J1978, Generic Scan Tool.
- J1979, Diagnostic Test Mode and Basic Serial Data Stream.
- J2008, Electronic Service Information Access and Data Format.
- J2012, Diagnostic Codes and Messages.
- J2190, Enhanced Diagnostic Test Modes and Serial Data Streams.

Access to all OBD II data is made by connecting an OBD II compatible scan tool to a standardized Data Link Connector (DLC) located under the left side of the instrument panel. The standards for data, the scan tool, diagnostic test modes, diagnostic trouble codes, and everything related to the introduction of the OBD II regulation was established by the Society of Automotive Engineers and adopted by the government and the manufacturers.

NOTE A glossary of SAE J1930 and Toyota terms and definitions can be found in the Introduction section of the Repair Manual.

OBD II Monitors

The goal of the OBD II regulation is to provide the vehicle with an on-board diagnostic system capable of continuously monitoring the efficiency of the emissions, the control system, and to improve diagnosis and repair efficiency when system failures occur.

As an example, OBD II systems test the operation of the oxygen sensor, exhaust gas recirculation system, and so forth, whenever conditions permit. It is the function of the ECM to monitor these systems and components and perform necessary tests to assure that the emission systems are operating properly.

Beginning with the 2000 model year, manufacturers will be required to phase-in diagnostic strategies to monitor the thermostat on vehicles so equipped for proper operation. In addition, beginning with the 2002 model year, manufacturers will begin to phase-in diagnostic strategies to monitor the PCV system on vehicles so equipped for system integrity.

OBD II Malfunction Indicator Light (MIL)

When a malfunction occurs and meets the criteria to set a DTC, the MIL illuminates and remains illuminated as long as the fault is detected. A Diagnostic Trouble Code (DTC) is then stored in the ECM memory. The MIL will be turned off after 3 warm-up cycles once normal conditions return.

OBD II Diagnostic Trouble Codes (DTC)

Unlike OBD Diagnostic Trouble Codes, OBD II codes have been standardized by SAE. They indicate the circuit, and the system in which a fault has been detected. Once the condition returns to normal, the DTC remains as an active code for 40 drive cycles. The code will be automatically erased after 40 cycles, but will remain in the ECM history until cleared.

Each DTC is assigned a number to indicate the circuit, component, or system area that was determined to be at fault. The numbers are organized such that different codes related to a particular sensor or system are grouped together.

OBD II Diagnostic Trouble Code Chart

	First Digit	Second Digit	Third Digit	Fourth & Fifth Digit
	Prefix Letter of DTC Indicates Component Group Area	SAE or Controlled 0 = SAE	Powertrain DTC Subgroup	Area or Component Involved
	P = Powertrain	1 = Manufacturer	0 = Total System	
	B= Body		1 = Fuel & Air Metering	
	C = Chassis		2 = Fuel & Air Metering	
	U = Network Communication		3 = Ignition System or Misfire	
			4 = Auxiliary Emission Controls	
			5 = Speed, Idle & Auxiliary Inputs	
			6 = ECM & Auxiliary Inputs	
			7 = Transmission	
Example			8 = Transmission	
Fuel Trim Malfunction	**P**	**0**	**1**	**71**

Fig. 1-18

OBD II DTC Freeze Frame The DTC screen may have additional information available such as freeze frame data and help screens.

Manufacturer Enhanced OBD II

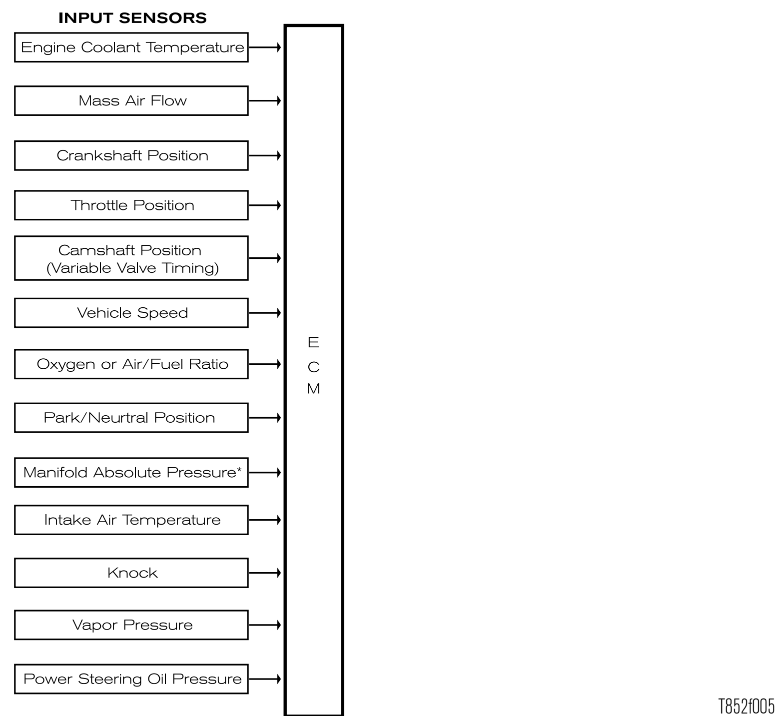
OBD II regulations allow the manufacturer to add additional information to the data stream and DTCs. A "1" in the second digit of the DTC code indicates it is a manufacturer specific DTC. Toyota has an enhanced data stream, which consists of 60 or more additional data words. As new systems are created, additional data is added to the data stream.

OBD	OBD II
Current related checks (open or short)	Circuit continuity and out of range values monitored
Limited system monitoring (A/F & EGR)	Systems monitored
Minimal use of rationality checks	Rationality checks used (logic)
Limited DTCs	Expanded DTCs
Limited use of Serial Data	Freeze Frame Data stored with DTC
System and component names not standardized	Serial Data required
DTCs not standardized	Active Tests
MIL will turn off if problem corrects itself	Standards established
DTC must be cleared from memory	MIL stays on until 3 consecutive trips have passed without the problem re-occurring
	DTC erased after 40 warm-up cycles
	OBD II can detect malfunctions that do not effect driveability

Fig. 1-19

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.

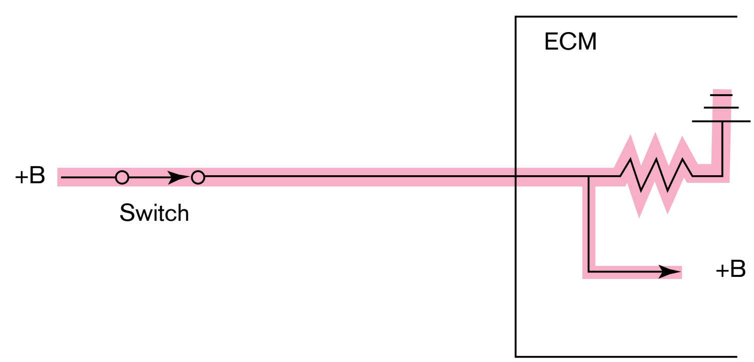


Fig. 2-02

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.

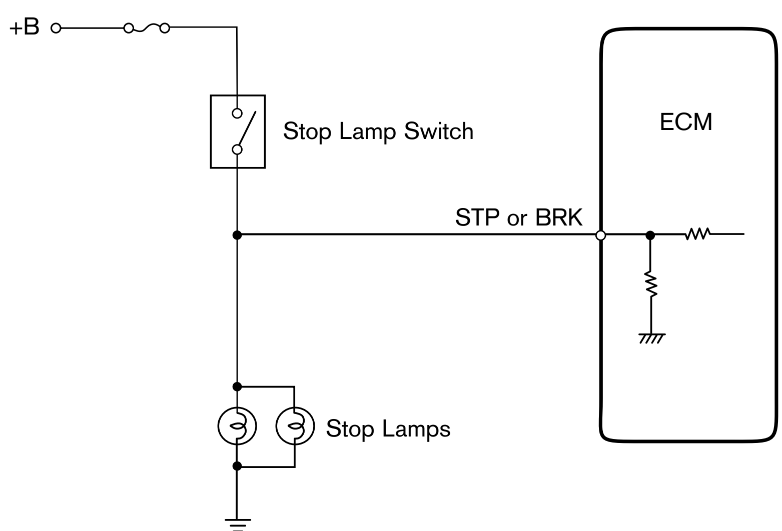


Fig. 2-03
T852f021

DVOM

A DVOM will measure 0 volts with the switch open.

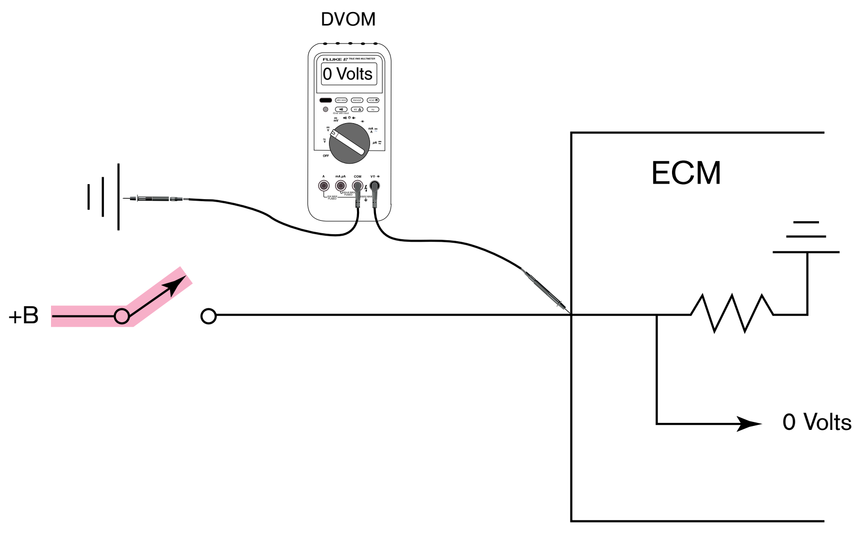


Fig. 2-04

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.

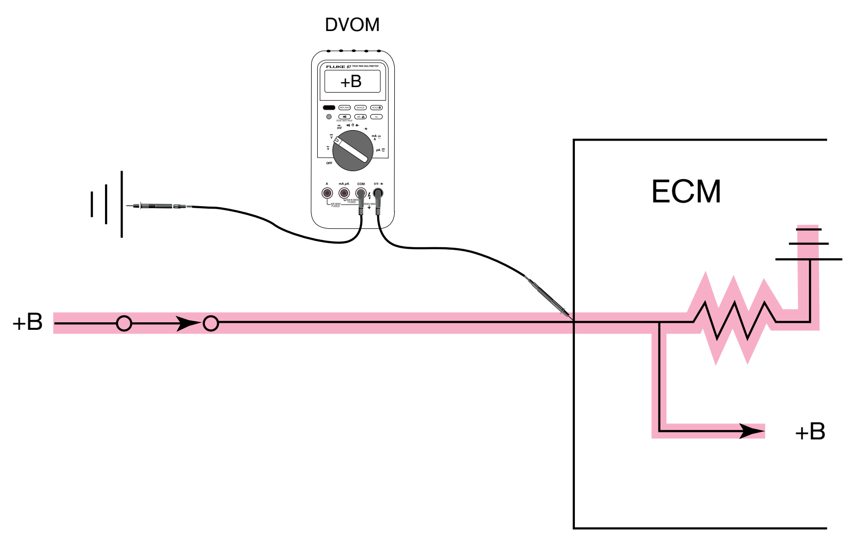


Fig. 2-05

T852f023

Ground Side Switch

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

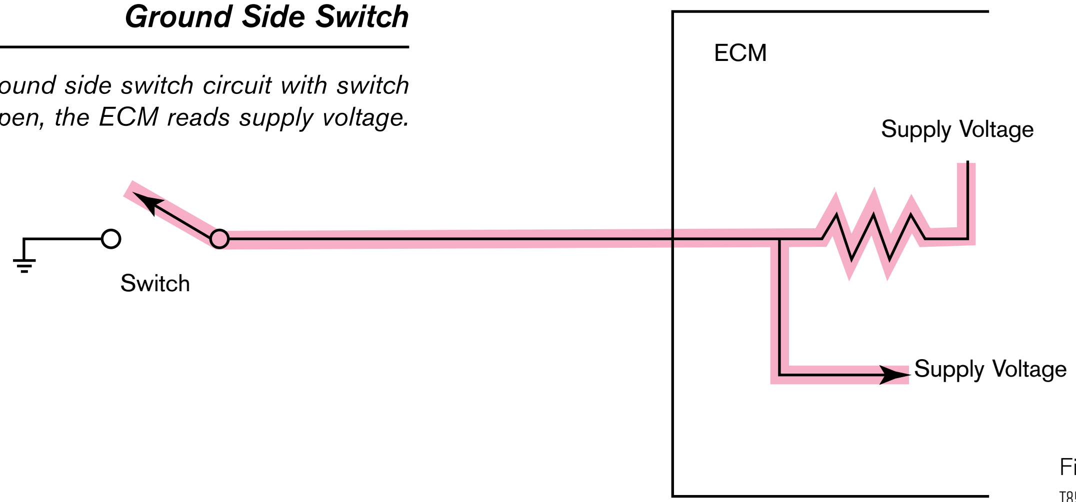


Fig. 2-06
T852f024

Switch Closed

When the switch closes, the ECM reads 0 Volts.

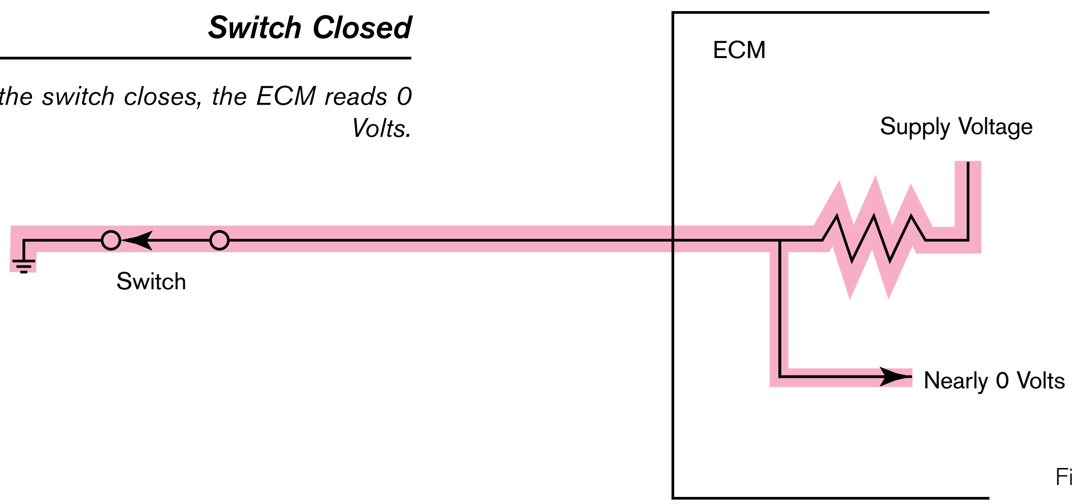


Fig. 2-07
T852f025

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.

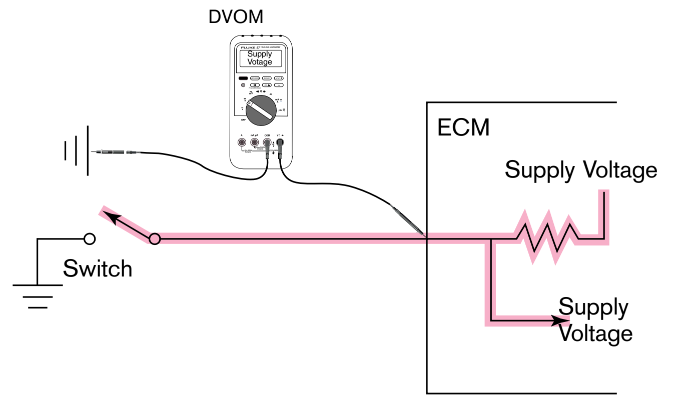


Fig. 2-08

T852f026

DVOM

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

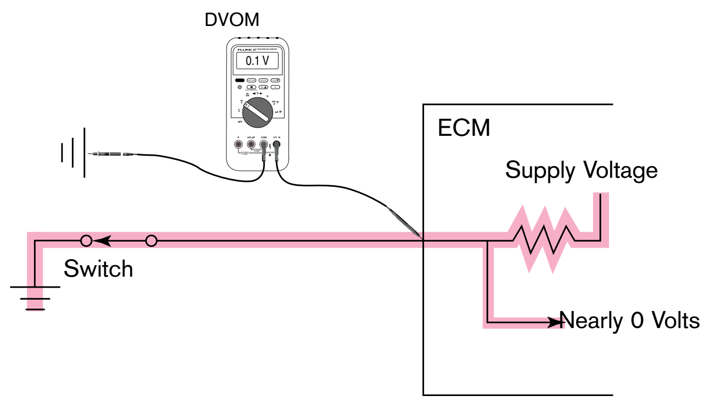


Fig. 2-09

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.

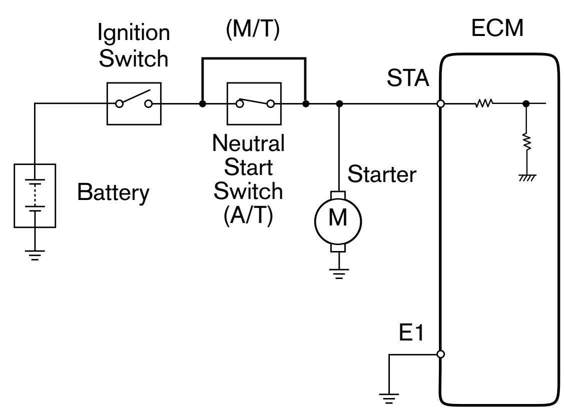


Fig. 2-10

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.

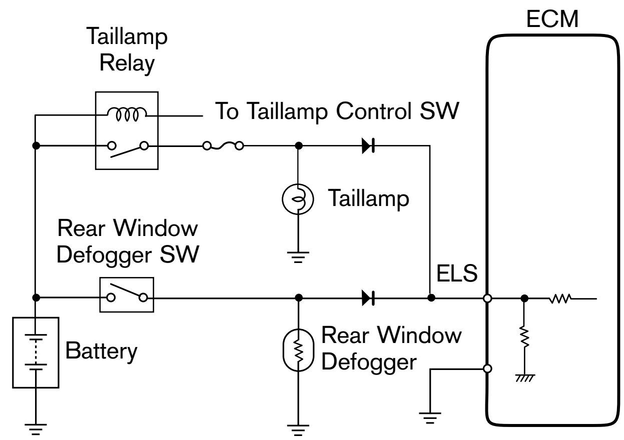


Fig. 2-11

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.

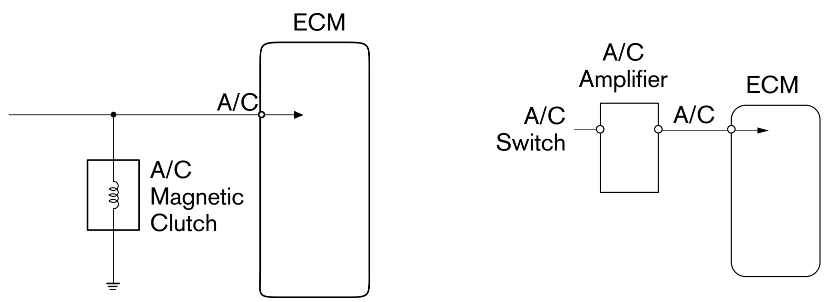


Fig. 2-12

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.

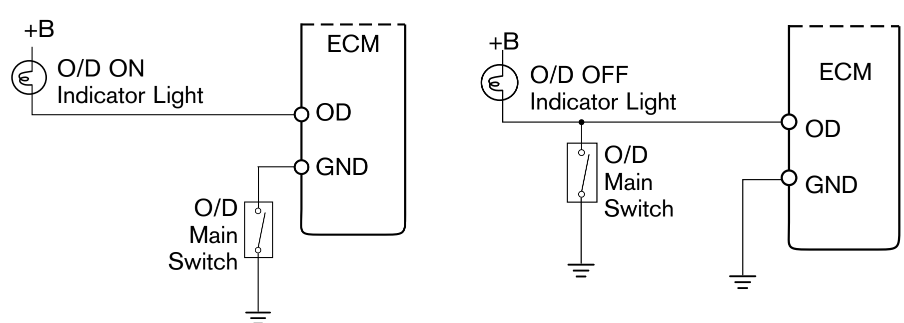


Fig. 2-13

T852f032/T852f349

Temperature Sensors

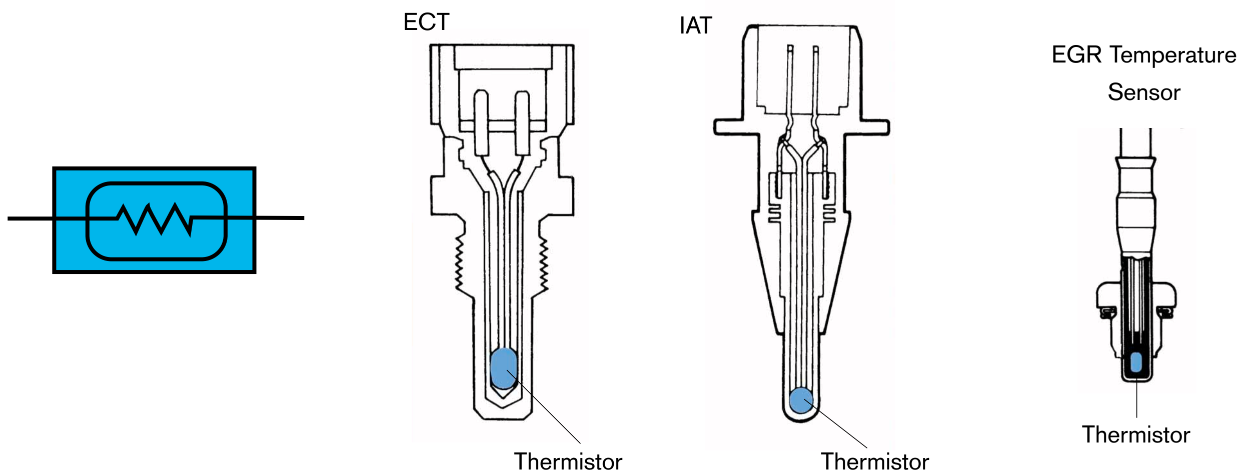


Fig. 2-14

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

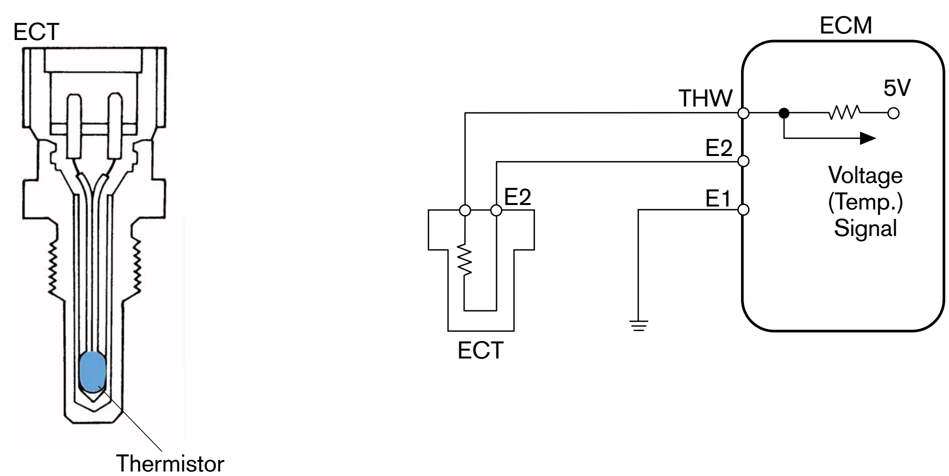


Fig. 2-15

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

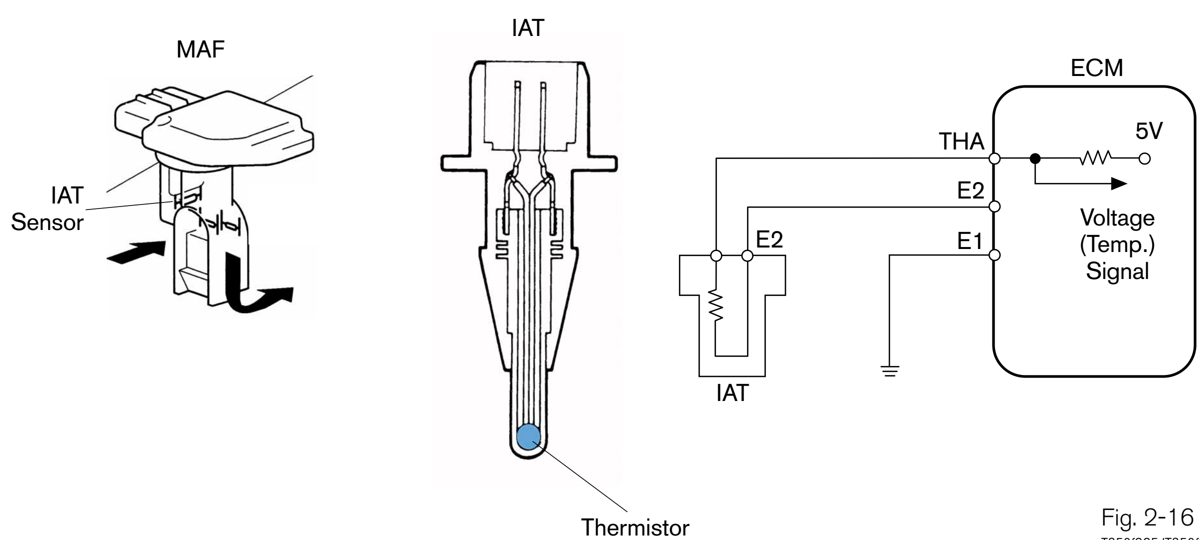


Fig. 2-16
T852f065/T852f035
T852f038

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

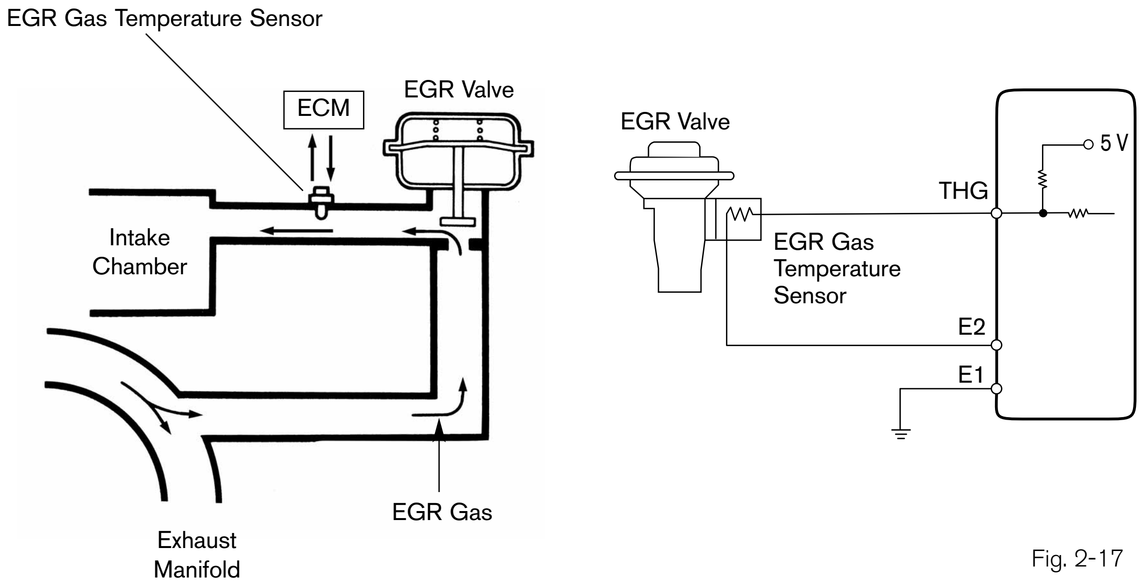


Fig. 2-17

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.

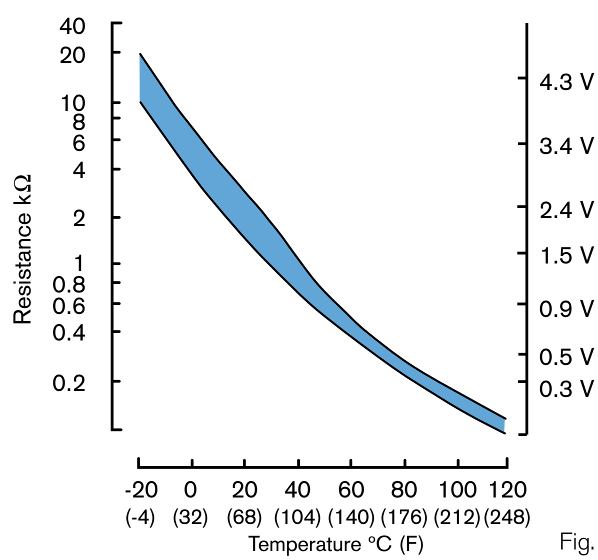


Fig. 2-18

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.

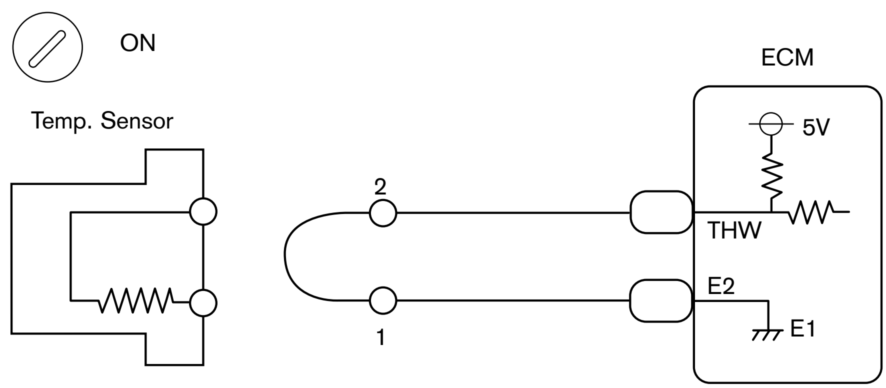


Fig. 2-19
T852f042

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.

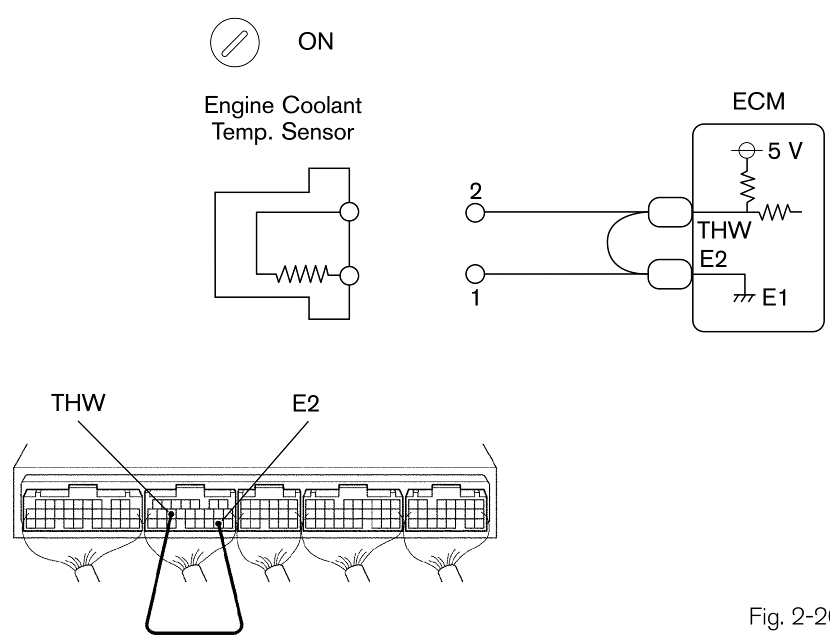


Fig. 2-20
T852f043/T852f044

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.

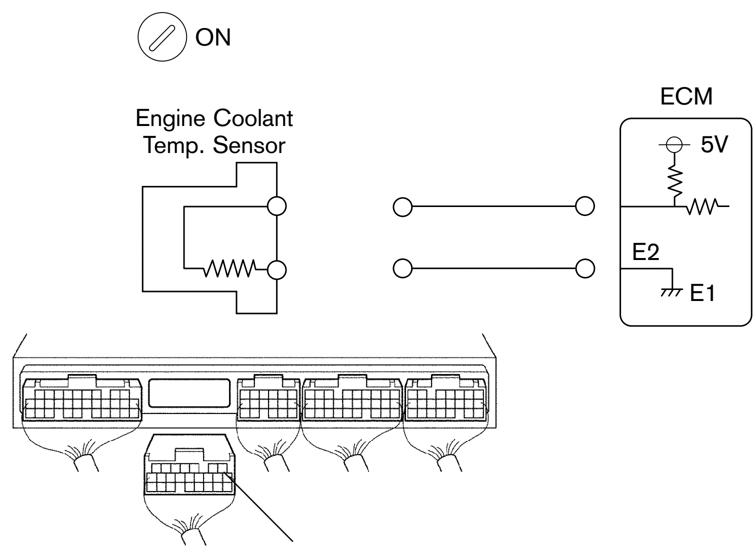


Fig. 2-21

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.

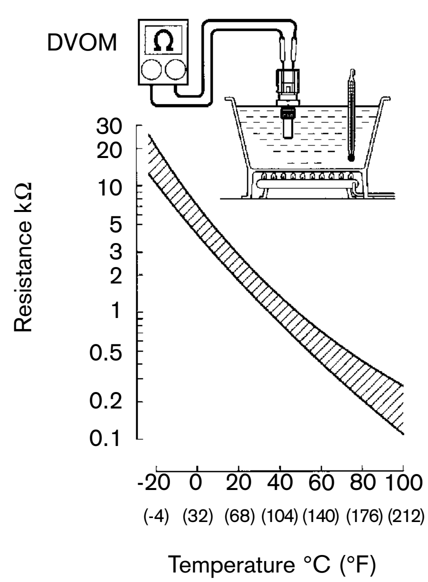


Fig. 2-22

T852f047

Position Sensor

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

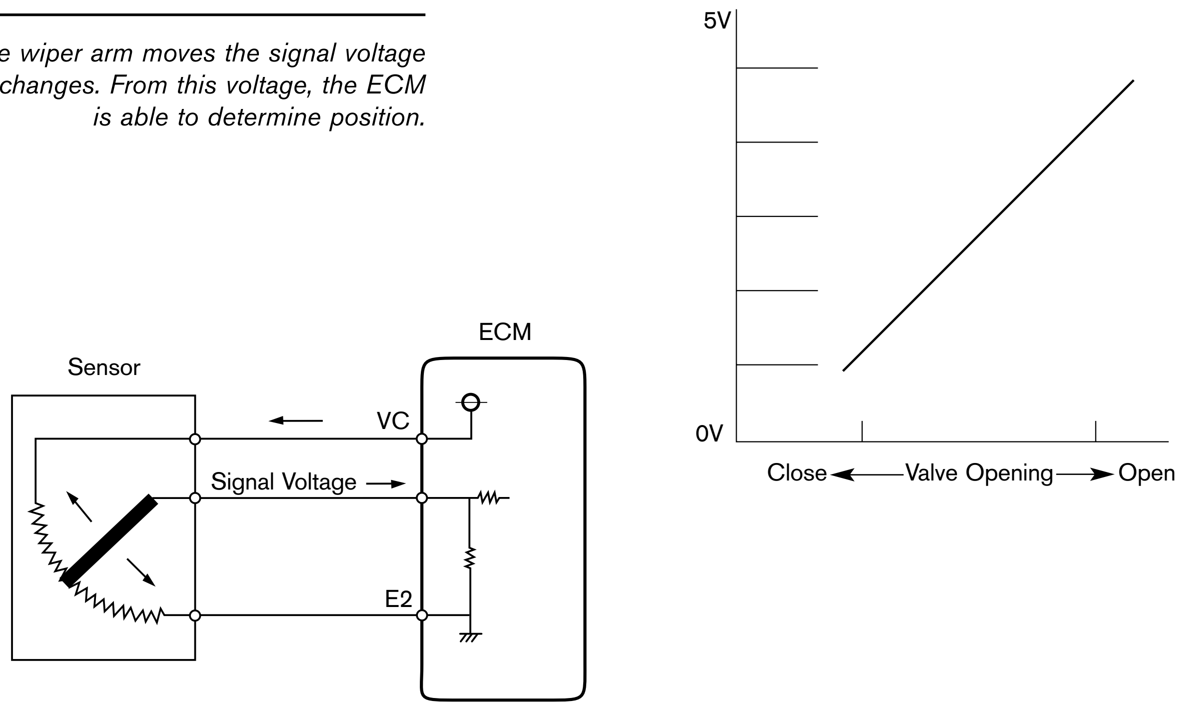


Fig. 2-23

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

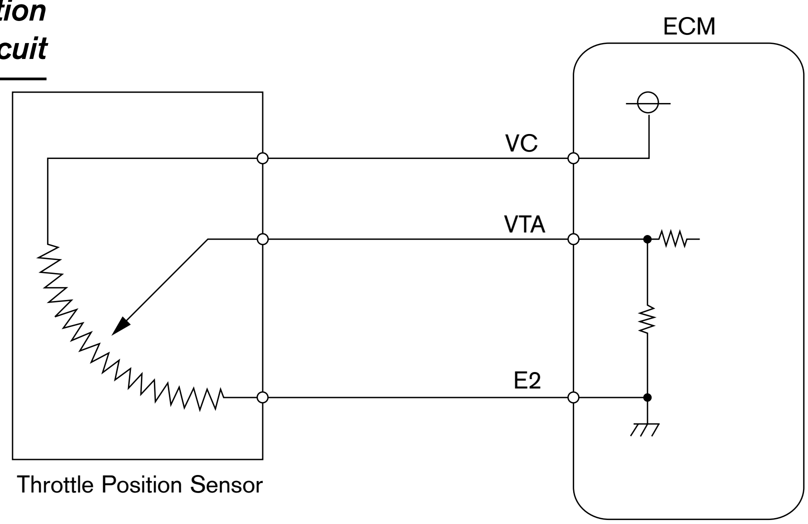


Fig. 2-24

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

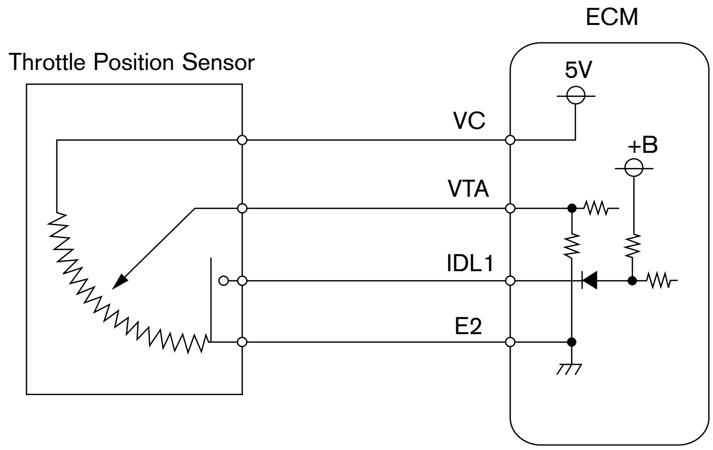


Fig. 2-25
T852f051

TPS With IDL

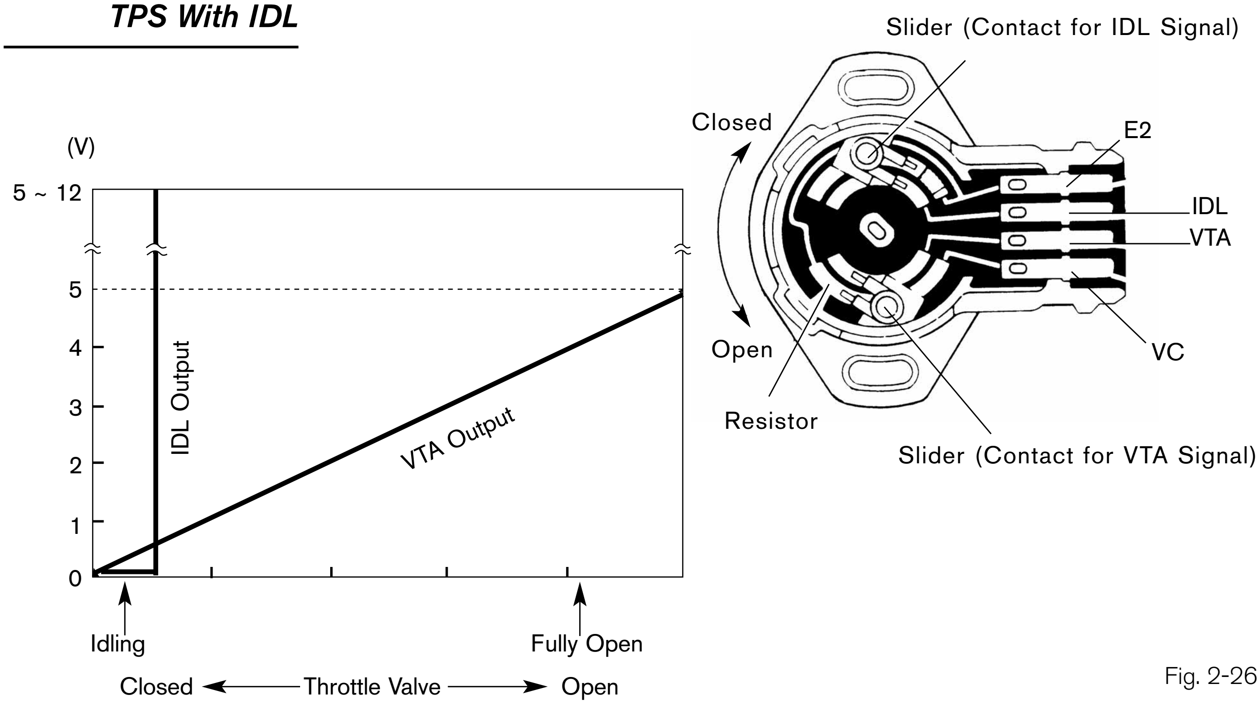


Fig. 2-26
T852f053/T852f052

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

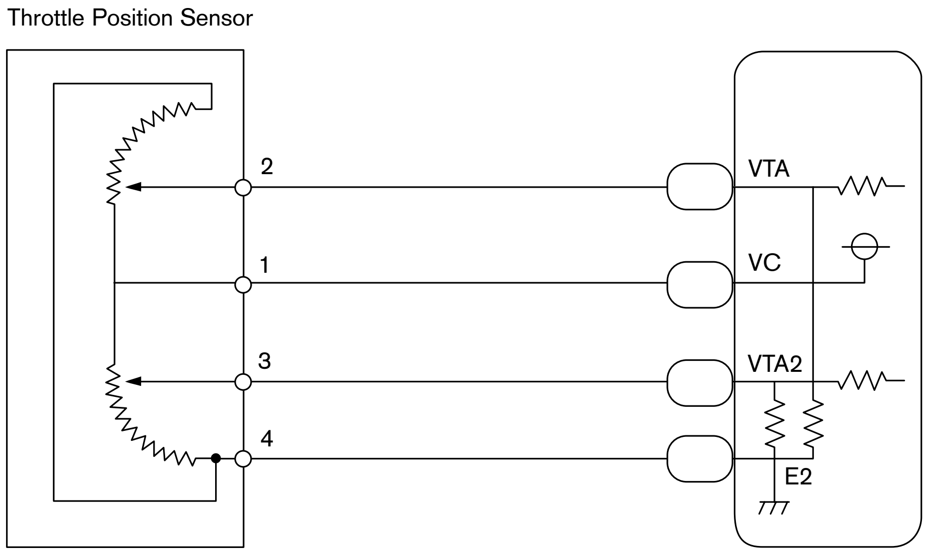


Fig. 2-27
T852f054

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.

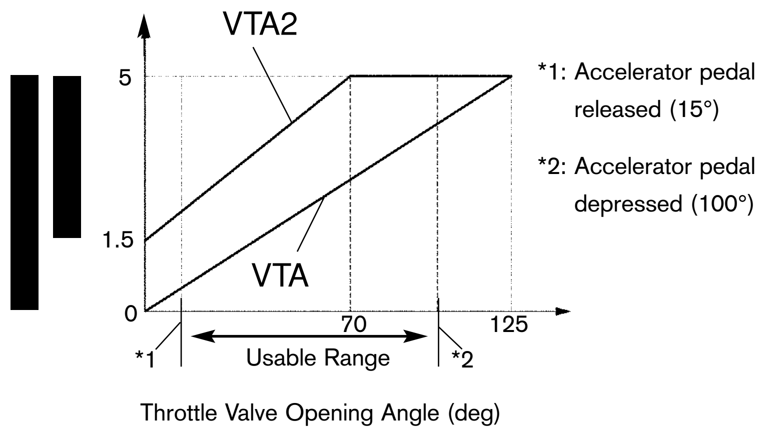


Fig. 2-28
T852f055

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

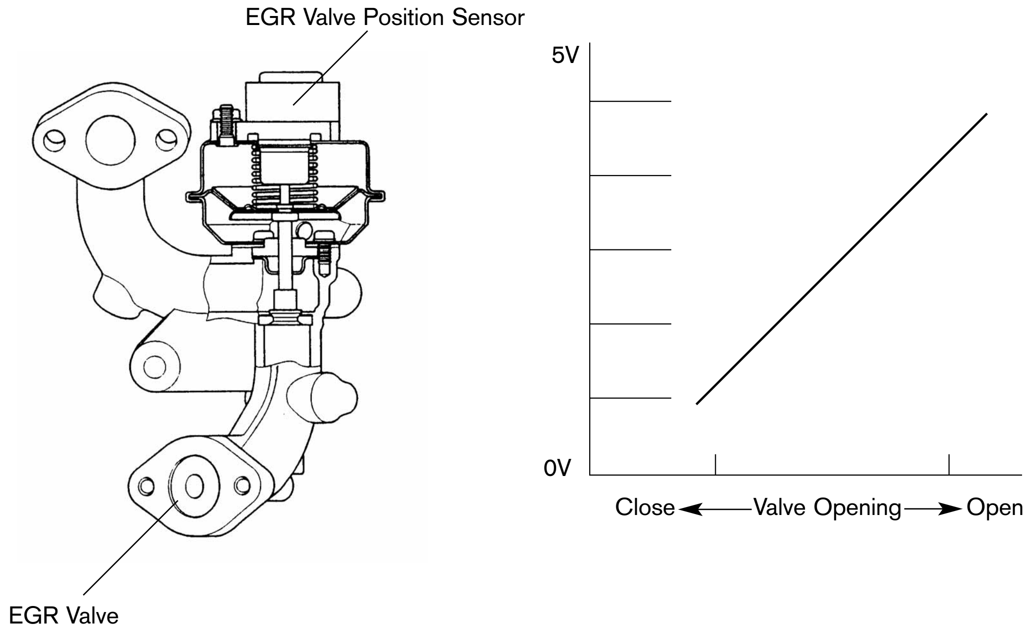


Fig. 2-29

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.

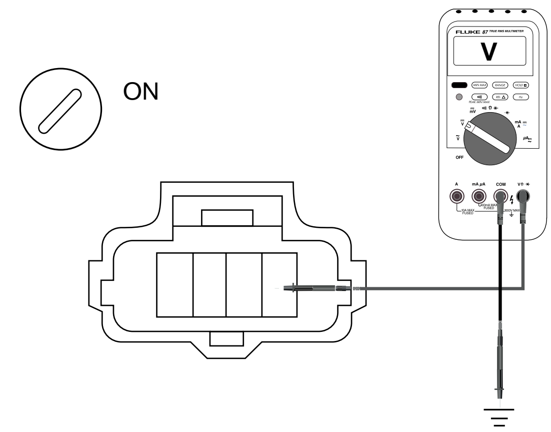


Fig. 2-30

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.

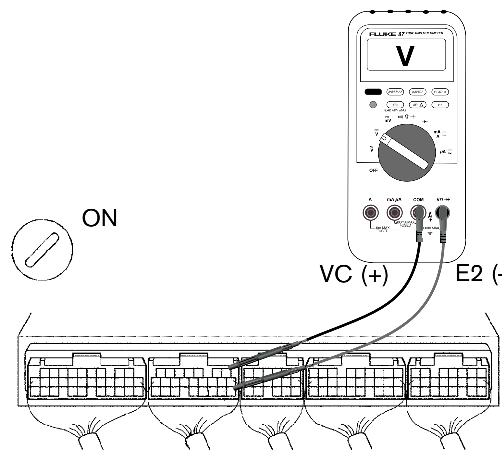


Fig. 2-31

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.

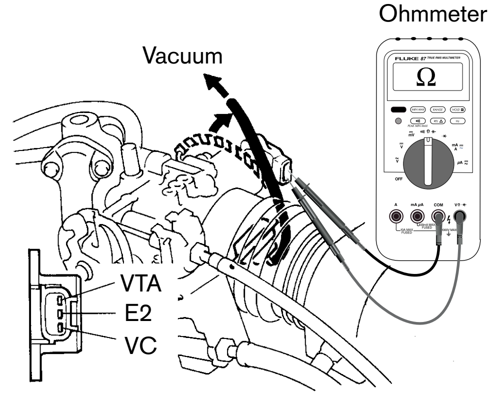


Fig. 2-32

T852f059

TPS Total Resistance Check

This resistance test is measuring total resistance.

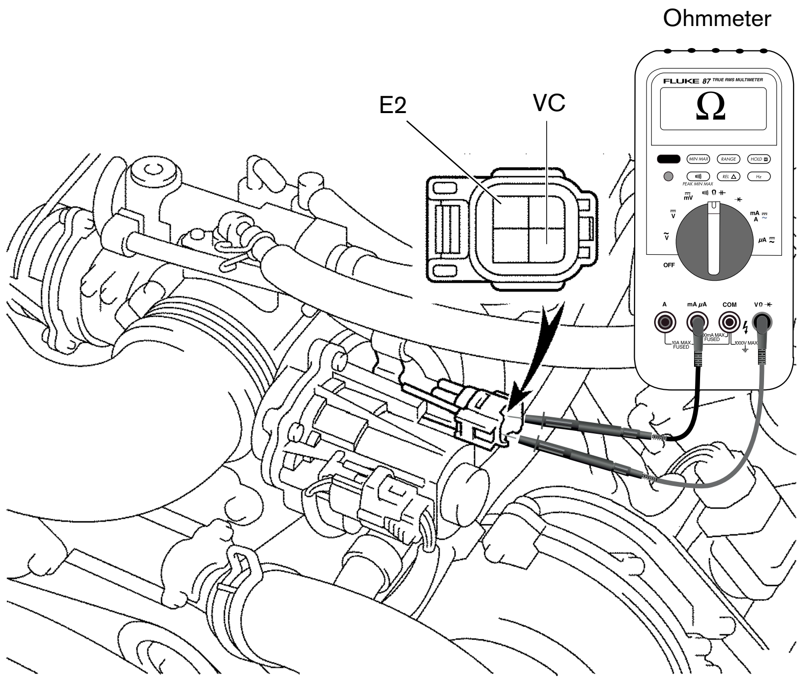


Fig. 2-33

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.

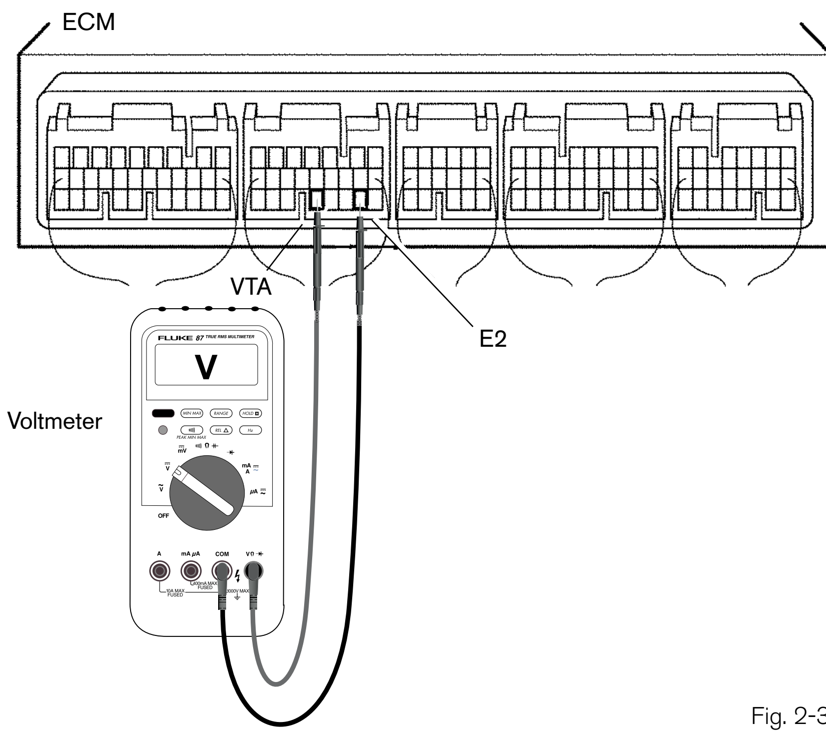


Fig. 2-34

T852f061

Air Flow Sensor

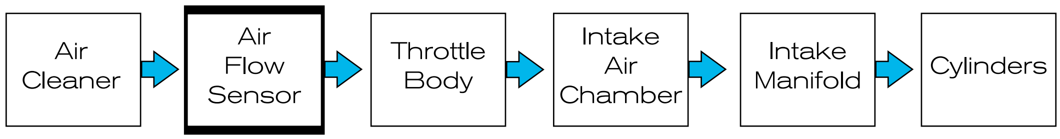


Fig. 2-35
T852f062

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

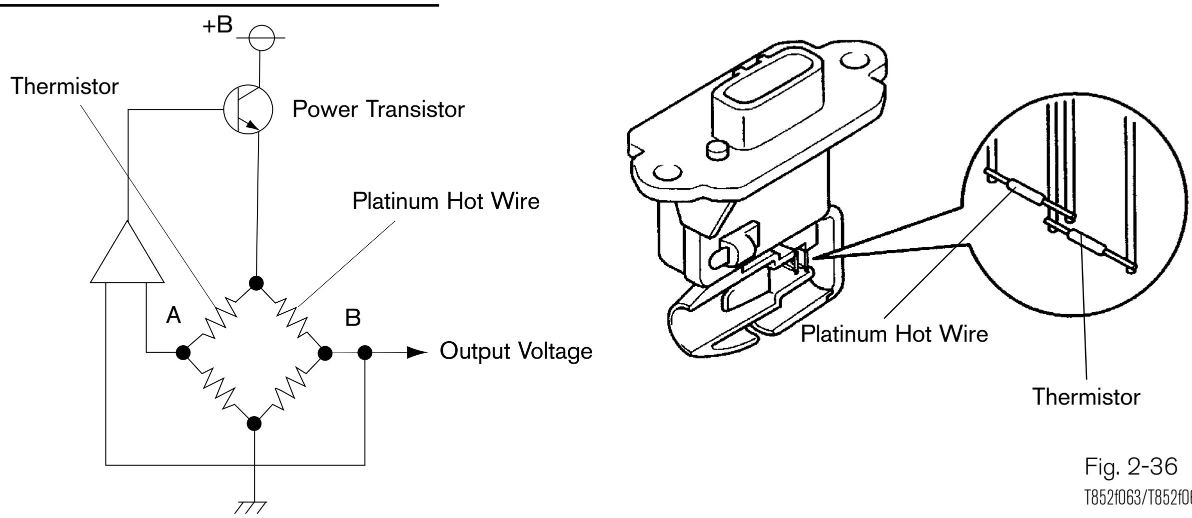


Fig. 2-36
T852f063/T852f064

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

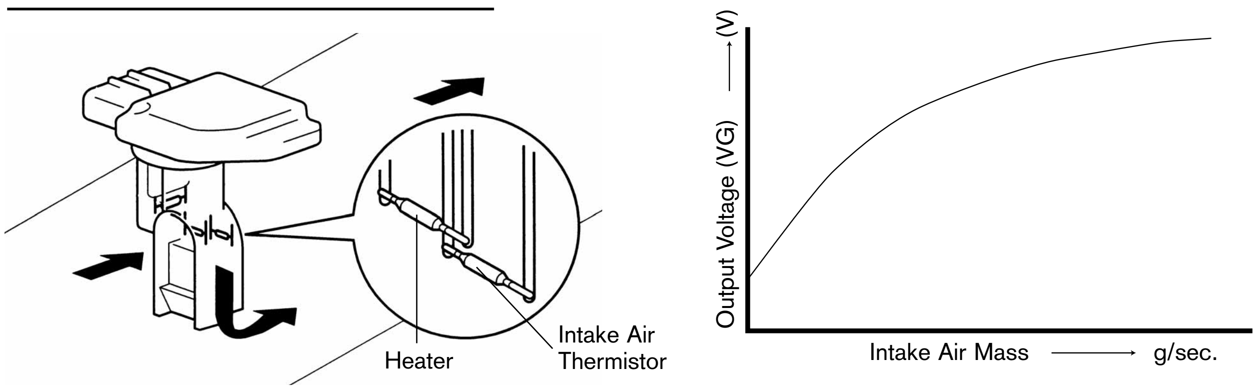


Fig. 2-37

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.

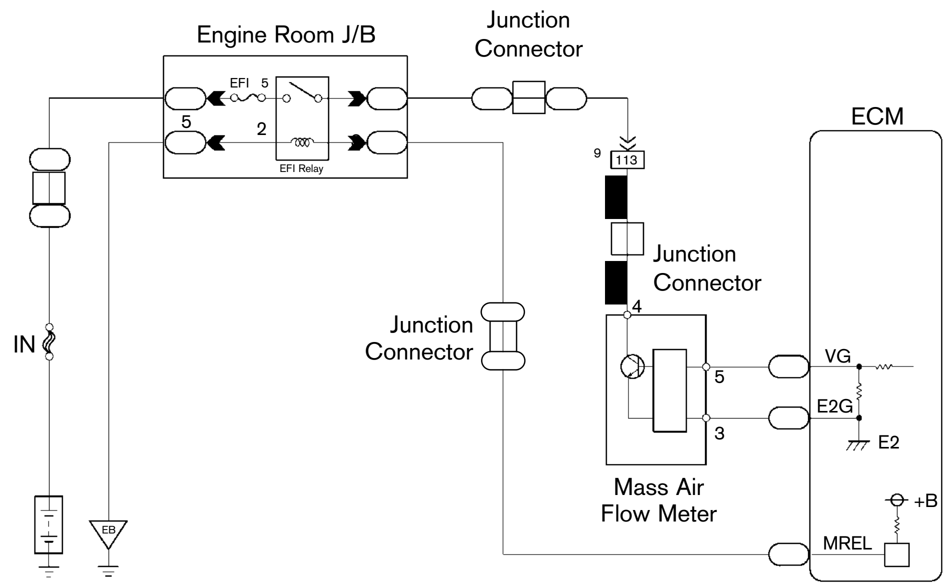


Fig. 2-38

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.

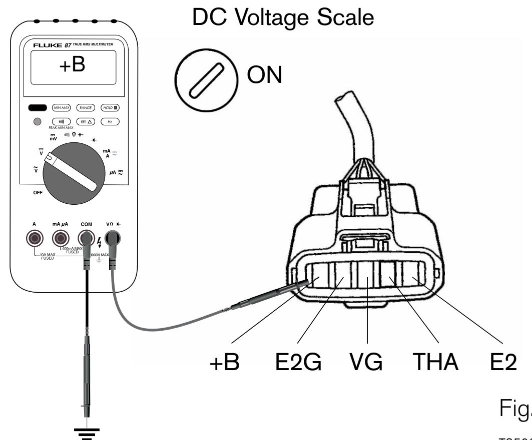


Fig. 2-39

T852f068

MAF Ground Circuit

MAF ground circuit check is performed with an ohmmeter.

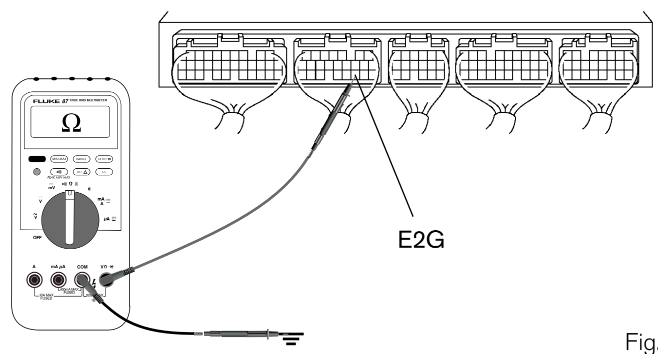


Fig. 2-40

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.

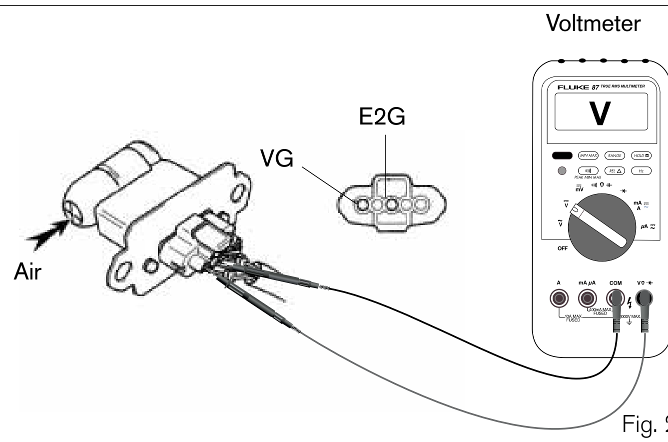


Fig. 2-41

T852f070

Vane Air Flow Meter

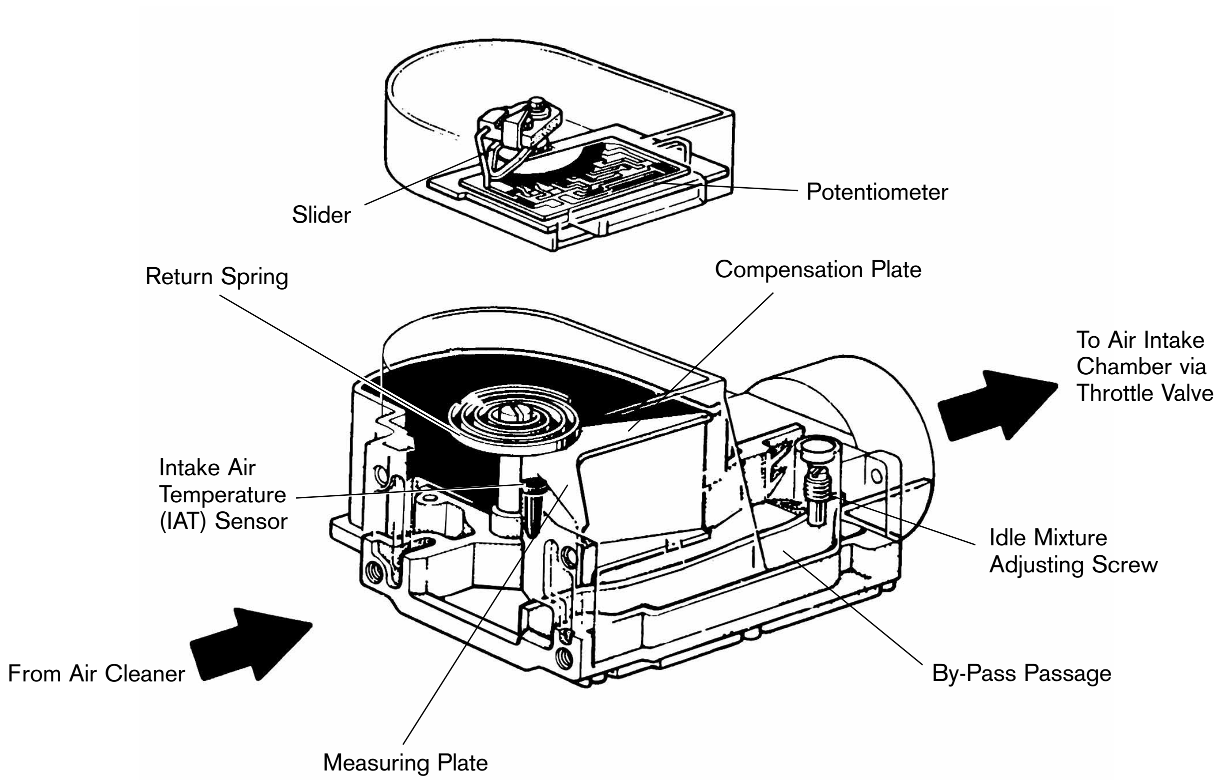


Fig. 2-42

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.

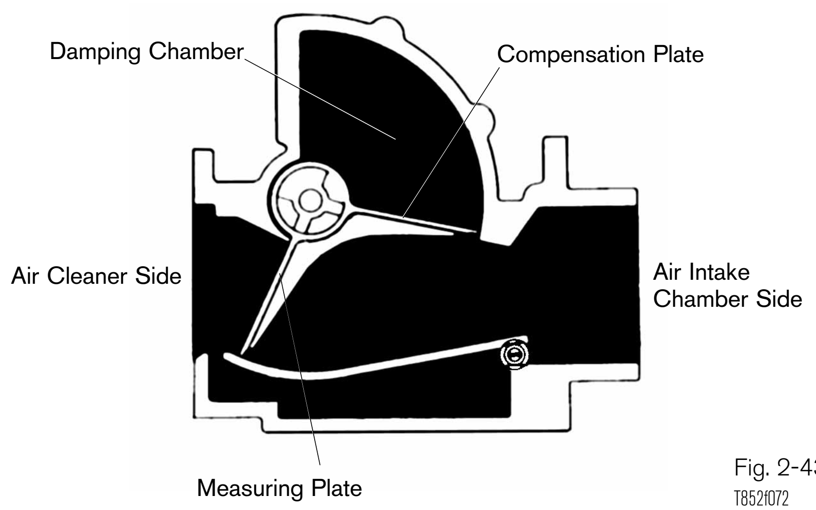


Fig. 2-43
T852f072

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.

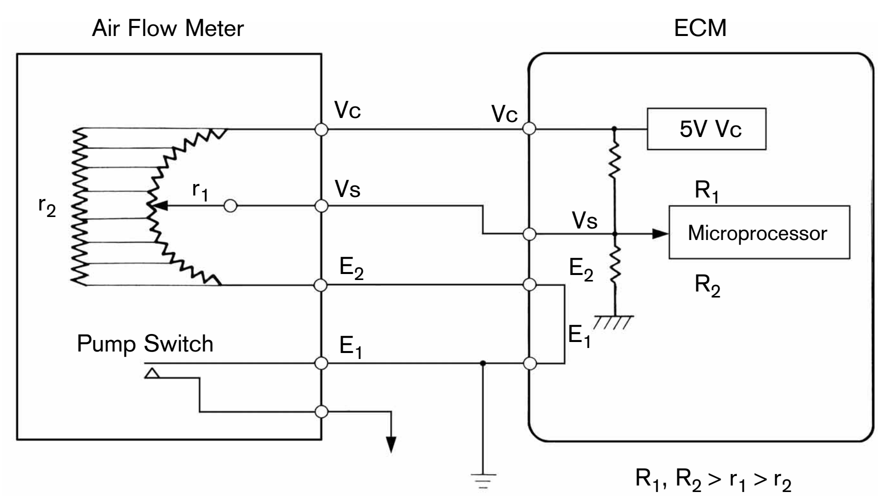


Fig. 2-44
T852f073

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.

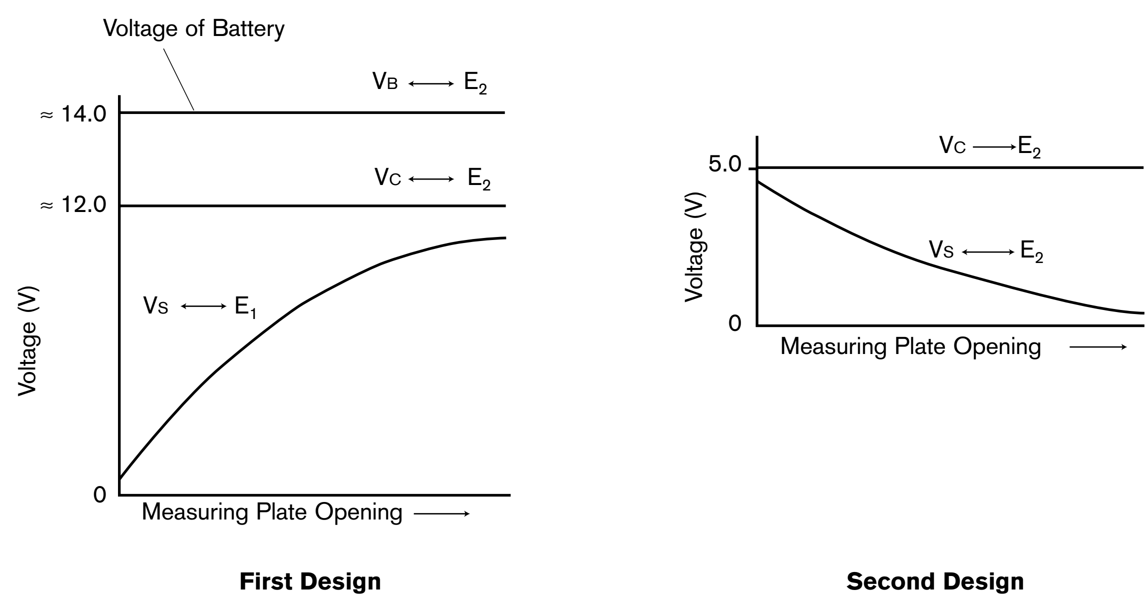


Fig. 2-45

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.

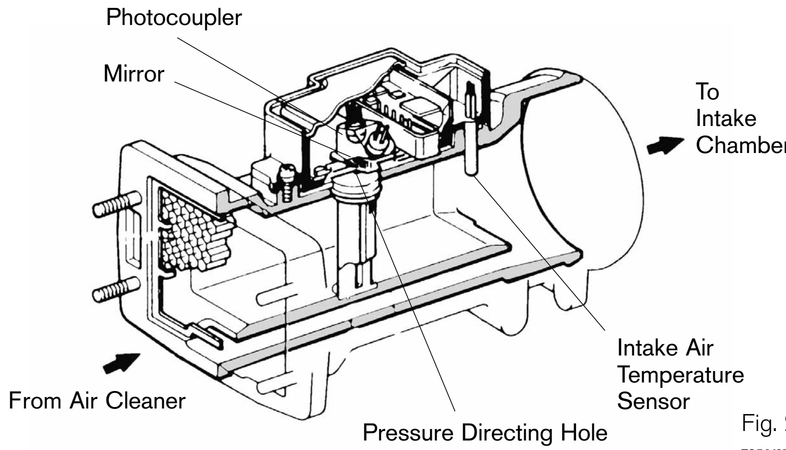


Fig. 2-46
T852f076

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

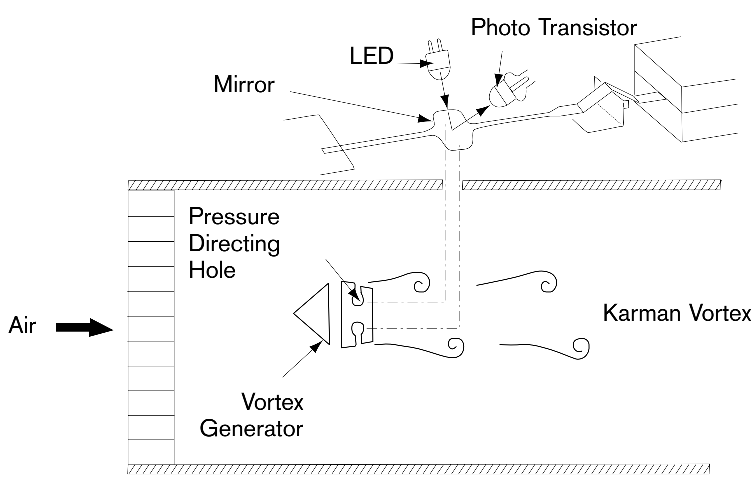


Fig. 2-47
T852f077

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.

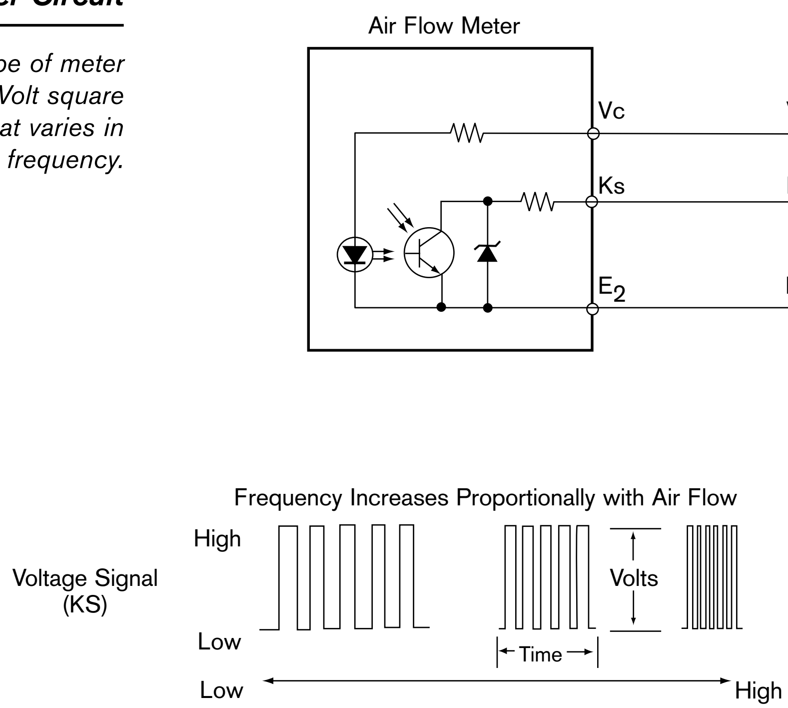


Fig. 2-48

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

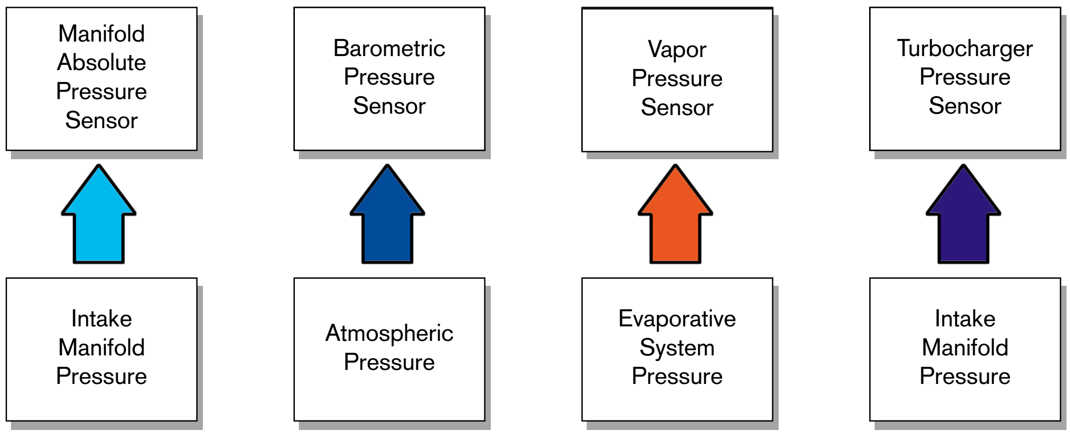


Fig. 2-49

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.

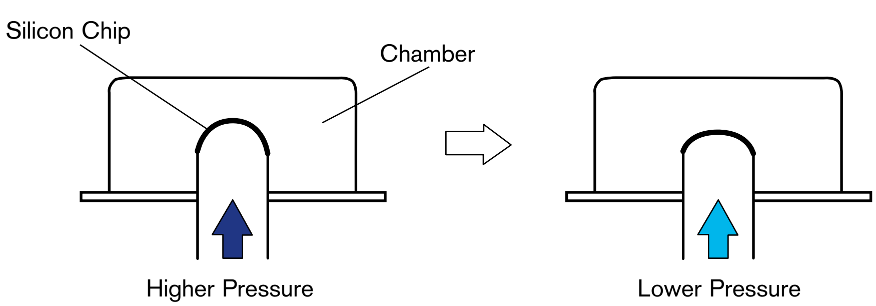


Fig. 2-50

T852f116

Manifold Absolute Pressure (MAP) Sensor

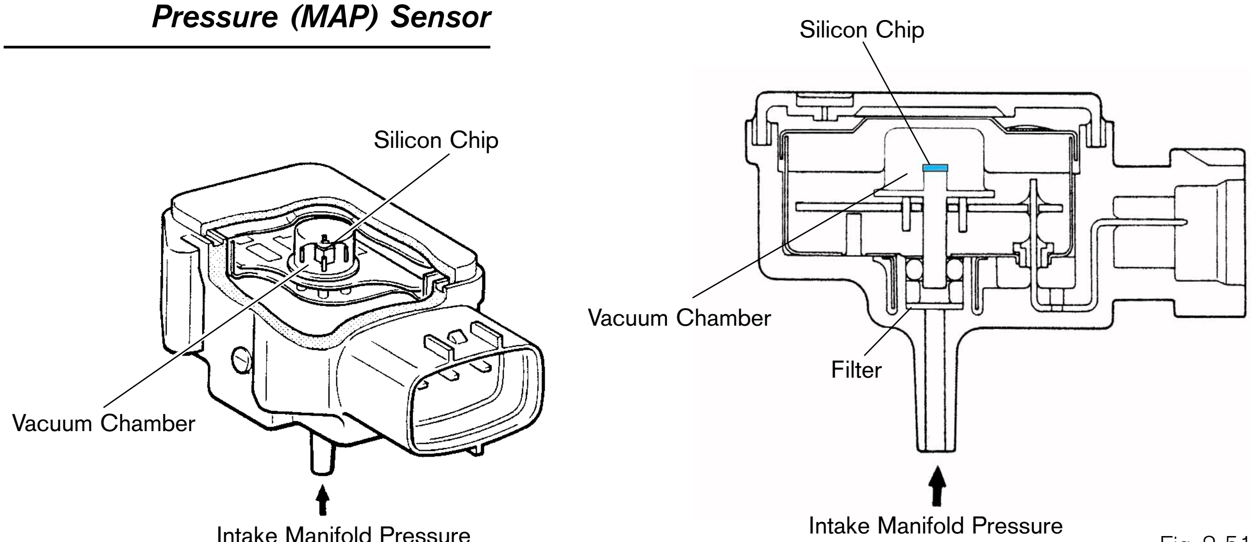


Fig. 2-51
T852f117/T852f118

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

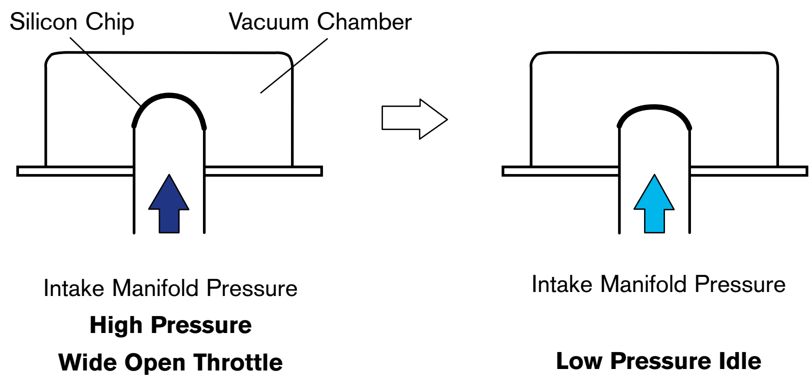


Fig. 2-52
T852f116

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.

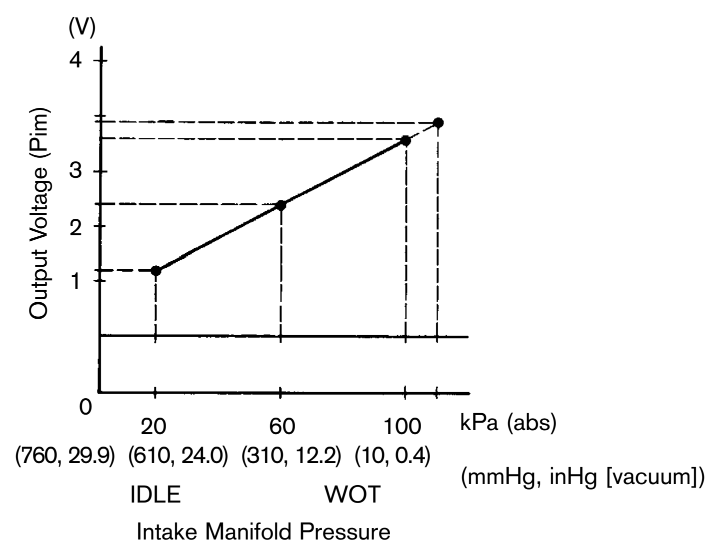


Fig. 2-53
T852f119

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.

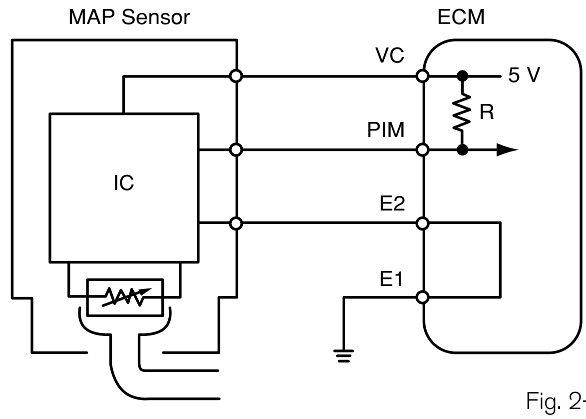


Fig. 2-54
T852f120

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

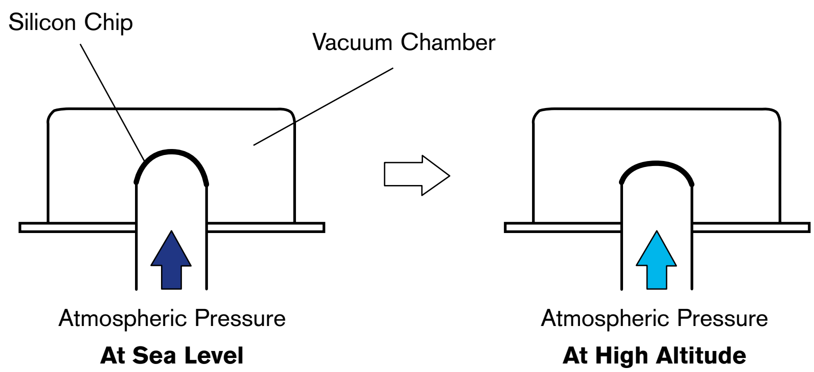


Fig. 2-56

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

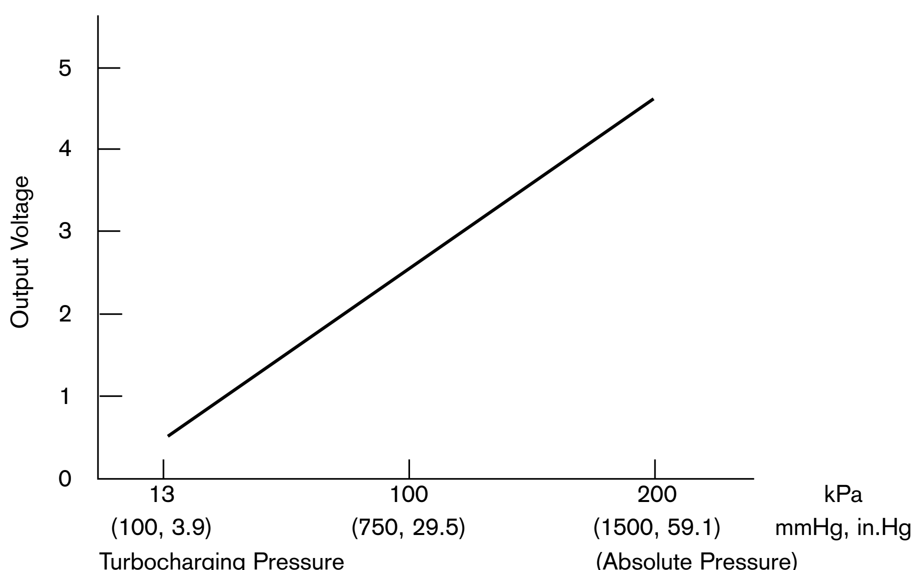


Fig. 2-57

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

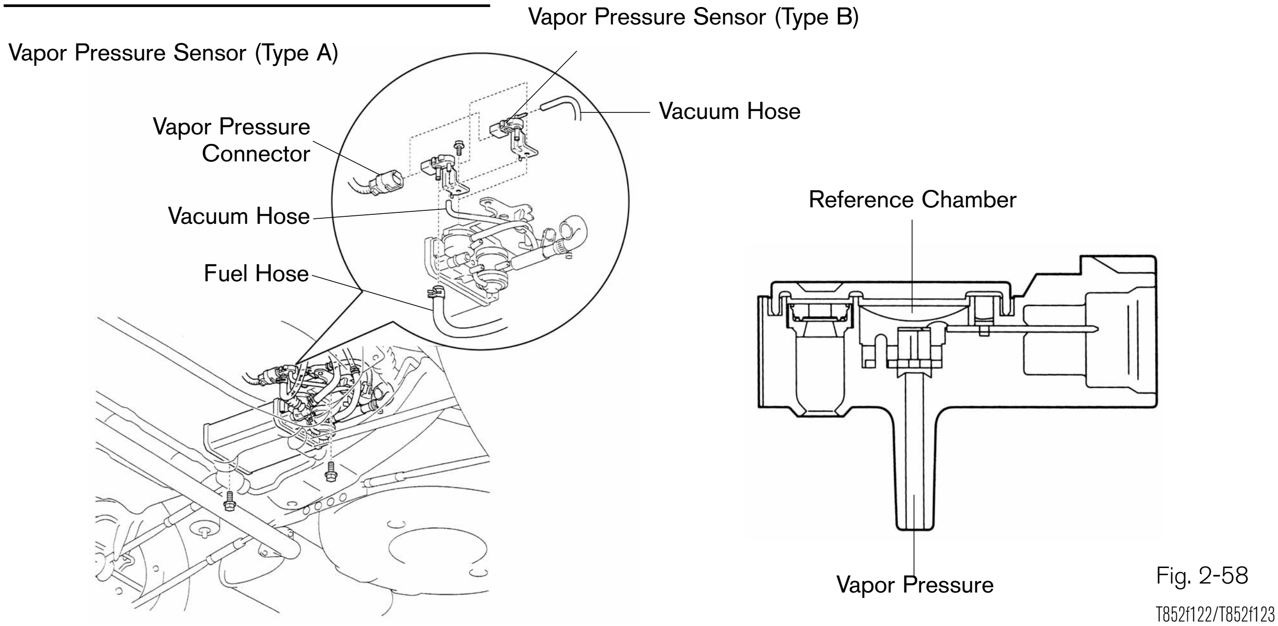


Fig. 2-58

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

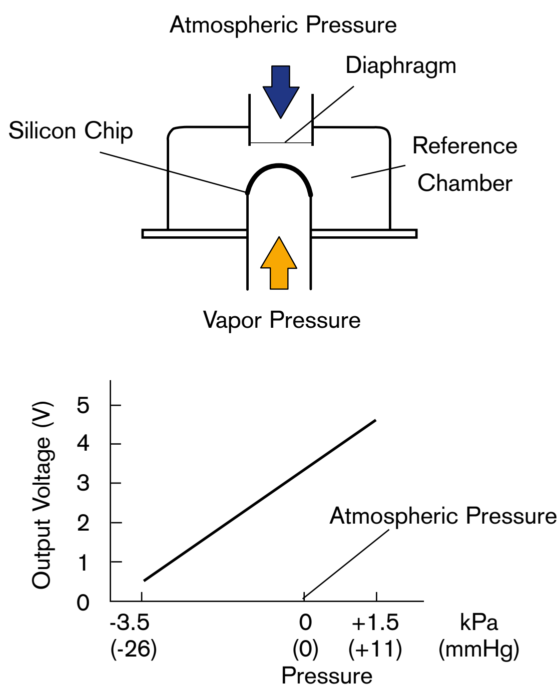


Fig. 2-59

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

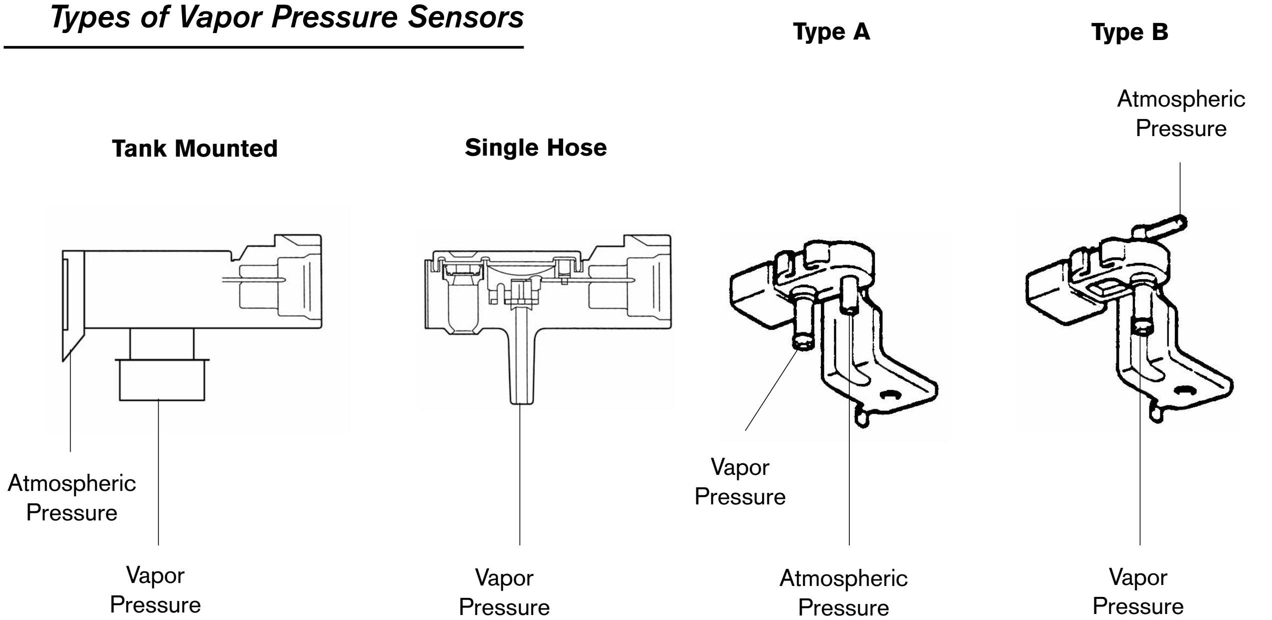


Fig. 2-60

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.

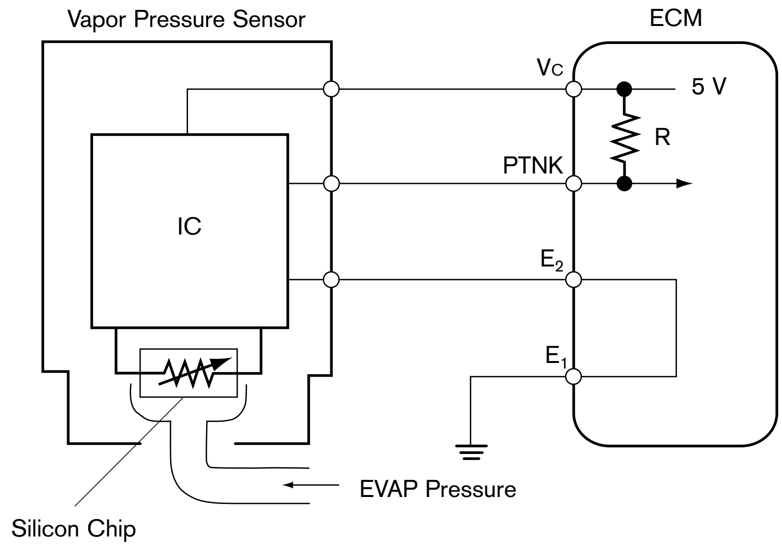


Fig. 2-61

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

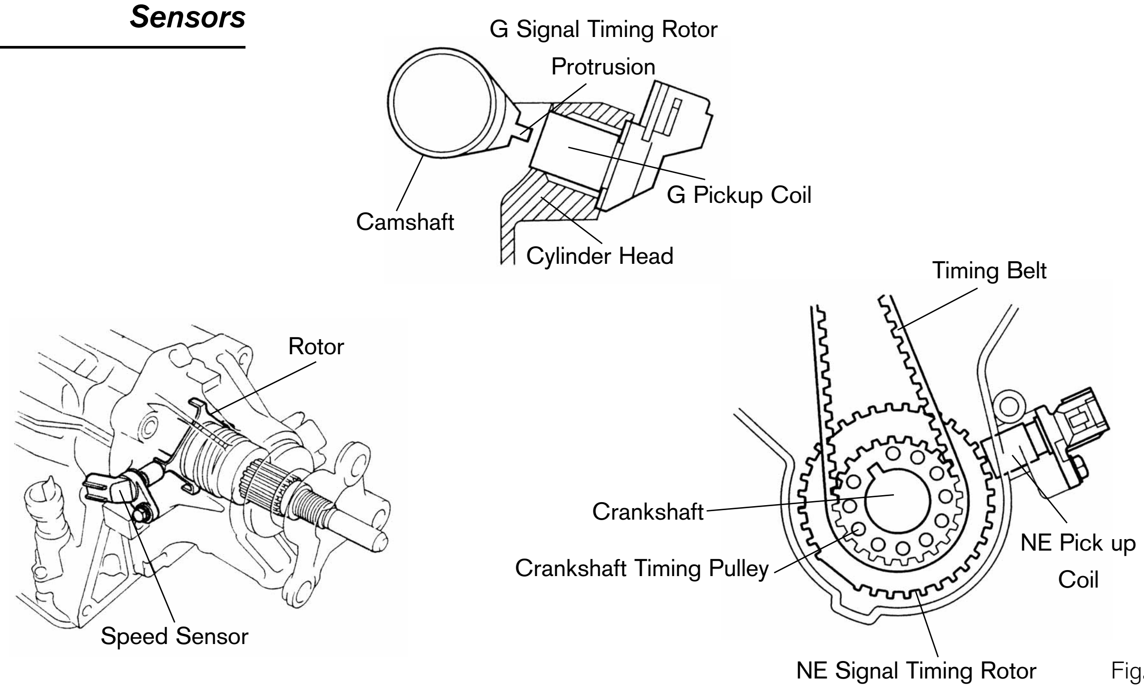


Fig. 2-62

T852f095/T852f096
T852f097

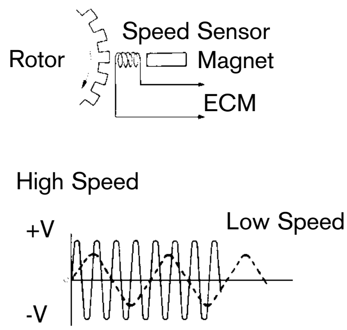
Pick-Up Coil (Variable Reluctance) Type Sensors

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.



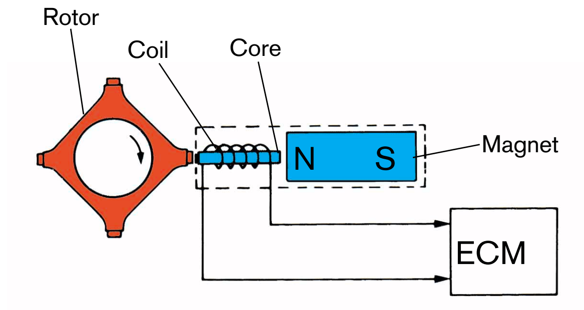


Fig. 2-63

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

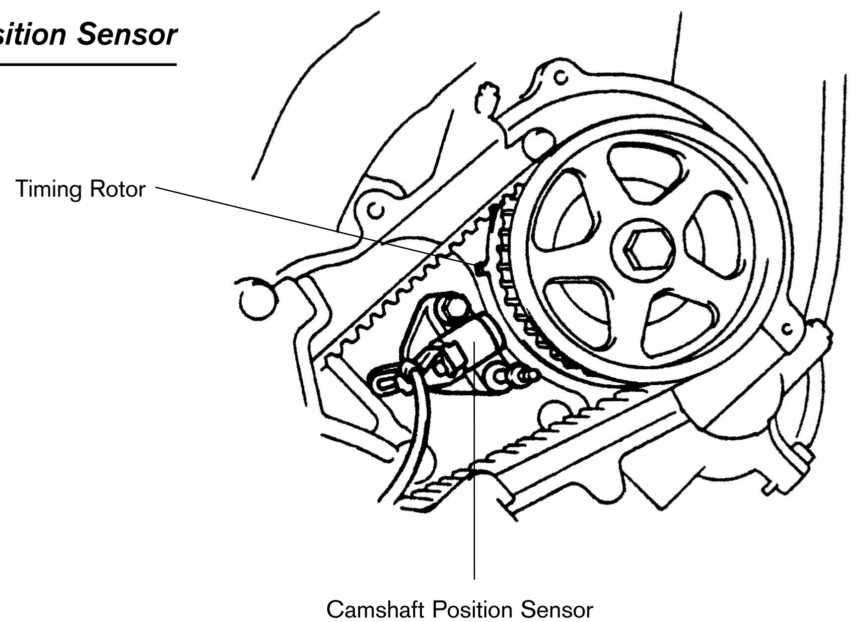


Fig. 2-64

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)

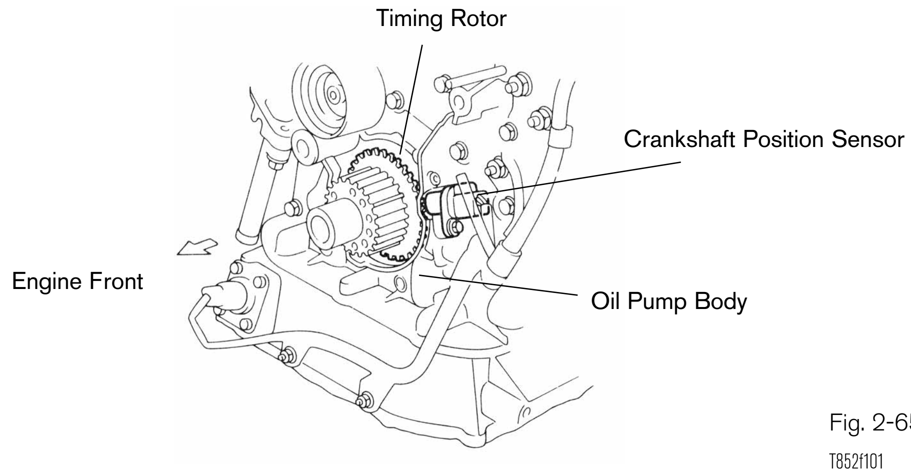


Fig. 2-65
T852f101

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.

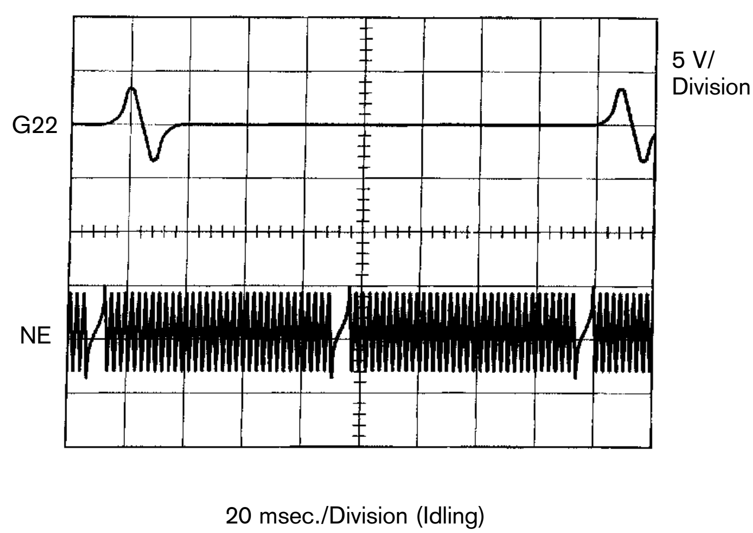


Fig. 2-66
T852f102

Vehicle Speed Sensor Signal Circuit Combinations

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

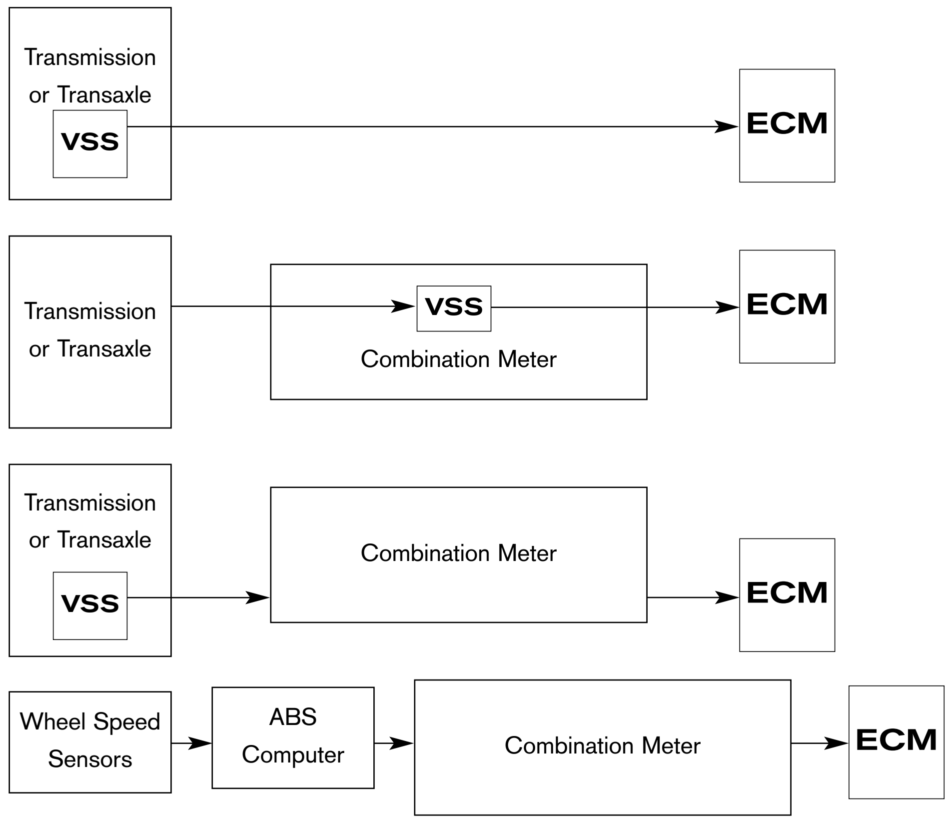


Fig. 2-67

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.

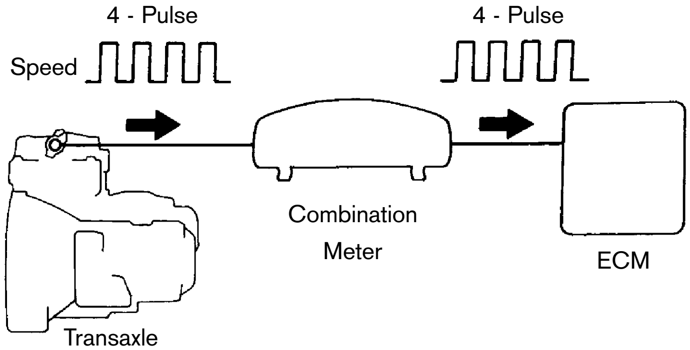
On some vehicles, the vehicle speed sensor signal is processed in the combination meter and then sent to the ECM.

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



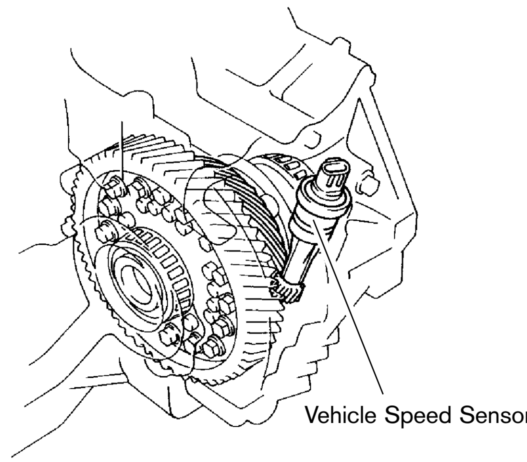
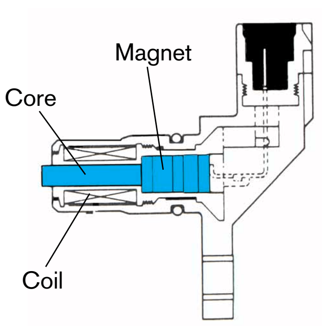


Fig. 2-68

T852f103/T852f104

VSS Mounted in Transmission



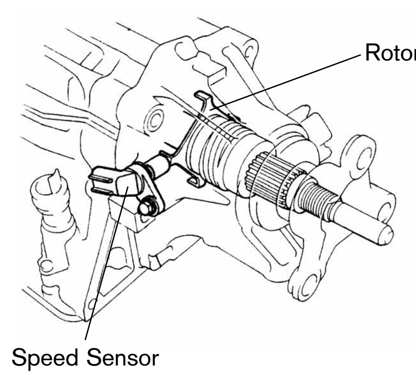
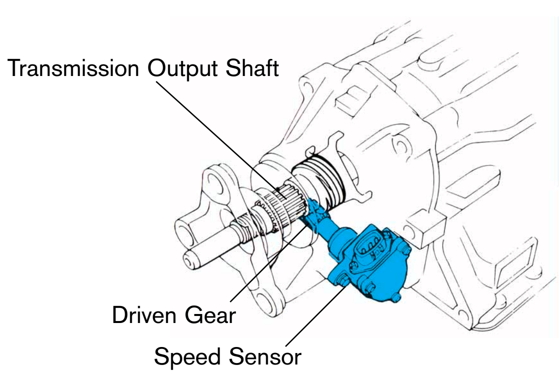


Fig. 2-69

T852f105/T852f095

MRE Type VSS



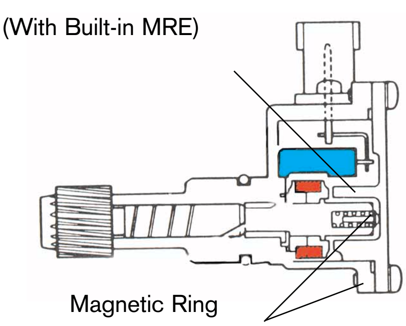
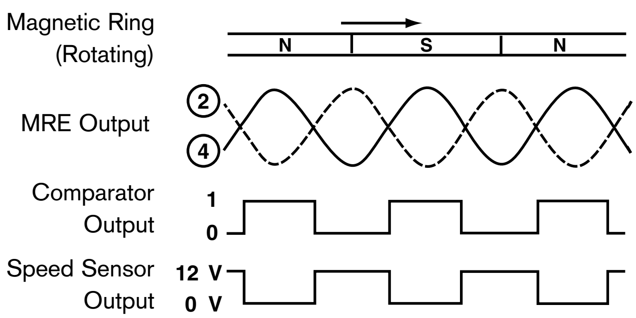


Fig. 2-70

T852f106/T852f107

MRE Operation

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



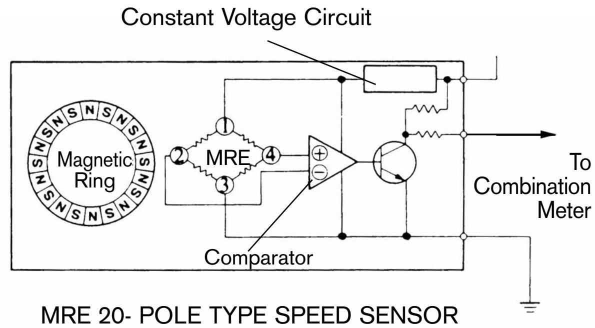


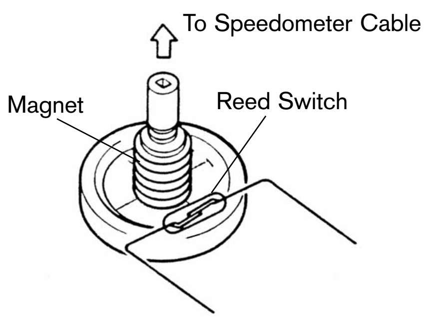
Fig. 2-71

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



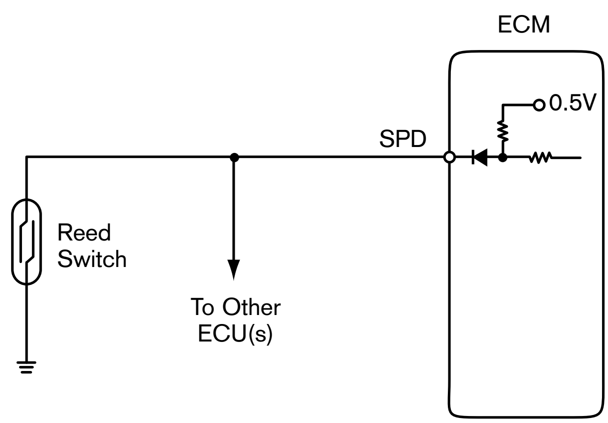


Fig. 2-72

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

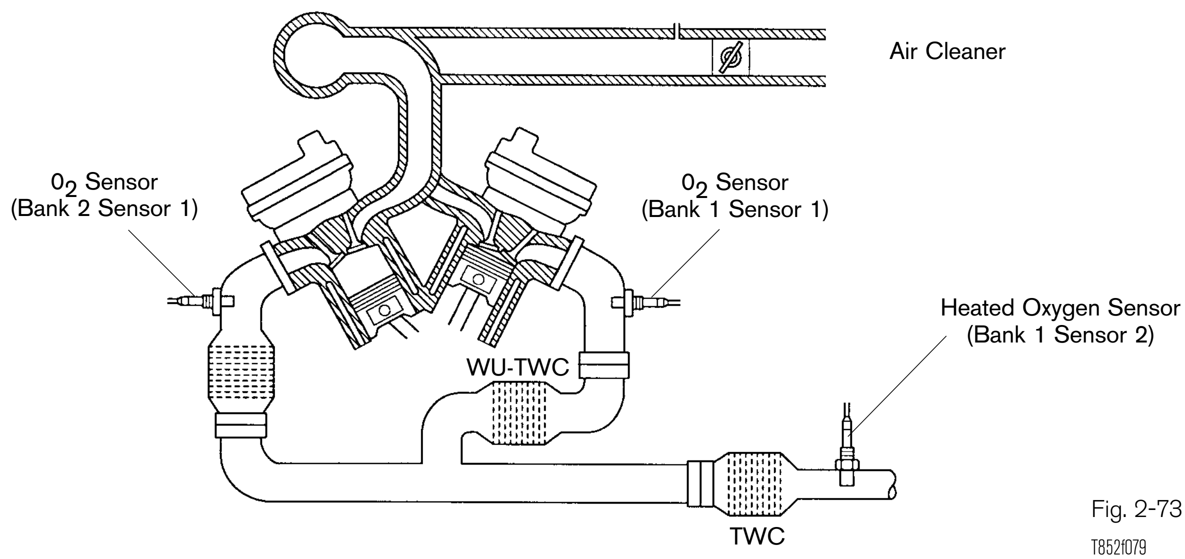


Fig. 2-73

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

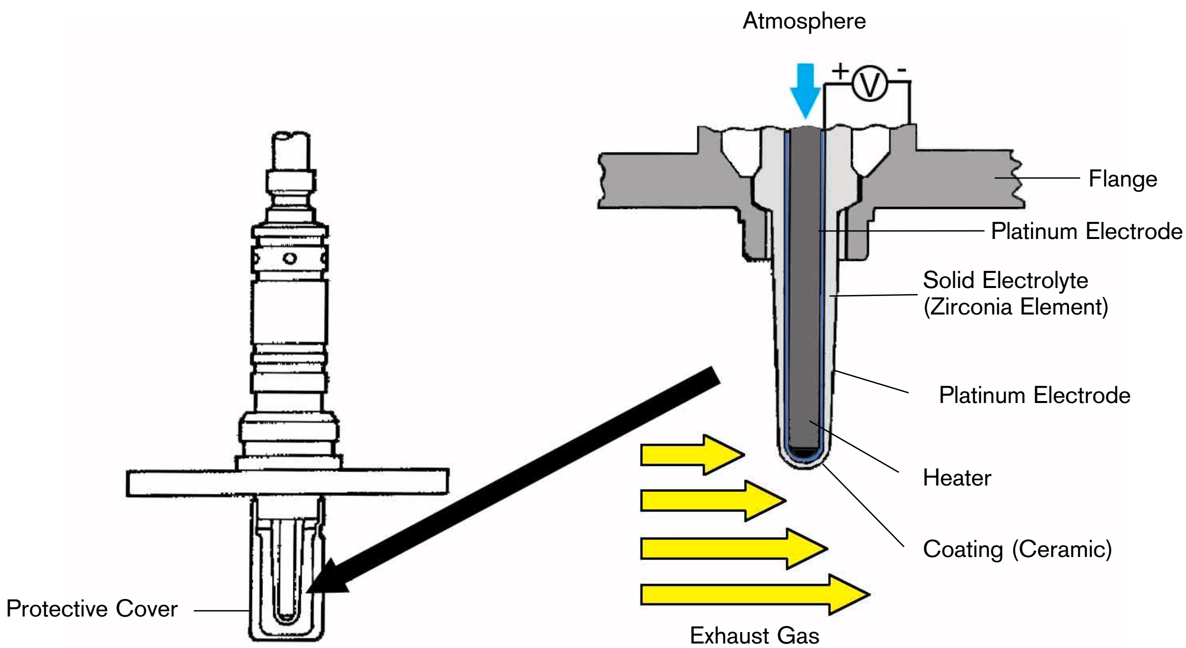


Fig. 2-74

T852f081

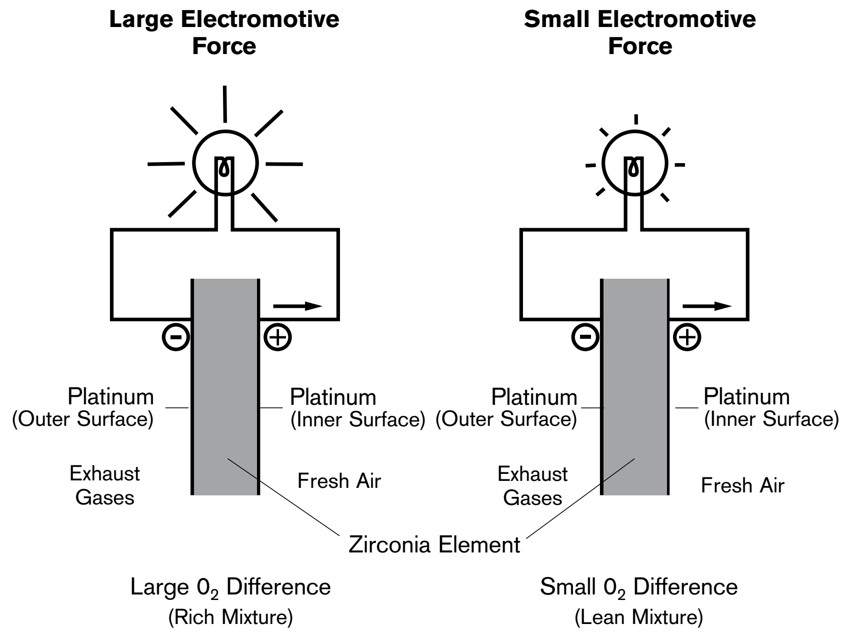
Oxygen Sensor

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.

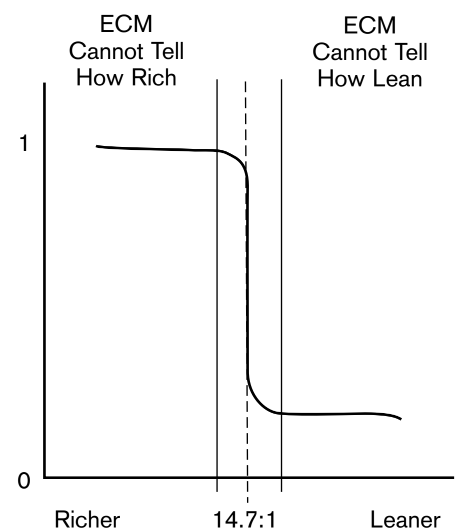


Fig. 2-76

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.

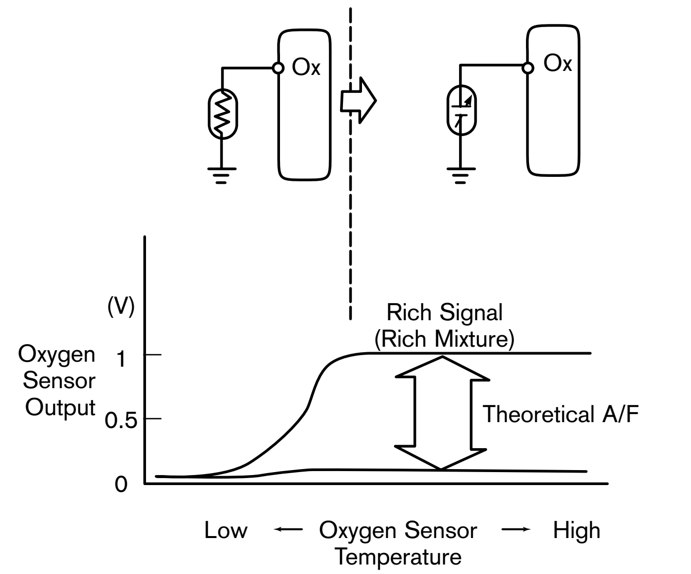


Fig. 2-77
T852f084

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

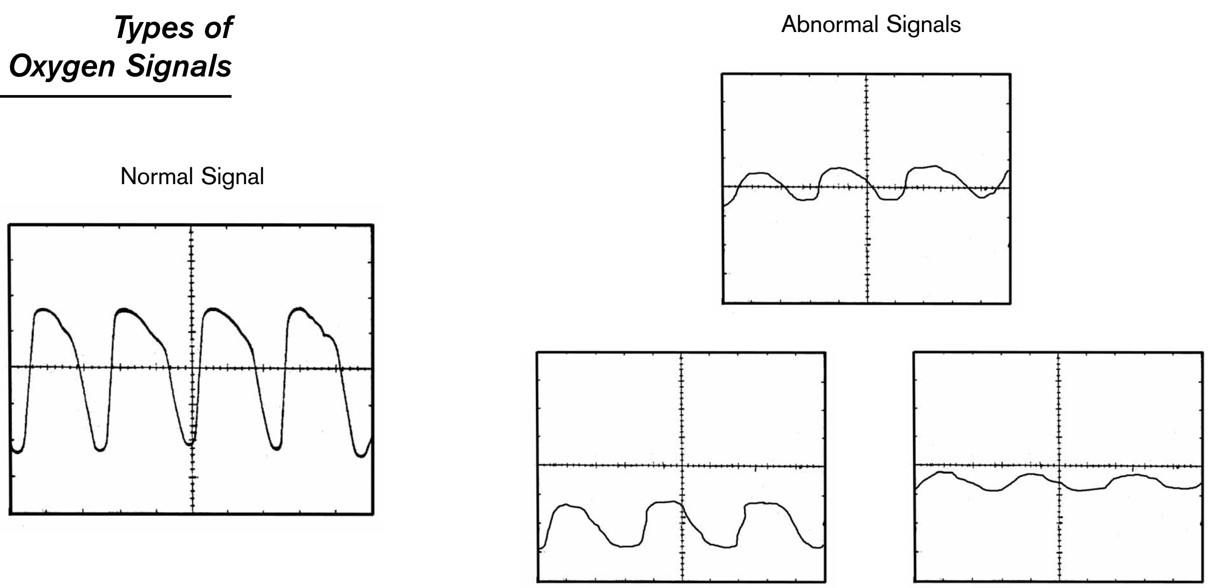
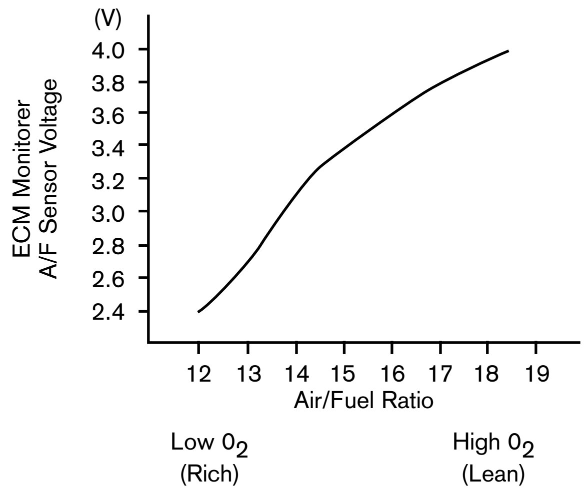


Fig. 2-78
T852f389/T852f390
T852f391/T852f392

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.



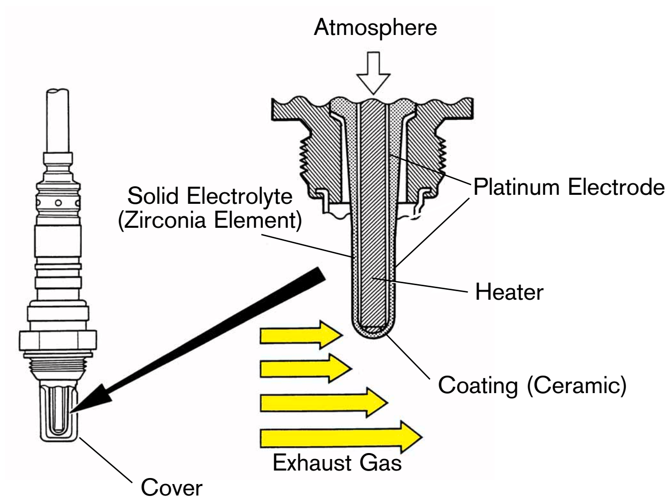


Fig. 2-79

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

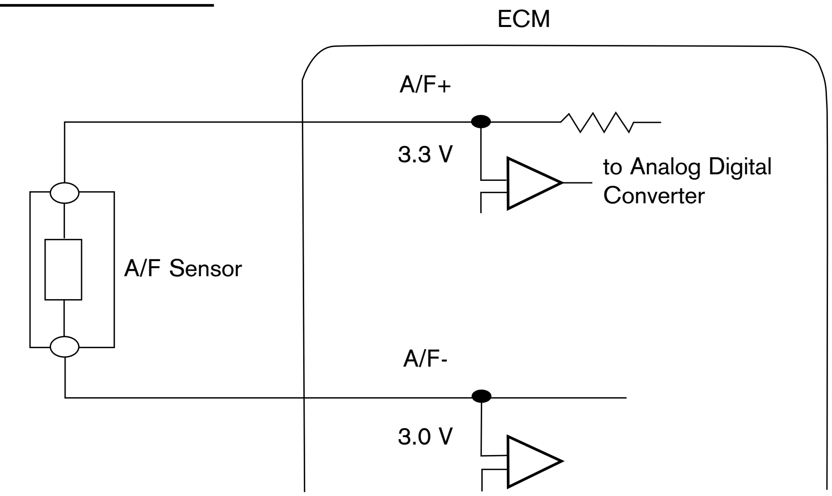


Fig. 2-80

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

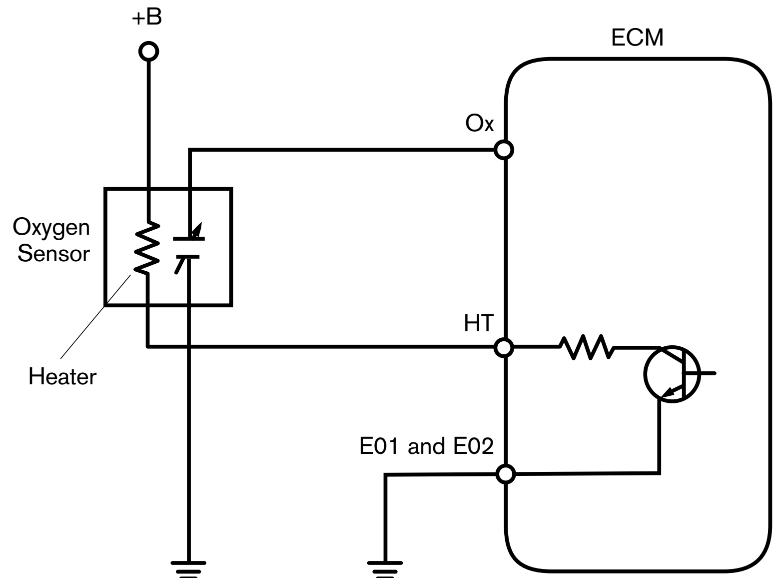


Fig. 2-81

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.

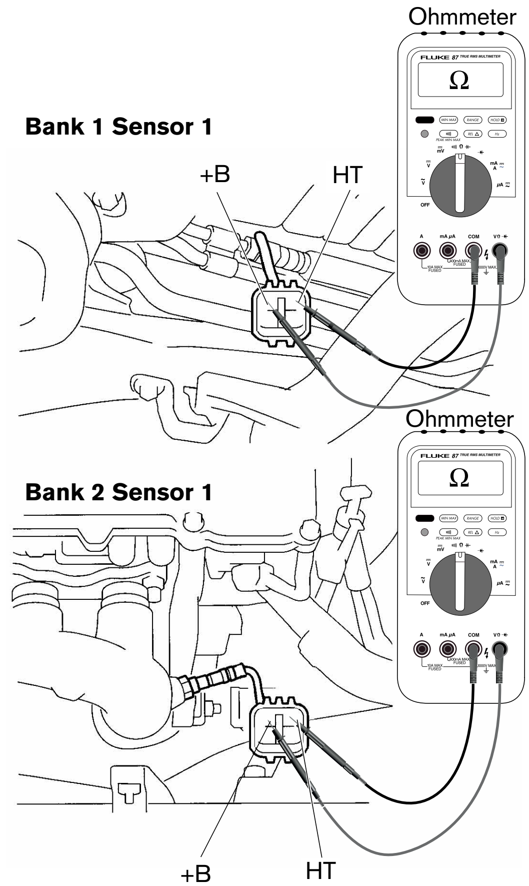


Fig. 2-82

T852f350

Air/Fuel Ratio Heater Circuit

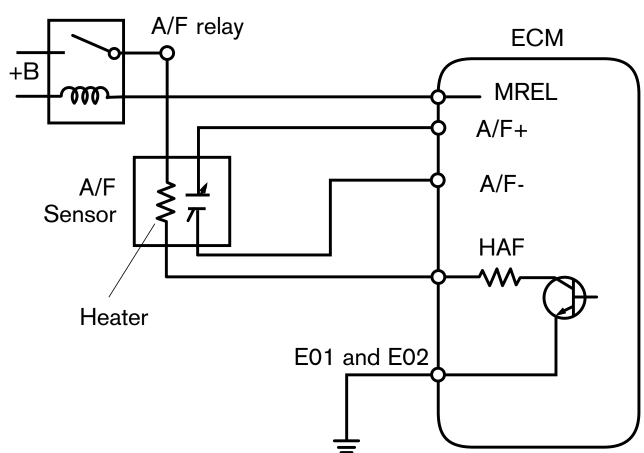


Fig. 2-83

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

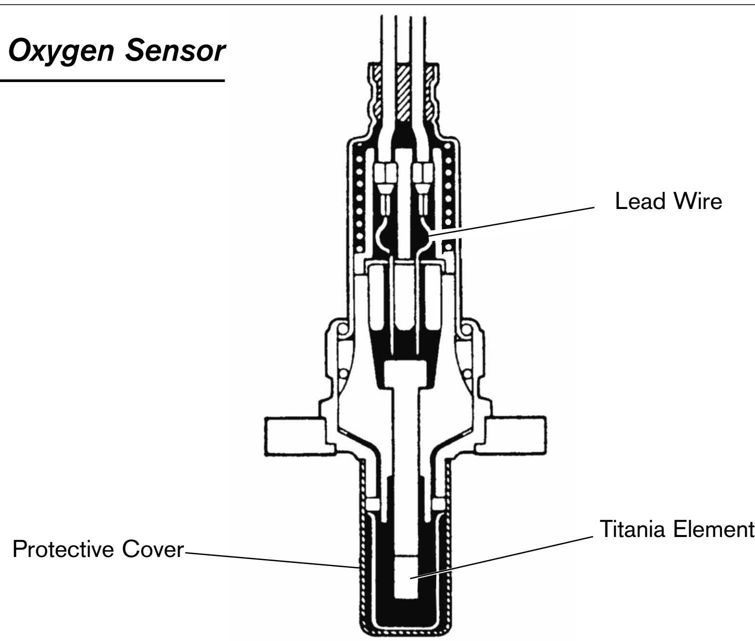


Fig. 2-84

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

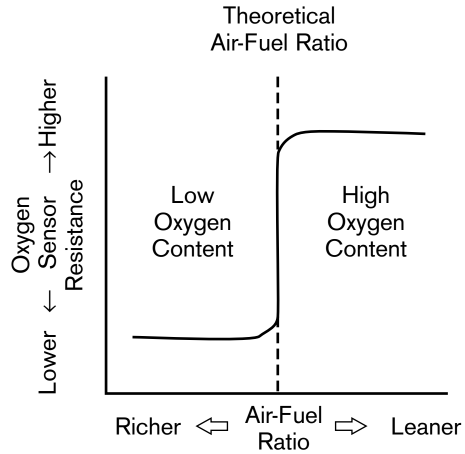


Fig. 2-85

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

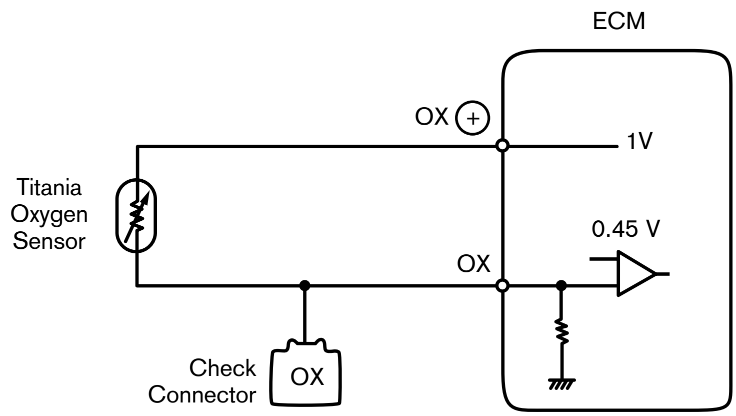


Fig. 2-86

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

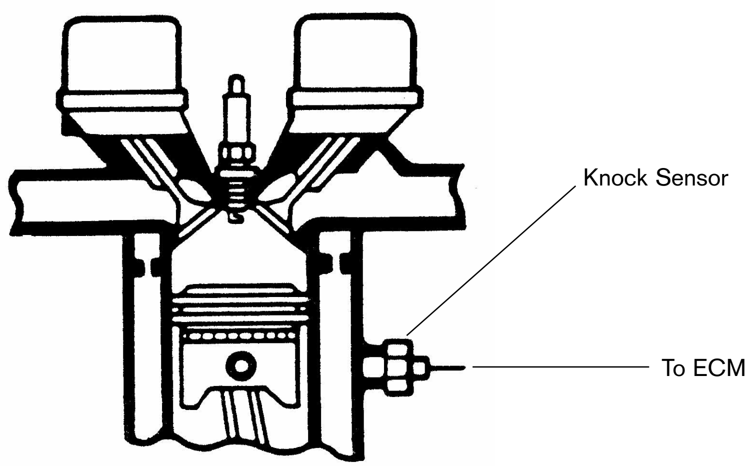


Fig. 2-87

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

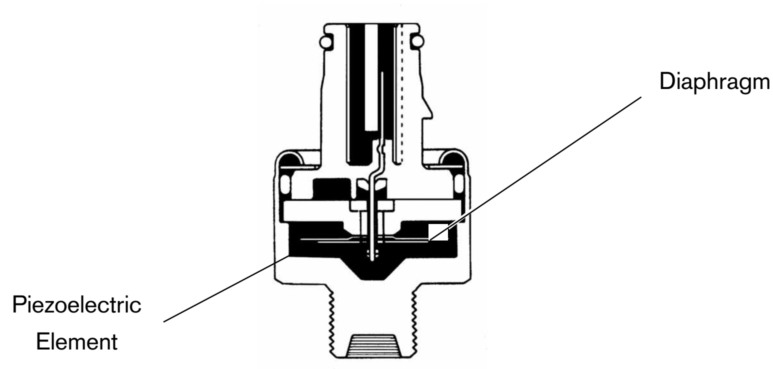


Fig. 2-88
T852f113

Knock Sensor Voltage Generation

When knock occurs, the voltage output increases.

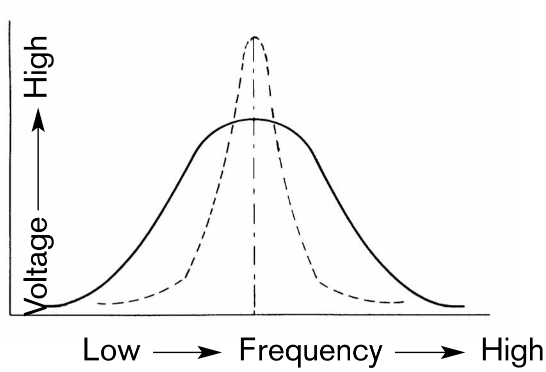


Fig. 2-89
T852f114

Knock Sensor

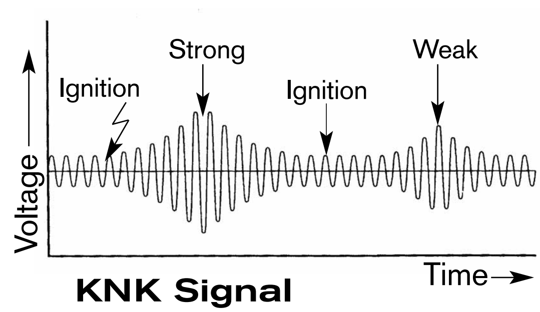


Fig. 2-90
T852f115

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

WORKSHEET 2–1
Position/Mode Switches and Circuits

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test position/mode circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set

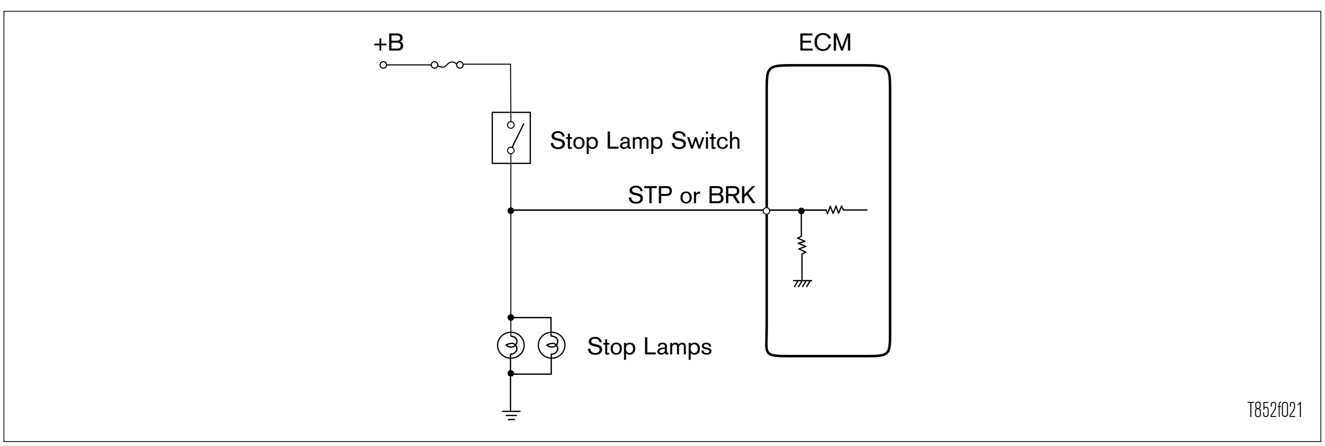
Section 1

The ECM needs to know the position of a component or when a circuit is being activated. A switch connected to the ECM is often used. The switch can be electrically connected to the ECM in two fundamental ways:

- The switch is between the Battery and ECM.
- The switch is between the ECM and Ground.

Section 2

Switch Between Battery and ECM



When the switch is located between the battery and ECM, the switch controls the voltage to the ECM. A very common example is the Stop Lamp Switch. When the driver steps on the brake, the switch closes completing the circuit. The ECM detects battery voltage and "knows" the vehicle is braking.

1. Connect the Diagnostic Tester to the ECM, scroll to Stop Light Switch and observe the reading.
2. Step on the brake and note the change.
3. Using the appropriate EWD and/or RM, locate the STP terminal.

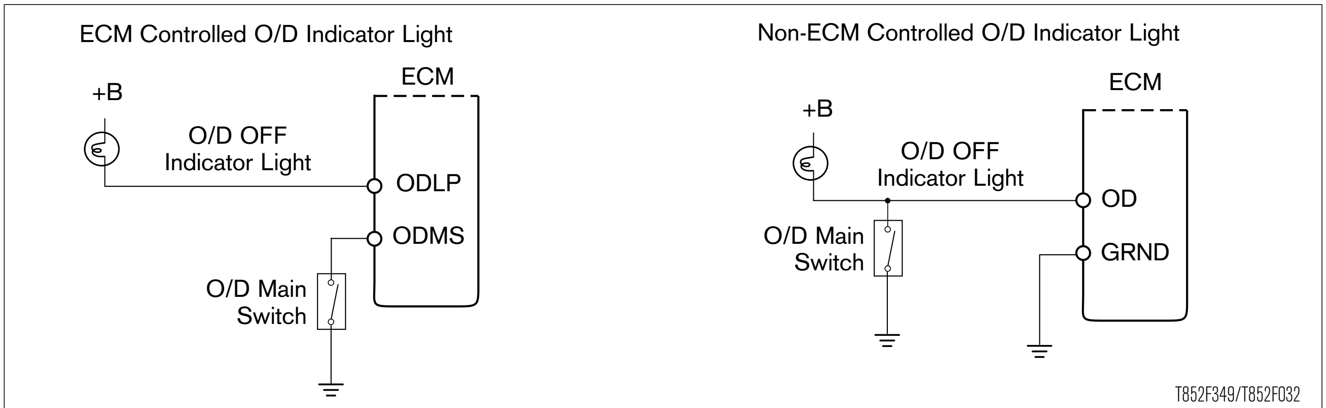
   STP Connector No: __________________ Pin No: ____________________ Wire Color: ____________________

4. Connect the positive (+) lead of the DVOM to the STP terminal, the Negative (-) lead to ground. Switch the DVOM to DC Volts.
   note the voltage reading: __________

5. Step on the brake, and note the voltage reading: __________
   Compare the Diagnostic Tester reading to the DVOM reading with brake ON/OFF. What is the difference?

   ____

Switch Between Battery And Ground



6. When the switch is located between the ECM and Ground, the switch controls the voltage to ground. An example is the Overdrive (O/D) main switch. (If O/D is unavailable, select another vehicle).

7. Connect the Diagnostic Tester to the ECM, scroll to O/D Switch, and observe the reading.

8. Locate the Overdrive(O/D) main switch terminal.

   Connector No: ____________________ Pin No: ____________________ Wire Color: ____________________

9. Predict the voltage at the Overdrive (O/D) main switch terminal
   with the Light Off __________ and with the light On __________.

10. Connect the positive (+) lead of the DVOM to the O/D main switch terminal, the negative (-) lead to ground. Switch the DVOM to DC Volts.

O/D Switch Position	Voltage @ ECM	Diagnostic Tester Shows
O/D Switch OFF		
O/D Switch ON		

Switch Position

As a rule, the EWD shows the switch in it's natural, at rest position. Most switches connected to the ECM are normally open switches, regardless if they are on the power or ground side.

The stop light switch is a normally open switch. The switch closes when the brake pedal; is stepped on.
From the EWD, locate the switches connected to the ECM. Identify if they are:

- Power side/ground side switched.
- Normally open/closed.

Fill in the Chart Blanks:

Section 3

Switch	Power/Ground Side	Normally Open/Closed	Voltage Signal at Rest	Voltage When Activated
Stop Light				
OD				
Power Steering				

Mode Circuits

There are times when the ECM needs to know what systems are being activated. For example, when the engine is being started, the ECM receives a signal at the STA terminal.

At the designated vehicle, locate the starter (STA) and electric load circuit (ELS) connected to the ECM and terminals. Connect the Diagnostic Tester and DVOM to the appropriate terminals. Try to predict the voltages in each state and compare to the readings.

Circuit	PREDICT The Voltage Signal with Circuit ON	PREDICT The Voltage Signal with Circuit OFF	ACTUAL DVOM Reading		ACTUAL Diagnostic Tester	
			ON	OFF	ON	OFF
STA						
ELS						
4WD						

Notes

Position/Mode Switches and Circuits

Name ______________________________ Date ________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	*I have questions*	*I know I can*	Comment
Locate components in the switch sensing circuits using the EWD and RM.			
Find wire colors, pin numbers in the switch sensing circuit using the EWD and RM.			
Identify a normally closed and normally open switch.			
Identify the switch sensors and position from the Data List.			
Measure the voltage signal of the switch sensor at the ECM.			
Test a supply side switch and compare to specifications to determine condition.			
Test a ground side switch and compare to specifications to determine condition.			
Check and retrieve relevant DTCs.			
Describe the difference between a supply side and ground side switched circuit.			
Describe the difference between a normally closed and normally open switch.			

Notes

WORKSHEET 2–2
Temperature Sensors

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test temperature sensors and circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester & DVOM
- Hand Tool Set
- Vehicle at room temperature

Section 1

Engine Coolant Temperature (ECT) and Intake Air Temperature (IAT) Operation

1. Connect the Diagnostic Tester and go to the Data List. Observe and record the IAT and ECT temperature. Do they match?

   ____

   Why is this important?

   ____

2. Using the Repair Manual/EWD, locate the THW and E2 terminals.

   THW Connector No. ______________ Pin No. ______________ Wire Color ______________

   E2 Connector No. ______________ Pin No. ______________ Wire Color ______________

3. Connect the positive (+) lead of the DVOM to the THW terminal and the negative (-) lead to terminal E2. With the ignition key in the run position, record the voltage: __________

4. Using the Repair Manual/EWD locate the THA terminal.

   THA Connector no. ______________ Pin No. ______________ Wire Color ______________

5. Move only the positive (+) lead of the DVOM to the THA terminal and record the voltage.

   ____

   HOLD the IAT sensor in your hand. What happened to the voltage and temperature?

   ____

6. Turn the Ignition key off.

7. Disconnect the IAT at the sensor. Using the test lead connector and DVOM, measure the resistance of the IAT. Does it match the Repair Manual chart?

____

8. HOLD the IAT sensor in your hand? What happened to the resistance and temperature?

____

9. Reconnect the IAT.

Section 2

Make sure the Parking Brake is securely set and exhaust hose is connected.

Connect the positive (+) lead of the DVOM to the THW terminal and the negative (-) lead to terminal E2.

Start the engine and observe the ECT reading on the Diagnostic Tester and the DVOM voltage reading. Plot the temperature and voltage on the chart below.

Temp (°F)	80	90	100	110	120	130	140	150	160	170	180
Volts											

Complete the following:

1. As the engine gets warmer, the ECT voltage signal is: __________

2. As the engine gets warmer, ECT resistance is: __________

3. Note the difference in voltage every 10°F. What happened to the change in voltage signal the last 40°F?

____

4. Shut the engine off, then turn the ignition key on. What should happen to ECT voltage signal?

____

5. Does the DVOM and Diagnostic Tester confirm your prediction?

____

Section 3

The following exercises will help you understand the Repair Manual diagnostic procedures.

Create an Open Circuit Fault

1. Disconnect the IAT (or ECT) at the sensor, and record the temperature and circuit voltage at the ECM:

   ____

Create a Short Circuit Fault

1. At the sensor connector, use a wire to connect the two terminals together and record the sensor temperature reading and voltage.

2. At the sensor connector, ground the TH_ wire. Is the reading approximately the same?

   ____

3. What DTC was created?

   ____

Repair Manual Logic

1. A customer vehicle comes in with DTC P0115, the Diagnostic Tester reads -40°(F). You would look for what type of circuit fault?

   ____

2. What step would you take next?

   ____

Section 4

Solving Open Circuit Faults

1. An open in the ECT or IAT will read on the DT: ___________; DVOM ___________

This step determines if the fault is with ECT or the circuit.

A jumper wire is inserted at the sensor connector. This creates a shorted circuit and the temperature should go high (hot). If it does:

What must be good?

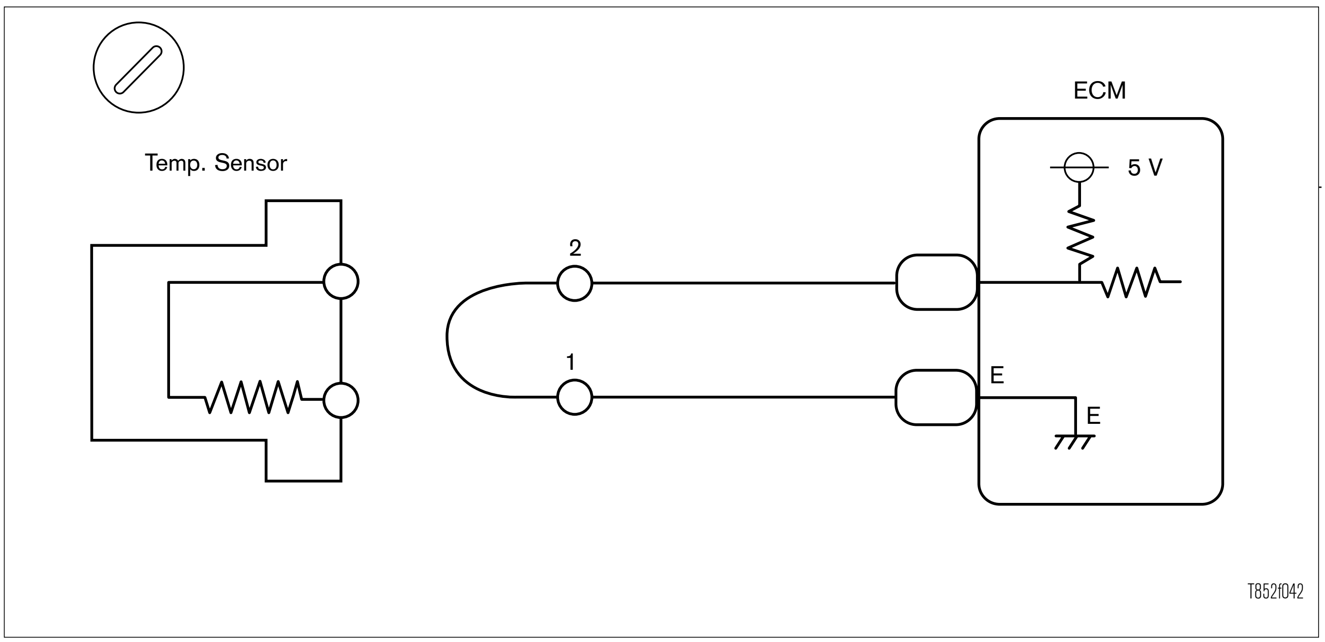
____

What must be at fault?

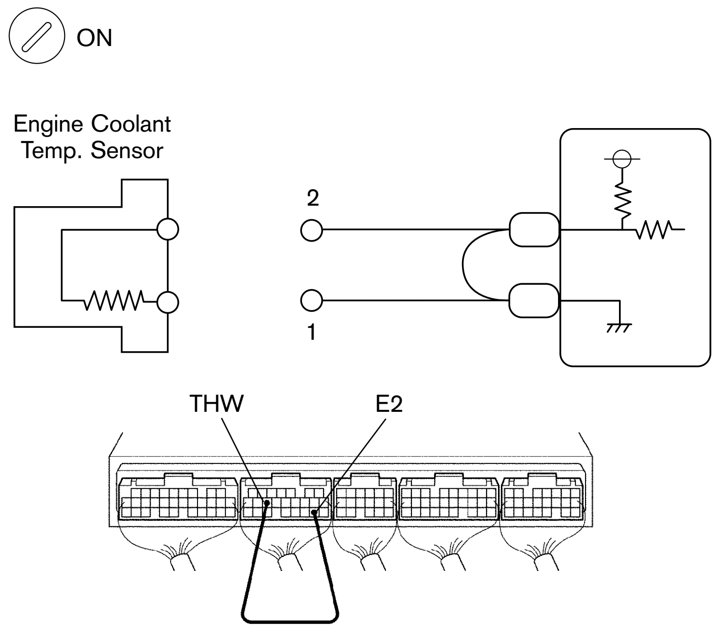
____

If the temperature did not go high (hot), then the problem is with:

____



Next, determine if the problem is with the circuit or the ECM.



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With a jumper wire between the THW terminal and E2 at the ECM, temperature should go high.

If it does, the problem is in:

____

If it does not go high it is either the:

____

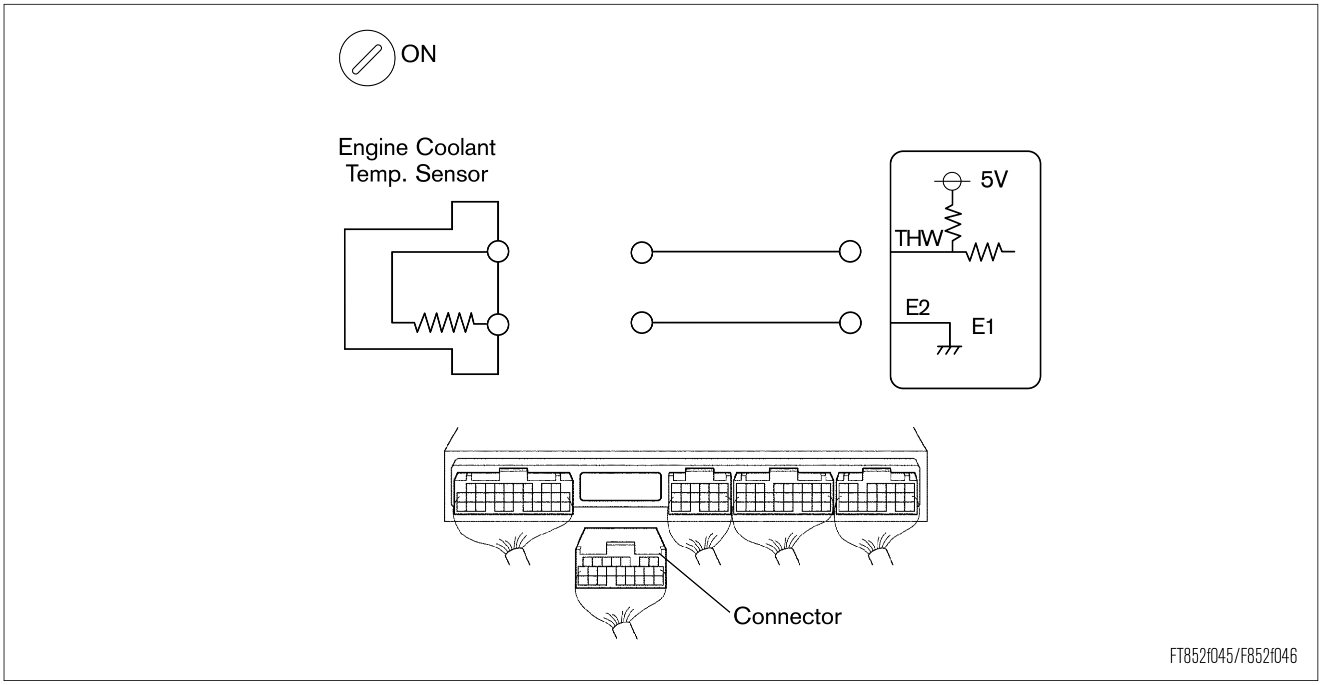
Solving Shorted Circuit Faults

1. A shorted ECT or IAT will read on the DT: ___________; DVOM ___________

Disconnecting the temperature sensor creates an open circuit and the temperature should go extremely low (cold). If it does, ____ must have been shorted to ground.

If not, the problem must be with the

____________________________________ or ____________________________________ .



With the connector at the ECM disconnected, temperature should go low (cold). If it does, the fault is:

____

If not, the problem is with:

____

Temperature Sensors

Name ______________________________ Date ______________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the temperature sensing circuits using the EWD and RM.			
Find wire colors, pin numbers in the temp. sensing circuit using the EWD and RM.			
Locate the temperature reading from the Data List.			
Measure the voltage drop of the sensor.			
Test VC (supply voltage) and compare to specifications to determine condition.			
Test E (ground line) and compare to specifications to determine condition.			
Test sensor resistance and compare to specifications to determine condition.			
Check and retrieve relevant DTCs.			
Describe purpose of ECT and IAT.			
Describe ECM strategy if the ECT and IAT circuit fails.			

Notes

WORKSHEET 2–3
Position Sensors

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test position sensors and circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set with DVOM
- Vehicle at room temperature
- Pencil

Section 1

The ECM needs to know the position of some components such as throttle valve position, EGR valve height, etc.

1. At the bottom of this page, draw a dark line approximately 1/4" wide. Connect the supply leads to VC and E2. Attach the DVOM ground lead to vehicle ground. Turn the ignition key on. With positive (+) lead of the DVOM touching VC, the DVOM should read 5v. Now slowly move the positive (+) lead on the drawn line towards E2 and note the DVOM reading. What happened to the voltage as the lead moved closer to E2?

   The strength of the voltage signal is how the ECM determines the position of the component.

Section 2

2. With the Diagnostic Tester connected to the vehicle, turn the ignition switch to ON and note the throttle position. Slowly depress the throttle and note the change on the Diagnostic Tester.

3. Connect a DVOM between the VTA and E2 terminals. Slowly depress the throttle and note the voltage on the DVOM. Did the voltage increase with throttle opening?

Just like the beginning exercise you did, the ECM measures position by the strength of the voltage signal.

The ECM sends 5 volts to the TPS on the VC wire. Voltage is then divided between the signal wire (VTA) and ground (E2). The closer the signal arm moves to the supply voltage, the higher the voltage signal.

Repair Manual Checks

The following explanations describe common diagnostic procedures found in the Repair Manual on throttle position sensors. You may find discrepancies with the order in the RM.

Diagnostic Tester

1. Compare throttle position to the Diagnostic Tester data at idle and WOT.
2. Do the readings match specifications?

   ____

Check voltage between terminal VC of the TPS and body ground.

1. Disconnect the TPS connector and measure the voltage at the VC terminal. It should be 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.

2. With the TPS disconnected, what did the DT read? __________

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

____.

If you did not get 5 volts, the ECM is at fault.

Inspect Throttle Position Sensor

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

1. With DVOM measure the resistance of the TPS at the specified terminal locations. What terminals are used?

   ____

2. Does the TPS meet specifications?

   ____

Check voltage between terminals VTA and E2 of ECM connector.

This test is the same as in the exercise you did above. 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 TPS may also be the problem.) If voltage readings are not in spec., there may be an open or short in harness and connector between ECM and TPS on the VTA or E2 line.

1. If the VTA line were shorted to ground, what would the voltage reading be?

   ____

2. If the VTA line were open, what would the voltage reading be?

   ____

3. What test(s) can be made to determine the difference?

   ____

4. If the E2 line were open, VTA voltage will be approximately?

   ____

Position Sensors

Name ______________________________ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the position sensing circuits using the EWD and RM.			
Find wire colors and pin numbers in the position sensing circuit using the EWD and RM.			
Locate the TPS/EGR VPS reading from the Data List.			
Measure the voltage signal of the sensor.			
Test VC (supply voltage) and compare to specifications to determine condition.			
Test E (ground line) and compare to specifications to determine condition.			
Test sensor resistance and compare to specifications to determine condition.			
Check and retrieve relevant DTCs.			
Describe purpose of TPS/EGR VPS.			
Describe ECM strategy if the TPS circuit fails.			

Notes

WORKSHEET 2–4
Mass Airflow (MAF) Sensors

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test MAF sensor and circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester & DVOM
- Hand Tool Set

Section 1

The MAF sensor is needed by the ECM to measure the volume of air entering the engine. From the air volume measurement, the ECM can inject the correct amount of fuel and adjust the ignition timing.

List each terminal on the MAF connector and explain the purpose.

Terminal	Purpose

Section 2

MAF Operation

1. With the DT, select the MAF reading from the Data List.

   ____

2. Locate MAF signal wire at:

   ECM connector: ____________ Terminal: ____________ Wire Color: ____________

3. Connect the positive (+) lead of the DVOM to MAF signal terminal. Connect negative (-) lead to E2.
4. Slowly accelerate the engine in the increments shown and record voltage and grams/sec.

RPM	Idle	1000	1250	1500	1750	2000	2250	2500	2750	3000
G/S										
Volts										

5. What happened to airflow and voltage as RPMs increased?

 ____

6. When finished, shut the engine off.
7. Remove the MAF from the air induction hose, but leave electrically connected. Start the engine. What happened?

 ____

8. If the MAF sensor were plugged with debris, what is the most likely engine symptom?

 ____

Section 3

MAF Sensor Component Check

According to the Repair Manual, perform the MAF test procedure for operation.

1. What indicates a good MAF sensor?

 ____

2. What DTCs are related to the MAF circuit?

 ____

3. What MAF DTC is a one trip? Two trip?

 ____

4. What are the Detecting Conditions for the one trip? Two trip?

 ____

5. Does this have a Fail-Safe condition?

 ____

Mass Airflow (MAF) Sensors

Name ____ Date __________________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	*I have questions*	*I know I can*	Comment
Locate components in the MAF circuit using the EWD and RM.			
Find wire colors, pin numbers in the MAF circuit using the EWD and RM.			
Locate the MAF reading from the Data List.			
Measure the voltage signal of the sensor.			
Test supply voltage and compare to specifications to determine condition.			
Test E (ground line) and compare to specifications to determine condition.			
Test sensor performance and compare to specifications to determine condition.			
Check and retrieve relevant DTCs.			
Describe purpose of the MAF sensor.			
Describe ECM strategy if the MAF circuit fails.			

Notes

WORKSHEET 2–5
Manifold Absolute Pressure (MAP) Sensor

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test the MAP sensor and circuit using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual & EWD
- Diagnostic Tester & DVOM
- Hand Tool Set Vacuum Pump
- Vehicle

Section 1

MAP Sensor signal

Use the positive (+) DVOM to measure MAP voltage signal and DT to measure pressure. *Fill in the blanks.*

1. Positive (+) lead Connected to: Connector No: ____________ Pin No. ____________.
2. Negative (-) lead connected to: Connector No: ____________ Pin No. ____________.
3. MAP voltage signal KOEO ____________.
4. MAP voltage signal at idle ____________.
5. MAP voltage signal at brief WOT ____________.
6. What happened to intake manifold pressure as the throttle opened?

   ____

7. Why does the ECM need the MAP (PIM) voltage signal?

   ____

Use the DVOM to measure the regulated voltage supply to the MAP. *Fill in the blanks.*

1. Positive (+) lead Connected to: Connector No: ____________ Pin No. ____________.
2. Negative (-) lead connected to: Connector No: ____________ Pin No. ____________.
3. MAP regulated voltage (VC) supply ____________.

Section 2

MAP Component Test

Applied Vacuum					
Key ON PIM					
PIM Voltage					
Calculated Voltage Drop					
Voltage Drop Specification					
DT Pressure*					

Use the RM for MAP sensor component test. Fill in the following:

* The RM does not give pressure readings by using the DT.

1. Is the MAP sensor good?

   ____

2. What DTCs are related to the MAP circuit?

   ____

3. What MAP DTC is a one trip? Two trip?

   ____

4. What are the Detecting Conditions for the one trip? Two trip?

   ____

5. Does this have a Fail-Safe condition?

   ____

Manifold Absolute Pressure (MAP) Sensors

Name ____ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the MAP circuit using the EWD and RM.			
Locate the MAP reading from the Data List.			
Measure the voltage signal of the sensor.			
Test the VC supply voltage and compare to specifications to determine condition.			
Test E (ground line) and compare to specifications to determine condition.			
Test sensor performance and compare to specifications to determine condition.			
Check and retrieve relevant DTCs			
Describe purpose of the MAP sensor.			
Describe ECM strategy if the MAP circuit fails.			

Notes

WORKSHEET 2–6
Position/Speed Sensors

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test camshaft and crankshaft sensors using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- DVOM
- Hand Tool Set

Section 1

The ECM needs to know position and speed of many components such as the engine crankshaft, camshaft, vehicle speed, transmission, etc.

Camshaft Position (Variable Valve Timing) Sensor

1. Connect the Diagnostic Tester Autoprobe and DVOM to the camshaft sensor circuit at the ECM.
   ECM terminals: ____________
2. Set the Diagnostic Tester to the Oscilloscope/autoprobe function, refer to Repair Manual for settings Connect DVOM and set to AC volts, Hz.
3. Start the engine and draw or print the waveform at IDLE. What is the frequency? ________________

IDLE **2000 RPM**

4. Does the waveform match the Repair Manual waveform?

   ____

5. Raise engine RPM to 2000. What happened to the waveform and frequency?

   ____

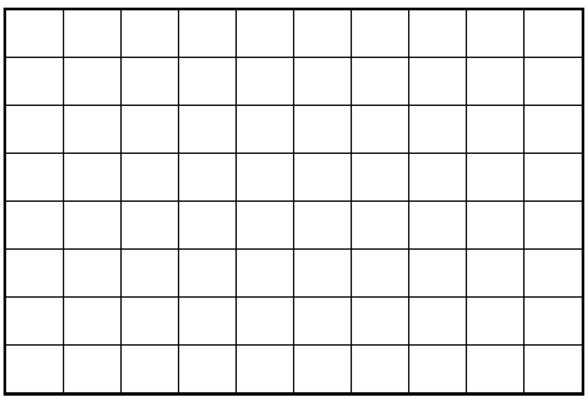
Crankshaft Position Sensor

1. Connect the Diagnostic Tester Autoprobe and DVOM to the crankshaft position sensor signal. ECM terminals: ___________
2. Start the engine and at idle RPM note the waveform.
3. Does the waveform match the Repair Manual waveform?

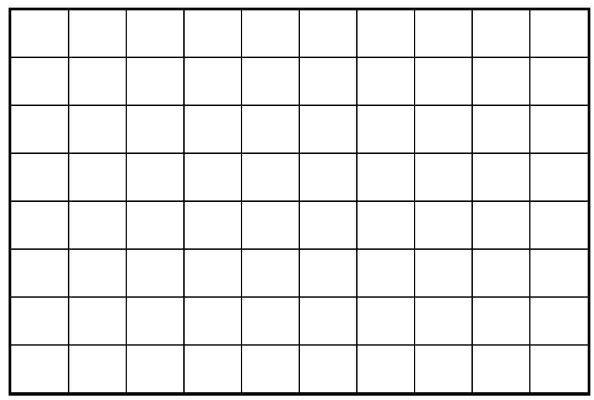
   ____

4. Draw or print the waveform at IDLE. What is the frequency? ___________

IDLE



2000 RPM



5. Raise engine RPM to 2000. What happened to the waveform and frequency?

   ____

6. What sections in the RM contain diagnostic information on these sensors?

   ____

7. What are the coil resistance specifications for the crankshaft and camshaft position sensors?

   ____

Position/Speed Sensors

Name ______________________________ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the crankshaft and camshaft sensing circuits using the EWD and RM			
Find wire colors, pin numbers in the crankshaft and camshaft sensing circuits using the EWD and RM			
Locate the crankshaft and camshaft readings from the Data List			
Measure the voltage signal of the sensors with a DVOM			
Observe the voltage signal pattern of the sensors with an oscilloscope			
Test wires for continuity and compare to specifications to determine condition			
Test sensor resistance and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Describe purpose of crankshaft and camshaft sensors			
Describe ECM strategy if the crankshaft circuit fails			
Describe ECM strategy if the camshaft circuit fails			

Notes

WORKSHEET 2–7
Oxygen Sensor

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

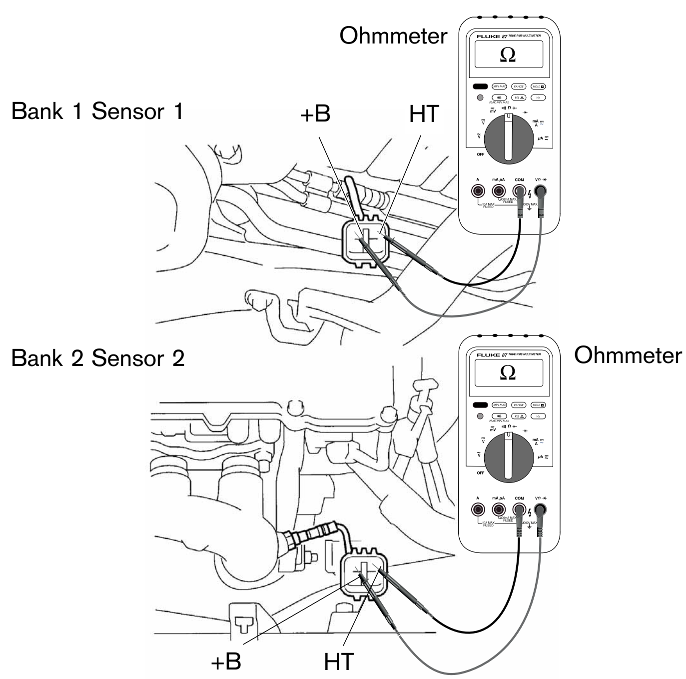
With this worksheet, you will learn to test oxygen sensor and circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- DVOM
- Hand Tool Set

Section 1

Disconnect the oxygen sensor connector. Using a DVOM, measure the heater element resistance and compare to specifications.



Heater Resistance Test

1. Record resistance readings B1S1 ___________ ohm, B2S1 ___________ ohms.

   Was the resistance within specification?

   ____

2. Use the EWD to trace the oxygen sensor heater circuit. What component supplies power to the oxygen sensor heater?

____

3. With the key on and engine off, at the HTL or HTR terminal of the ECM, measure oxygen sensor heater voltage: ___________
4. Start the engine. What happened as the engine warmed up?

____

____

5. What DTCs could set if the heater did not work?

____

Section 2

Oxygen Sensor Signal

1. Connect the Diagnostic Tester and scroll to the oxygen sensor.
2. Locate the oxygen sensor terminal on the ECM. Connect the positive (+) lead of the DVOM to the oxygen sensor signal terminal, connect the negative (-) lead to E2. Set the DVOM to the DC scale.
3. With vehicle in park, exhaust hose connected, parking brake set, start the engine. Note that initial readings will change based on engine temperature.
4. After the engine has warmed up, record the oxygen sensor signal at idle. Are the readings normal?

____

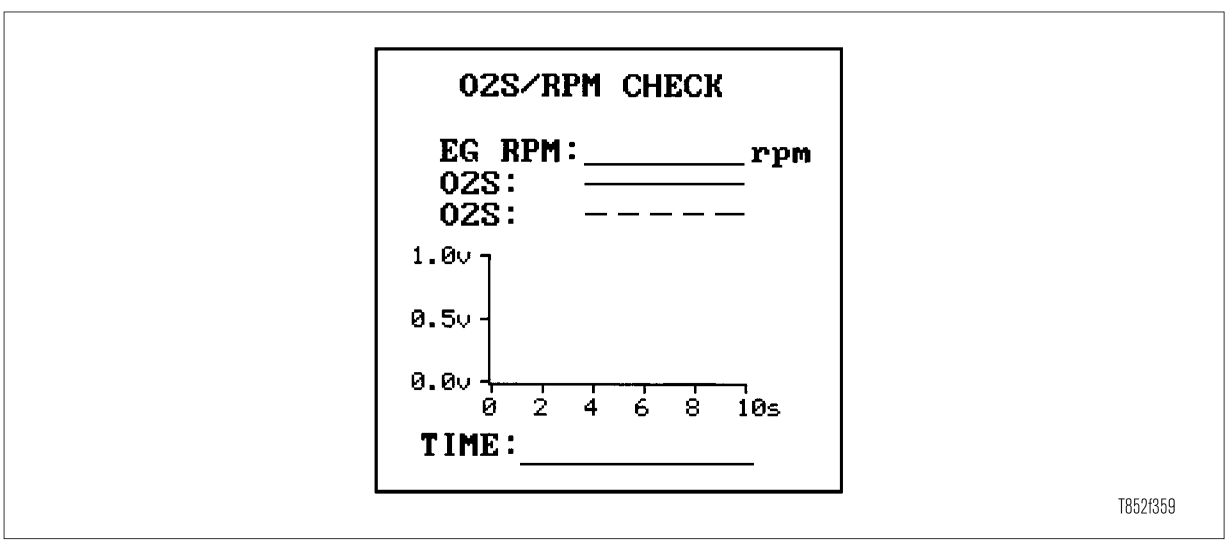
5. Briefly snap the throttle wide open and release. What happened to the oxygen sensor signal?

____

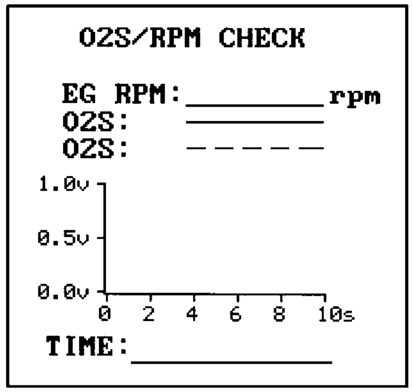
6. Hold the engine at 2,500 RPM. What happened to Oxygen sensor readings?

____

7. With the Diagnostic Tester, go to the O2S/RPM check. (Instructions found in Diagnostic Toolset manual.) Raise engine to 1000 RPM. Draw the pattern on the following graph.



Raise engine to 2500 RPM. Draw the pattern on the following graph.



T852f359

1. What happened to oxygen sensor frequency?

   ____

2. With the engine at idle, create an intake manifold vacuum leak, by disconnecting a vacuum hose. What happened to the O2 sensor reading?

   ____

3. Reconnect the vacuum hose. What happened?

   ____

Section 3

Oxygen Sensor Response

With the engine at operating temperature, go to Data List and note the oxygen sensor voltage signal and Fuel Trim.

1. Disconnect a vacuum hose. Was there a change to oxygen voltage signal and Short Term Fuel Trim?

   ____

2. Reconnect vacuum hose.
3. **Predict** what **will** happen to oxygen sensor signal voltage if more fuel is added?

   ____

4. Go to Injector Volume Active test. Add fuel using the Active Test to increase injector duration. What happened to oxygen sensor voltage signal?

   ____

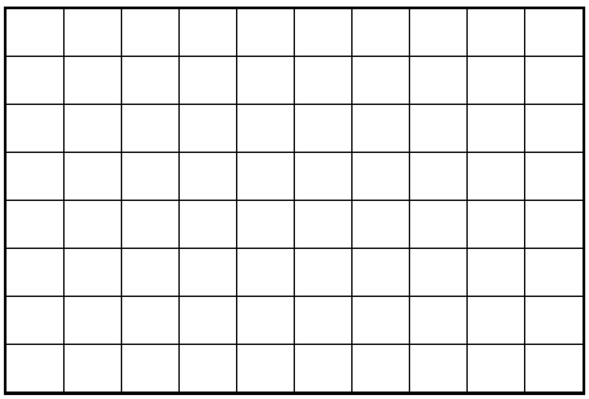
5. Decrease injector duration. What happened to oxygen sensor signal voltage?

   ____

Section 4

Oxygen Sensor Signal Using AutoProbe

1. Connect AutoProbe to the Diagnostic Tester and calibrate according to the Diagnostic Tester manual. Go to oscilloscope screen. Set the time and voltage according to the instructor's directions. (typically 1 second and 0.2 volts)
2. Connect the AutoProbe to the oxygen sensor signal wire at the ECM. Start the engine and observe the pattern.
3. Draw the pattern. TIME setting __________, VOLT setting __________.



4. What is the major difference between using the AutoProbe and the OS2 Check?

____

____

Oxygen Sensor

Name ______________________________________ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the oxygen sensing circuits using the EWD and RM			
Find wire colors, pin numbers in the oxygen sensing circuits using the EWD and RM			
Locate the oxygen sensor readings from the Data List			
Measure the voltage signal of the sensor with DVOM and compare to specifications to determine condition			
Test sensor performance with oscilloscope and compare to specifications to determine condition			
Test heater supply voltage and compare to specifications to determine condition			
Test ground lines and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Describe purpose of the front oxygen sensor(s)			
Describe ECM strategy if the front oxygen sensor circuit(s) fails			

Notes

WORKSHEET 2–8
Air/Fuel Ratio

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objective

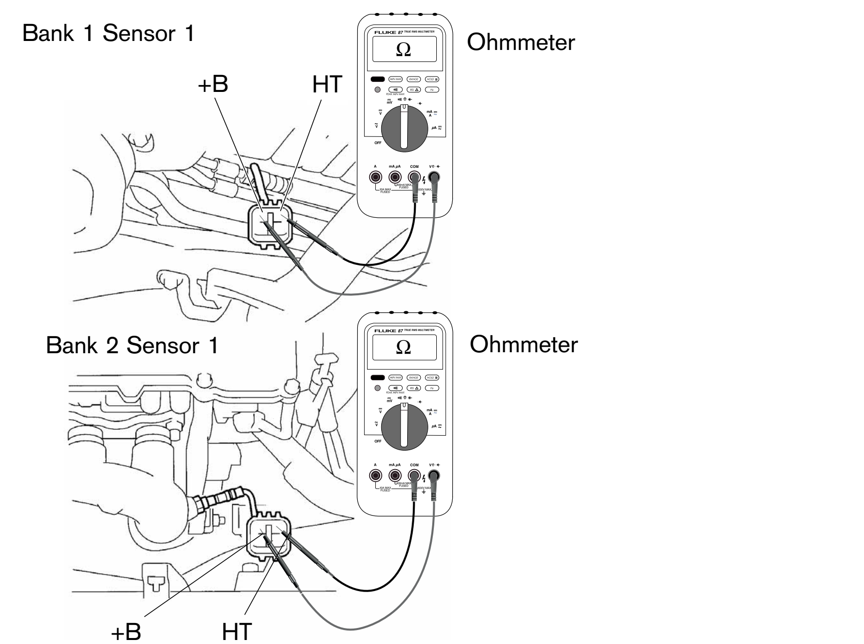
With this worksheet, you will learn to test A/F sensor and circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual & EWD
- Diagnostic Tester & DVOM
- Hand Tool Set Vacuum Pump
- Vehicle

Section 1

A/F Sensor Heater



Heater Resistance Test

1. Disconnect the A/F sensor connector. Using a DVOM, measure the heater element resistance.

   Record resistance readings B1S1: ___________ ohms, B2S1 ___________ ohms.

   Was the resistance within specification?

   ____

2. Reconnect A/F sensor. With the key on and engine off, measure A/F sensor heater voltage and body ground.

   ____

3. With the engine cold connect a DVOM and AutoProbe to the A/F sensor heater terminal at the ECM. Go to oscilloscope screen. Set the time and voltage according to the instructor's directions.

   Start the engine and observe the DVOM voltage and oscilloscope pattern.

   What was the voltage at start? __________ Warm idle? __________

   Draw the pattern. TIME setting: __________ VOLT setting: __________

   Increase engine RPM to 2500. Draw the pattern.

4. What happened to the pattern?

   ____

5. Use the EWD to trace the A/F Sensor Heater circuit. What turns on the A/F sensor heater relay?

   ____

6. These tests confirm the operation of which components and continuity of which circuits?

   ____

7. What DTCs could set if the heater did not work?

   ____

Section 2

A/F Sensor Response

Connect the Diagnostic Tester. With the engine at operating temperature, go to Data List, USER DATA and select one of the A/F sensors, Short Term Fuel Trim, and select ENTER. Select F4.

1. Record A/F sensor engine idling. Briefly, snap the throttle wide open and release. What happened?

   ____

2. Disconnect a vacuum hose. Was there a change to A/F voltage signal and Short Term Fuel Trim?

   ____

3. Reconnect vacuum hose.
4. **Predict** what **will** happen to A/F signal voltage if more fuel is added?

   ____

5. Go to Injector Volume Active Test. Increase injector duration. What happened to A/F sensor voltage signal?

   ____

6 Decrease injector duration. What happened to A/F sensor signal voltage?

   ____

Notes

Air/Fuel Ratio

Name ____ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the A/F Ratio sensing circuits using the EWD and RM			
Find wire colors, pin numbers in the A/F Ratio sensing circuits using the EWD and RM			
Locate the A/F ratio sensor readings from the Data List and compare to specs. to determine condition			
Test sensor performance and compare to specifications to determine condition			
Test heater resistance and compare to specifications to determine condition			
Test heater supply voltage and compare to specifications. to determine condition			
Test ground lines and compare to specs. to determine condition			
Check and retrieve relevant DTCs			
Describe purpose of the A/F sensor(s)			
Describe ECM strategy if the A/F sensor circuit(s) fails			

Notes

WORKSHEET 2–9
Knock Sensor

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test knock sensor and circuit using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set

Section 1

The knock sensor is will generate a signal, based on the strength and frequency of the knocking sound caused spontaneous combustion. Engine mechanical noises, such as a worn connecting rod may also be the cause.

Section 2

1. Locate and connect the Autoprobe to the knock sensor terminal on the ECM according to the Repair Manual.
2. Accelerate the engine to the RPM specified in the manual or per instructor's recommendation. Connect DVOM and set to AC volts, Hz. Start the engine and draw or print the waveform.
3. Note the DVOM reading: ____________

   Draw the waveform pattern.

4. Does the waveform match the Repair Manual waveform?

   ____

5. What is the frequency? ____________

6. List any other test method(s) for the knock sensor.

____

7. For DTC P0325, what are the Detecting Conditions?

____

____

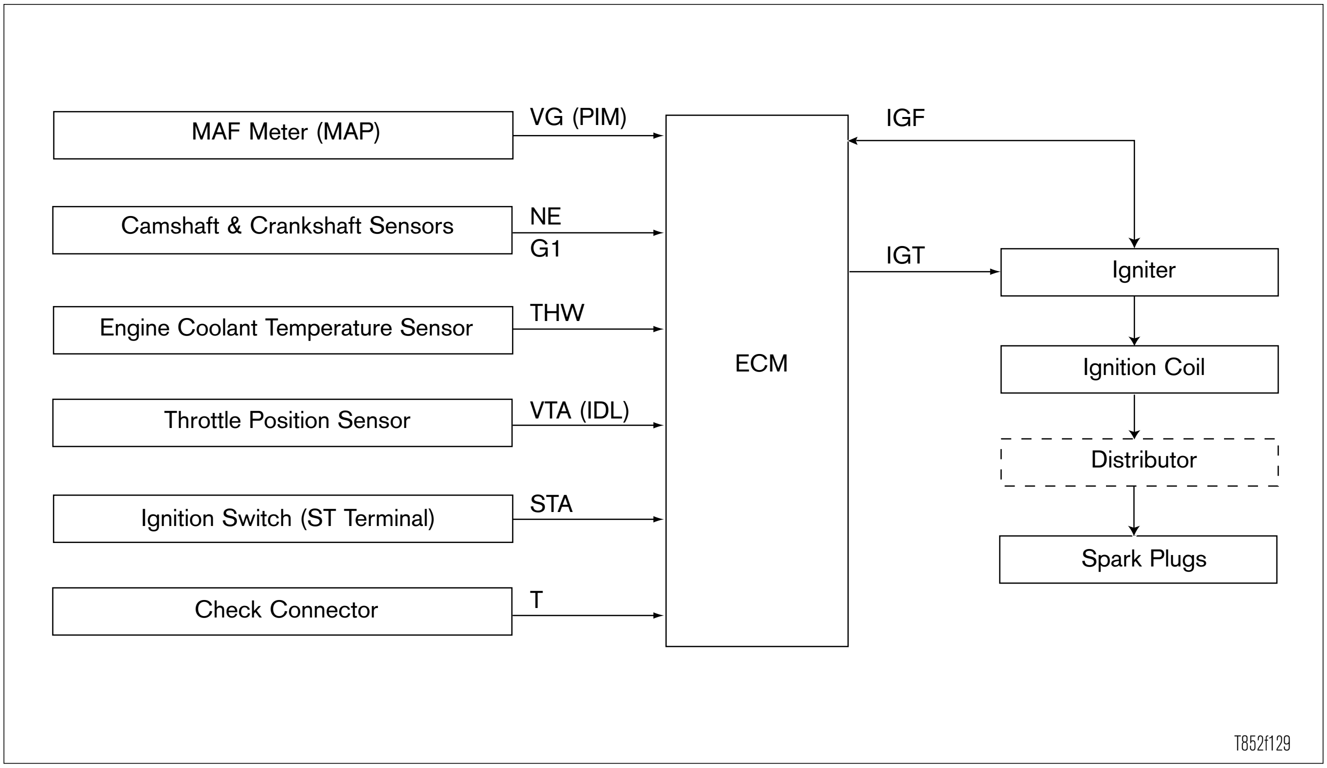
____

8. Is it 1 or 2 trip logic detection?

____

Section 3

Ignition Systems



Lesson Objectives

1. Determine the condition of the ignition system based on relevant input sensor signals and output signals
2. Determine the root cause of a failure(s) in the ignition system using appropriate diagnostic procedures

Ignition Systems

Ignition System Overview

The purpose of the ignition system is to ignite the air/fuel mixture in the combustion chamber at the proper time. In order to maximize engine output efficiency, the air-fuel mixture must be ignited so that maximum combustion pressure occurs at about 10° after top dead center (TDC).

However, the time from ignition of the air-fuel mixture to the development of maximum combustion pressure varies depending on the engine speed and the manifold pressure; ignition must occur earlier when the engine speed is higher and later when it is lower. In early systems, the timing is advanced and retarded by a governor in the distributor.

Combustion Pressure and Duration

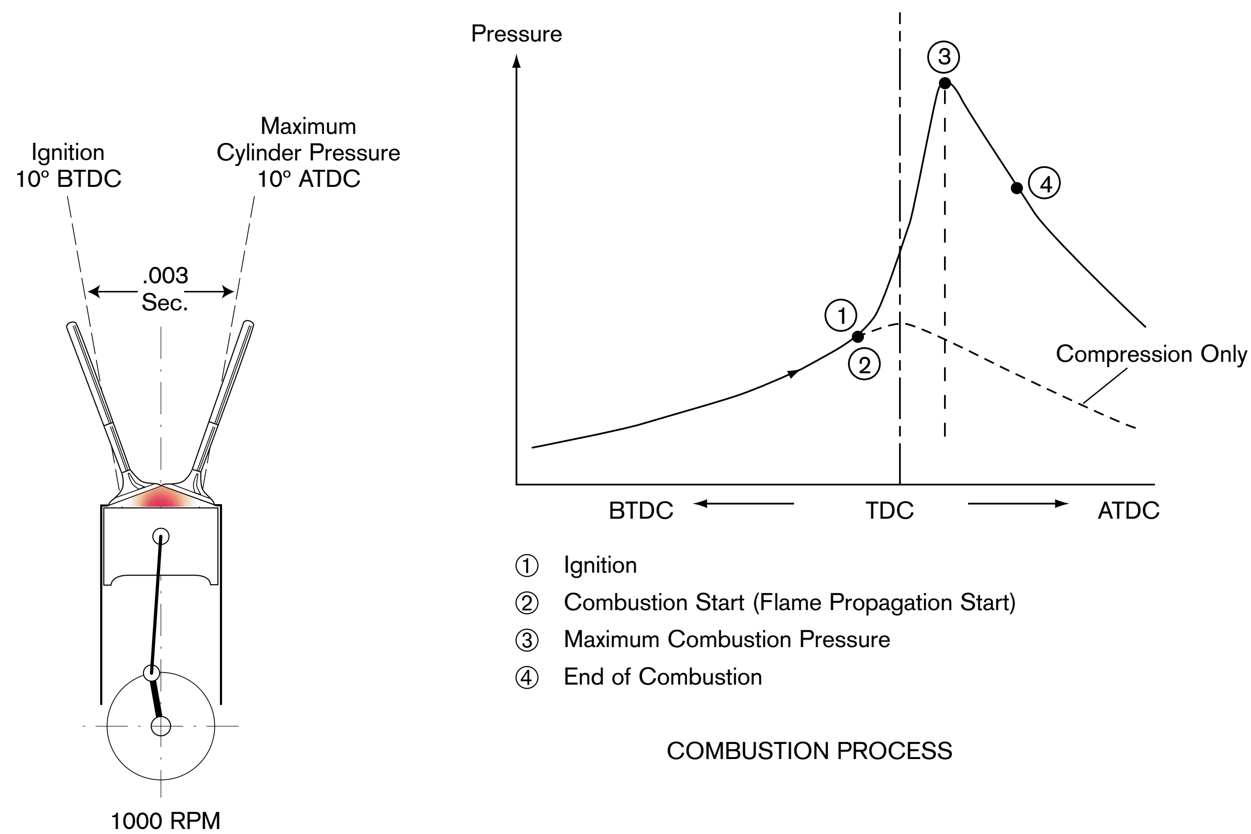


Fig. 3-01

T852f125/T852f126

Ignition Advance

Ignition must occur earlier so that the cylinder achieves maximum cylinder pressure as engine RPMs increase.

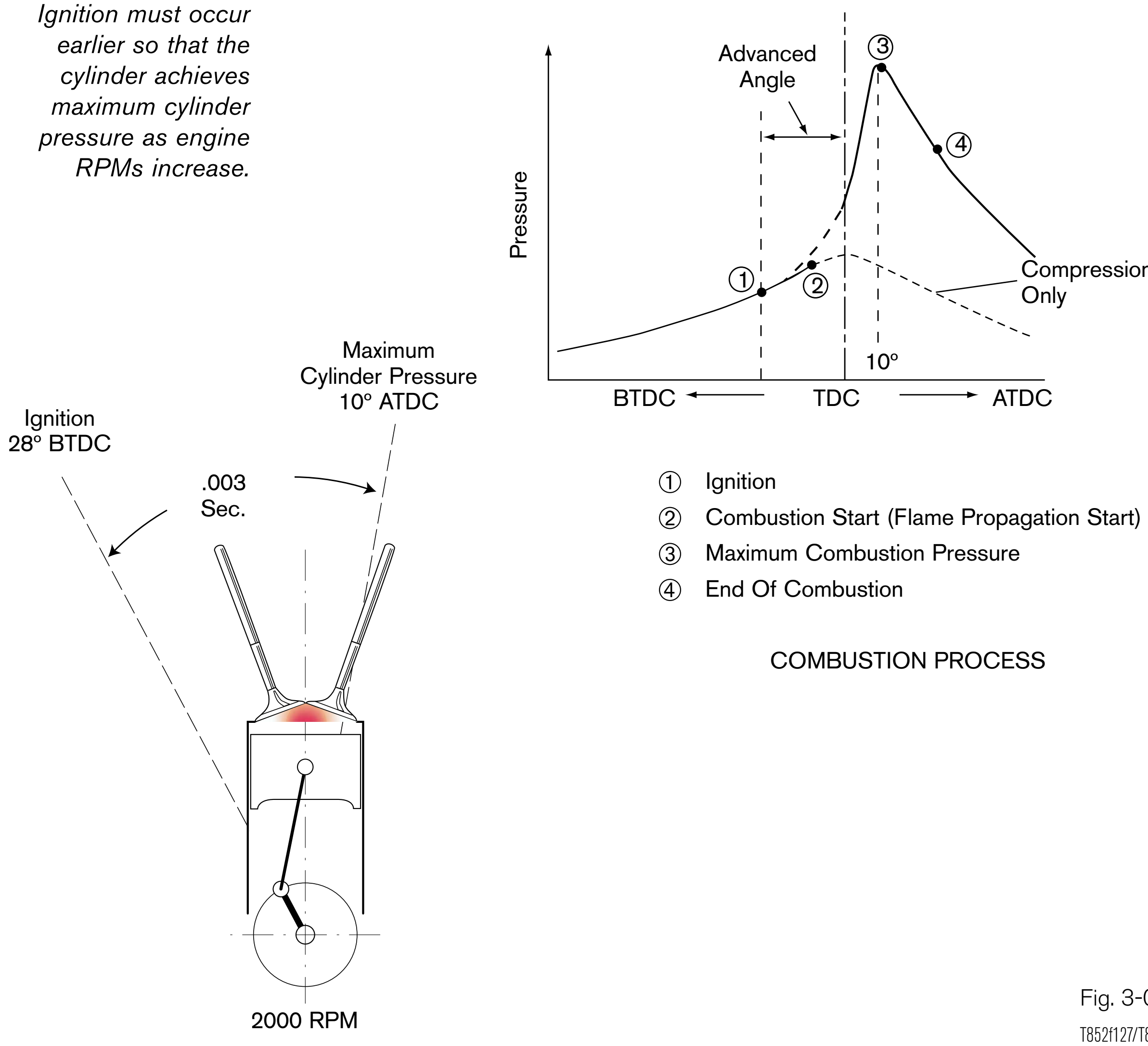


Fig. 3-02

T852f127/T852f128

Furthermore, ignition must also be advanced when the manifold pressure is low (i.e. when there is a strong vacuum). However, optimal ignition timing is also affected by a number of other factors besides engine speed and intake air volume, such as the shape of the combustion chamber, the temperature inside the combustion chamber, etc. For these reasons, electronic control provides the ideal ignition timing for the engine.

ESA Block Diagram

The distributor is not used on Distributorless and Direct Ignition Systems.

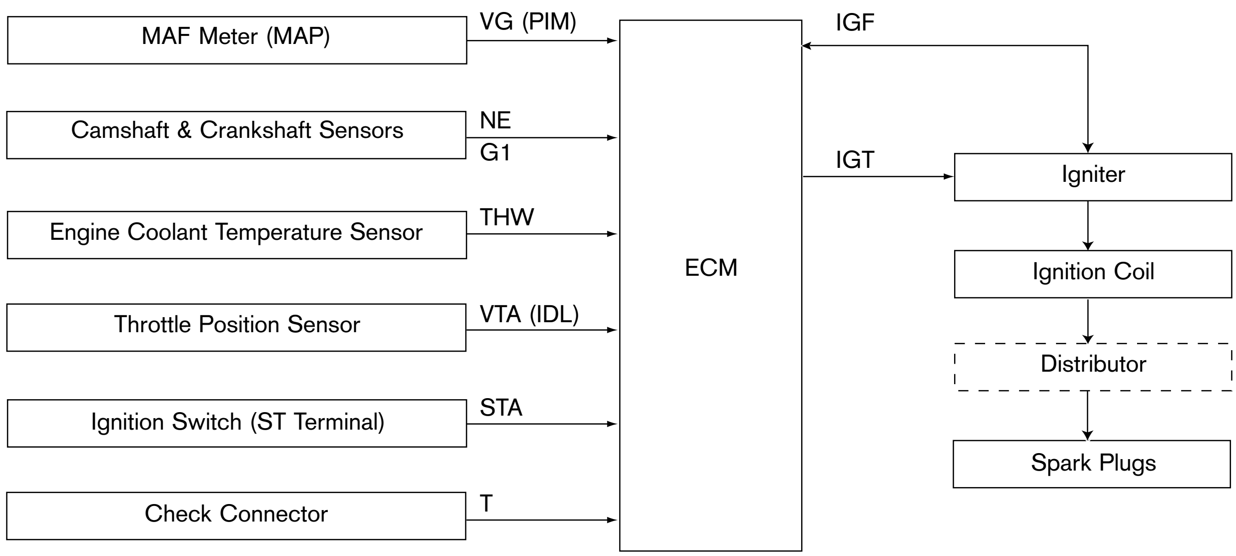


Fig. 3-03

T852f129

Electronic Spark Advance Overview

In the Electronic Spark Advance (ESA) system, the engine is provided with nearly ideal ignition timing characteristics. The ECM determines ignition timing based on sensor inputs and on its internal memory, which contains the optimal ignition timing data for each engine running condition. After determining the ignition timing, the ECM sends the ignition Timing signal (IGT) to the igniter. When the IGT signal goes off, the Igniter will shut off primary current flow in the ignition coil producing a high voltage spark (7kV - 35kV) in the cylinder.

Since the ESA always ensures optimal ignition timing, emissions are lowered and both fuel efficiency and engine power output are maintained at optimal levels.

Types of Ignition Systems

Ignition systems are divided into three basic categories:

- Distributor.
- Distributorless Ignition System (DLI) Electronic Ignition.
- Direct Ignition System (DIS).

Essential Ignition System Components

Regardless of type the essential components are:

- Crankshaft sensor (Ne signal).
- Camshaft sensor (also called Variable Valve Timing sensor) (G signal).
- Igniter.
- Ignition coil(s), harness, spark plugs.
- ECM and inputs.

Ignition Spark Generation

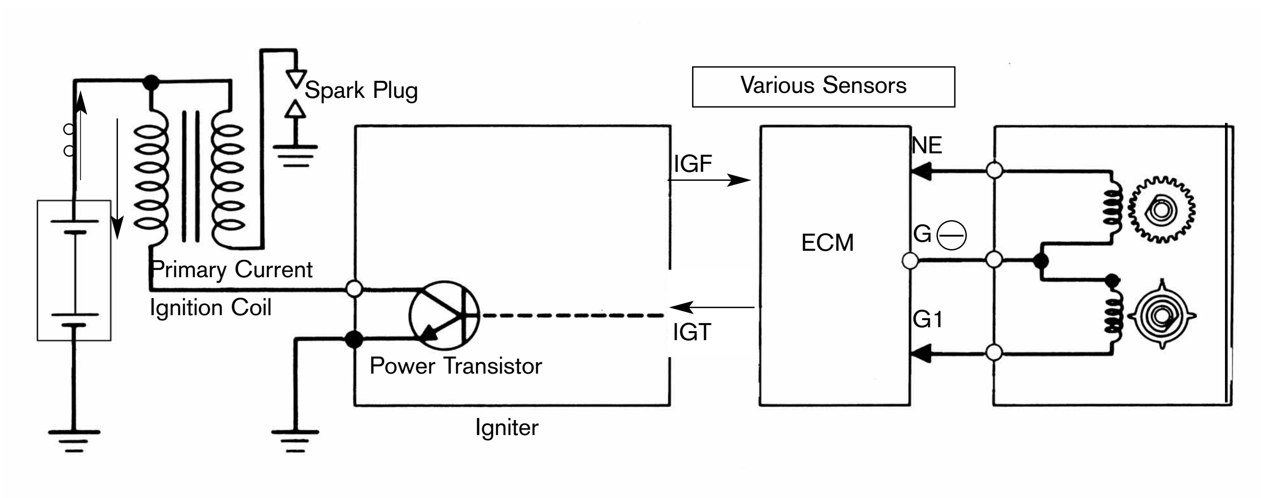


Fig. 3-04
T852f130

Ignition Spark Generation

The ignition coil must generate enough power to produce the spark needed to ignite the air/fuel mixture. To produce this power, a strong magnetic field is needed. This magnetic field is created by the current flowing in the primary coil. The primary coil has a very low resistance (approximately 1-4 ohms) allowing current flow. The more current, the stronger the magnetic field. The power transistor in the igniter handles the high current needed by the primary coil.

Another requirement to produce high voltages is that the current flow in the primary coil must be turned off quickly. When the transistor in the igniter turns off, current flow momentarily stops and the magnetic field collapses. As the rapidly collapsing magnetic field passes through the secondary winding, voltage (electrical pressure) is created. If sufficient voltage is created to overcome the resistance in the secondary circuit, there will be current flow and a spark generated.

NOTE The higher the resistance in the secondary circuit, the more voltage that will be needed to get the current to flow and the shorter spark duration. This is important when observing the ignition spark pattern.

IGT Signal

The IGT signal determines when ignition will occur.

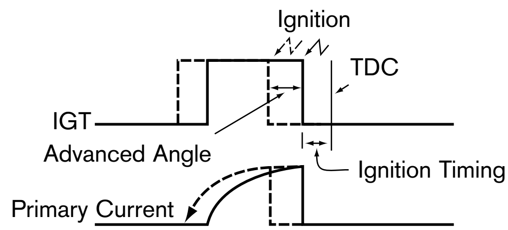


Fig. 3-05

T852f131

IGT Signal

The primary coil current flow is controlled by the ECM through the Ignition Timing (IGT) signal. The IGT signal is a voltage signal that turns on/off the main transistor in the igniter. When IGT signal voltage drops to 0 volts, the transistor in the igniter turns off. When the current in the primary coil is turned off, the rapidly collapsing magnetic field induces a high voltage in the secondary coil. If the voltage is high enough to overcome the resistance in the secondary circuit, there will be a spark at the spark plug.

IGC

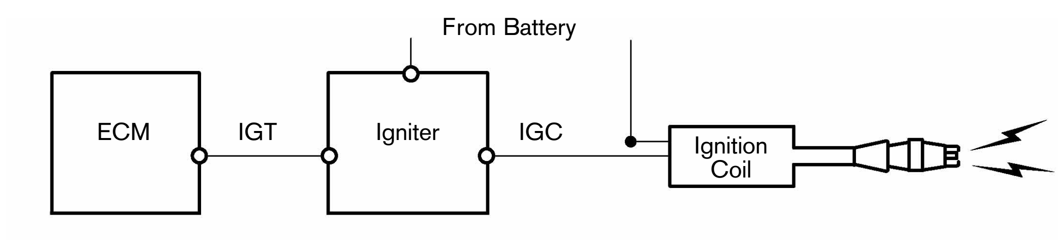


Fig. 3-06

T852f132

IGC

On some ignition systems, the circuit that carries the primary coil current is called IGC. IGC is turned on and off by the igniter based on the IGT signal.

Igniter

The primary function of the igniter is to turn on and off the primary coil current based on the IGT signal received from the ECM. The igniter or ECM may perform the following functions:

- Ignition Confirmation (IGF) signal generation unit.
- Dwell angle control.
- Lock prevention circuit.
- Over voltage prevention circuit.
- Current limiting control.
- Tachometer signal.

It is critical that the proper igniter is used when replacing an igniter. The igniters are matched to the type of ignition coil and ECM.

IGF Signal

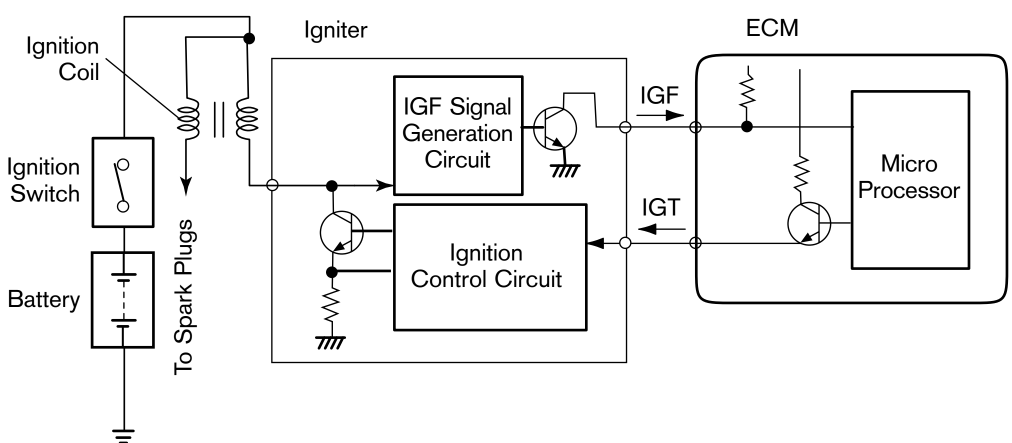


Fig. 3-07

T852f133

IGF Signal

The IGF signal is used by the ECM to determine if the ignition system is working. Based on IGF, the ECM will keep power supplied to the fuel pump and injectors on most ignition systems. **Without IGF, the vehicle will start momentarily, then stall. However, with some Direct Ignition Systems with the igniter in the coil, the engine will run.**

IGF Signal Detection Using CEMF

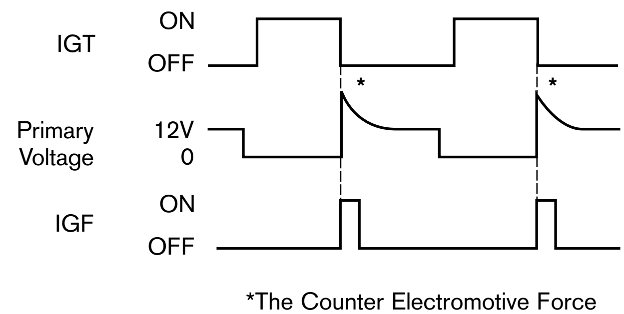


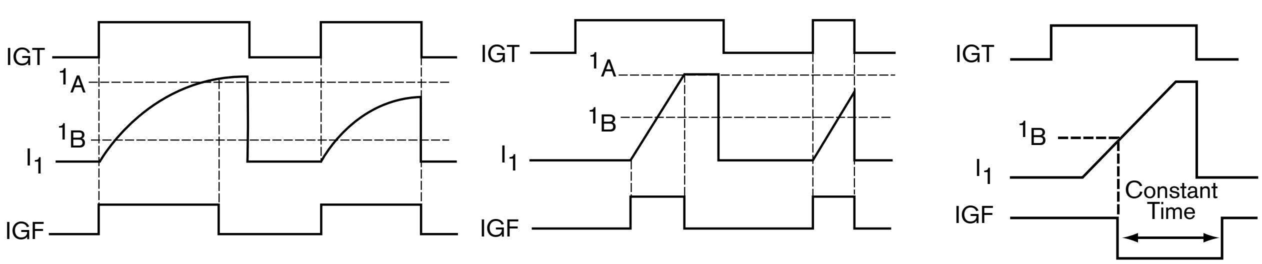
Fig. 3-08

T852f134

IGF Signal Detection using CEMF

There are two basic methods of detecting IGF. Early systems used the Counter Electromotive Force (CEMF) created in the primary coil and circuit for generating the IGF signal. The collapsing magnetic field produces a CEMF in the primary coil. When CEMF is detected by the igniter, the igniter sends a signal to the ECM. This method is no longer used.

IGF Detection through Primary Current



I_1 Primary current

I_A Maximum current level for successful spark generation

I_B Minimum current level for successful spark generation

Fig. 3-09

T852f135/T852f136
T852f137

IGF Detection Using Primary Current Method

The primary current level method measures the current level in the primary circuit. The minimum and maximum current levels are used to turn the IGF signal on and off. The levels will vary with different ignition systems. Regardless of method, the Repair Manual shows the scope pattern or provides you with the necessary voltage reading to confirm that the igniter is producing the IGF signal.

Lack of an IGF on many ignition systems will produce a DTC. On some ignition systems, the ECM is able to identify which coil did not produce an IGF signal and this can be accomplished by two methods.

The first method uses an IGF line for each coil.

With the second method, the IGF signal is carried back to the ECM on a common line with the other coil(s). The ECM is able to distinguish which coil is not operating based on when the IGF signal is received. Since the ECM knows when each cylinder needs to be ignited, it knows from which coil to expect the IGF signal.

IGF Circuit (8 Cylinder Engine)

Note that there are only two IGF lines for eight cylinders. Because the ECM knows when the coil is triggered, it knows when to expect the IGF signal. This capability allows the ECM to correctly identify the cylinder and set the appropriate DTC.

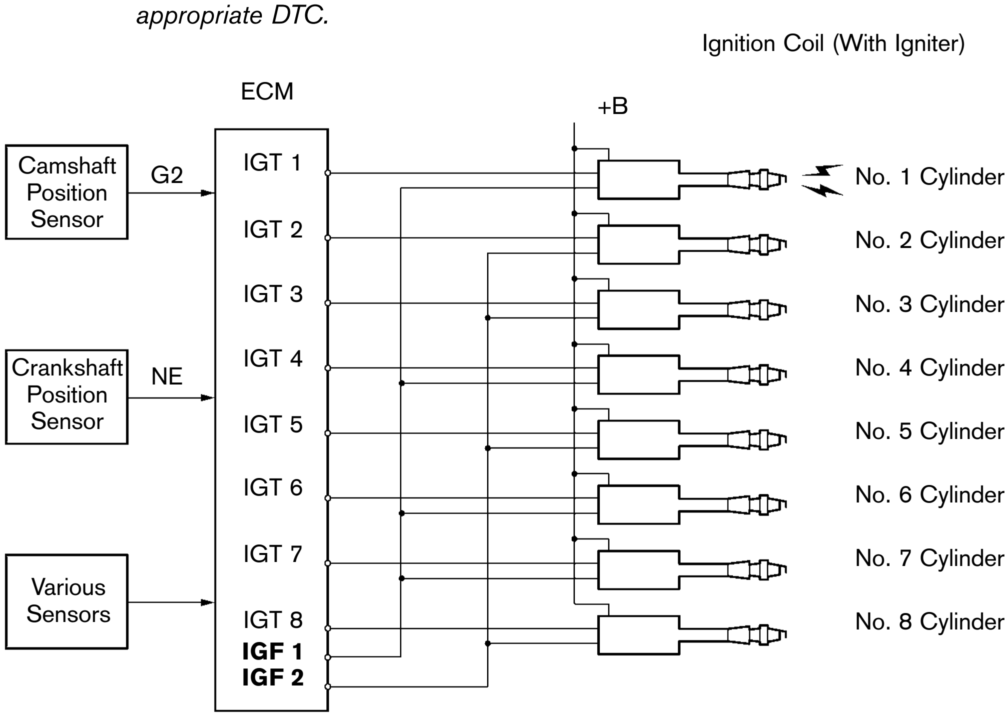


Fig. 3-10

T852f138

Dwell Angle Control

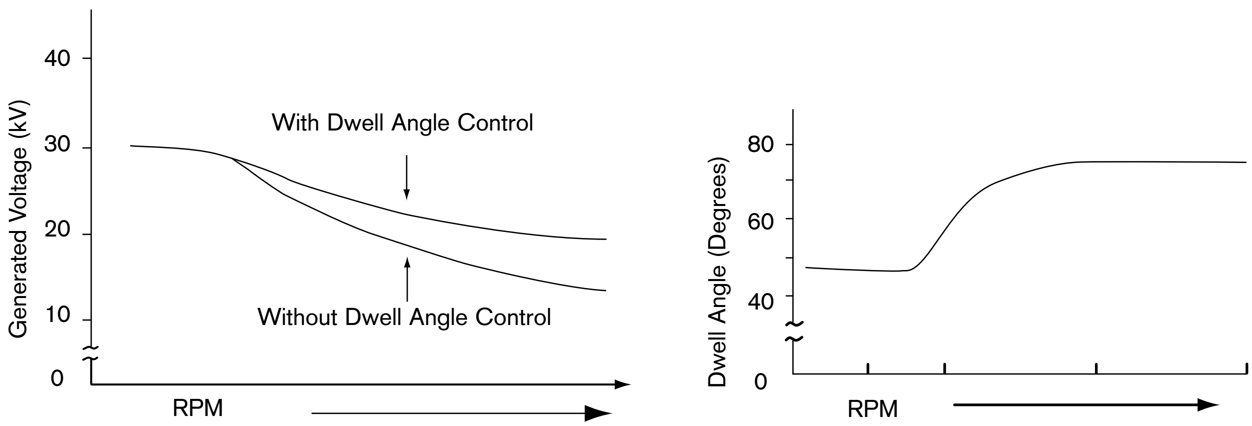


Fig. 3-11

T852f139/T852f140

Dwell Angle Control This circuit controls the length of time the power transistor (current flow through the primary circuit) is turned on.

The length of time during which current flows through the primary coil generally decreases as the engine speed rises, so the induced voltage in the secondary coil decreases.

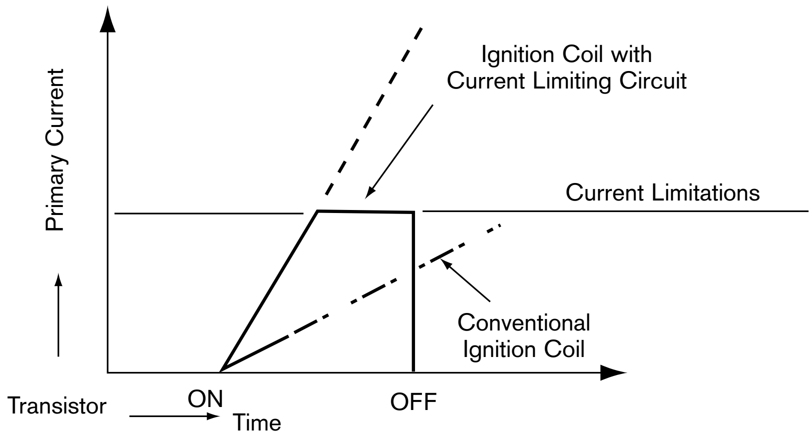
Dwell angle control refers to electronic control of the length of time during which primary current flows through the ignition coil (that is, the dwell angle) in accordance with distributor shaft rotational speed.

At low speeds, the dwell angle is reduced to prevent excessive primary current flow, and increased as the rotational speed increases to prevent the primary current from decreasing.

Lock Prevention Circuit This circuit forces the power transistor to turn off if it locks up (if current flows continuously for a period longer than specified), to protect the ignition coil and the power transistor.

Over Voltage Prevention Circuit This circuit shuts off the power transistor(s) if the power supply voltage becomes too high, to protect the ignition coil and the power transistor.

Current Limiting (Over Current Prevention)



CURRENT LIMITING CONTROL

Fig. 3-12
T852f141

Current Limiting (Over Current Prevention)

Current limiting control is a system that improves the rise of the flow of current in the primary coil, ensuring that a constant primary current is flowing at all times, from the low speed to the high speed range, and thus making it possible to obtain a high secondary voltage.

The coil's primary resistance is reduced improving the current rise performance, and this will increase the current flow. But without the current limiting circuit, the coil or the power transistor will burn out. For this reason, after the primary current has reached a fixed value, it is controlled electronically by the igniter so that a larger current will not flow.

Since the current-limiting control limits the maximum primary current, no external resistor is needed for the ignition coil.

NOTE

Since igniters are manufactured to match ignition coil characteristics, the function and construction of each type are different. For this reason, if any igniter and coil other than those specified are combined, the igniter or coil may be damaged. Therefore, always use <u>the correct parts specified for the vehicle.</u>

Tachometer Signal

On some systems the Tach signal is generated in the igniter.

NE Signal and G Signal

Though there are different types of ignition systems, the use of the NE and G signals is consistent. The NE signal indicates crankshaft position and engine RPM.

The G signal (also called VVT signal) provides cylinder identification. By comparing the G signal to the NE signal, the ECM is able to identify the cylinder on compression. This is necessary to calculate crankshaft angle (initial ignition timing angle), identify which coil to trigger on Direct Ignition System (independent ignition), and which injector to energize on sequential fuel injection systems.

As ignition systems and engines evolved, there have been modifications to the NE and G signal. Timing rotors have different numbers of teeth. For some G signal sensors, a notch is used instead of a tooth to generate a signal. Regardless, you can determine what style is used by visually examining the timing rotor or consulting the Repair Manual. Many of the different styles are represented with their respective ignition system.

Ignition Advance Angle

As engine RPM increases, ignition must begin earlier.

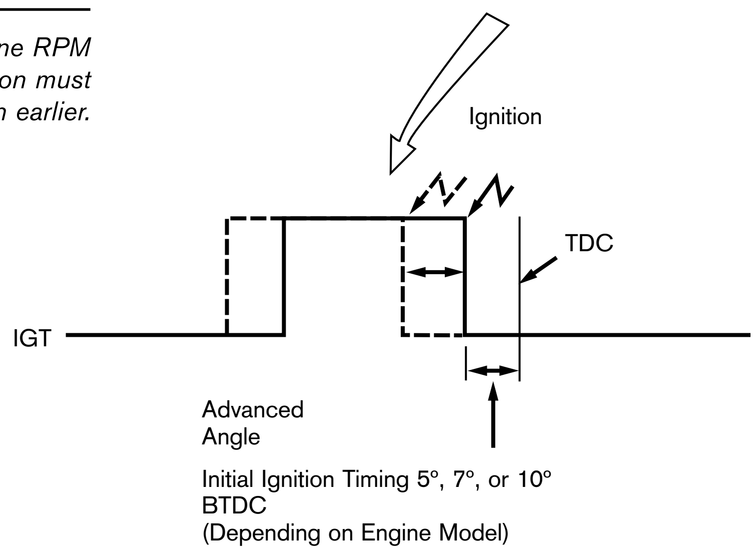


Fig. 3-13

T852f142

Electronic Spark Advance Operation

For maximum engine output efficiency, the air/fuel mixture must be ignited so that maximum combustion pressure occurs approximately 10°-15° after TDC. As engine RPM increases, there is less time for the mixture to complete its combustion at the proper time because the piston is traveling faster. The ECM controls when the spark occurs through the IGT signal. By varying the time the IGT signal is turned off, the ECM changes ignition spark timing.

Ignition Advance Modes and Corrections

The ECM calculates the IGT signal on time based on engine operating modes and conditions. The IGT signal is based primarily on the crankshaft position sensor signal, engine load, temperature, knock sensor, etc.

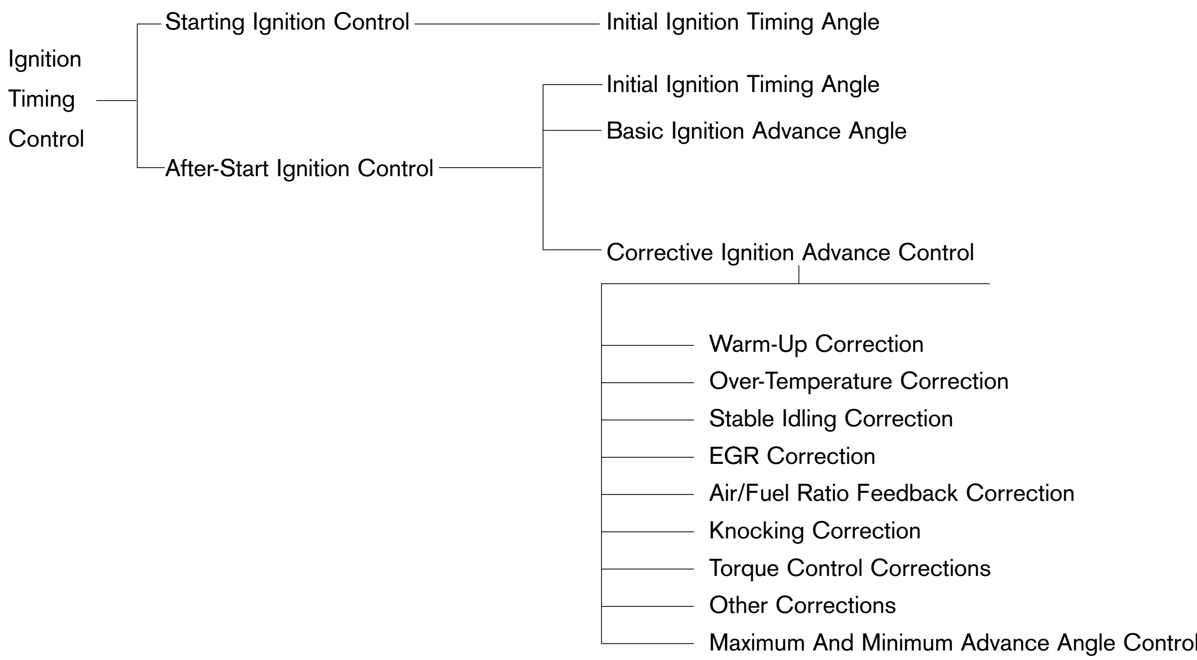


Fig. 3-14

Starting Ignition Control

Ignition timing control consists of two basic elements:

- Ignition control during starting.
- After-start ignition control.

Ignition Control During Starting

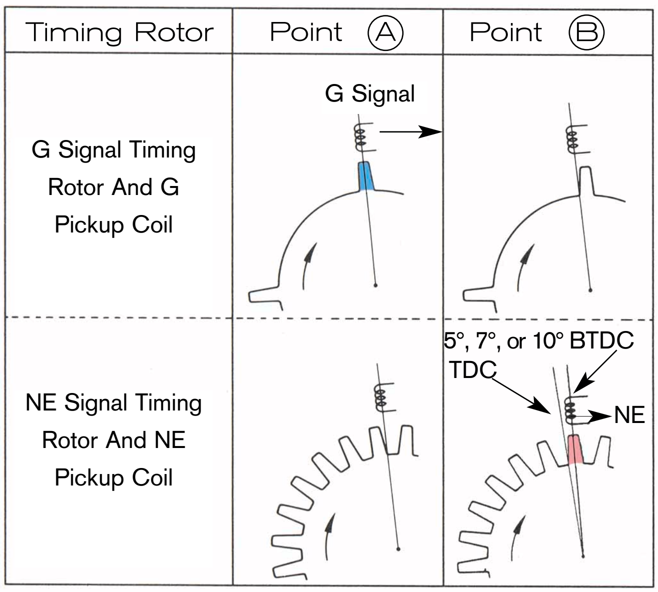
Ignition control during starting is defined as the period when the engine is cranking and immediately following cranking. The ignition occurs at a fixed crankshaft angle, approximately 5°-10° BTDC, regardless of engine operating conditions and this is called the initial timing angle.

Since engine speed is still below a specified RPM and unstable during and immediately after starting, the ignition timing is fixed until engine operation is stabilized.

The ECM recognizes the engine is being cranked when it receives the NE and G signal. On some models, the starter (STA) signal is also used to inform the engine is being cranked.

Initial Ignition Timing Angle

This angle is calculated from the first NE signal that follows a G signal. The ignition occurs at a fixed crankshaft angle, approximately 5°-10° BTDC, regardless of engine operating conditions, and this is called the initial timing angle.



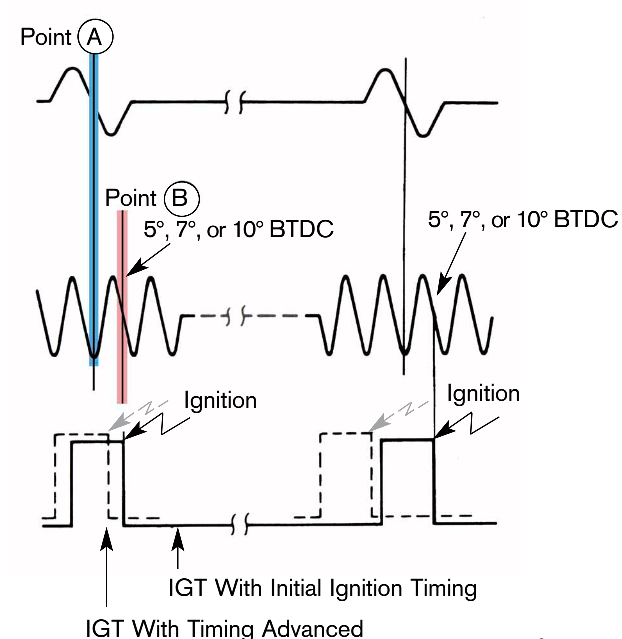


Fig. 3-15

T852f143/T852f144

Initial Ignition Timing Angle Symbol

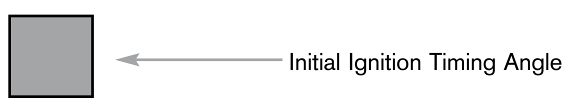


Fig. 3-16

T852f145

After-Start Ignition Control

After-start ignition control will calculate and adjust ignition timing based on engine operating conditions. The calculation and adjustment of ignition timing is performed in a series of steps, beginning with basic ignition advance control.

Various corrections are added to the initial ignition timing angle and the basic ignition advance angle during normal operation.

After-start ignition control is carried out during normal operation.

The various corrections (that are based on signals from the relevant sensors) are added to the initial ignition timing angle and to the basic ignition advance angle (determined by the intake air volume signal or intake manifold pressure signal) and by the engine speed signal:

Ignition timing = initial ignition timing angle

+ basic ignition advance angle

+ corrective ignition advance angle

During normal operation of after-start ignition control, the Ignition Timing (IGT) signal calculated by the microprocessor in the ECM and is output through the back-up IC.

Ignition Advance Angles

When spark ignition occurs is a result of a calculation based on initial timing angle plus the basic ignition angle plus additional corrections.

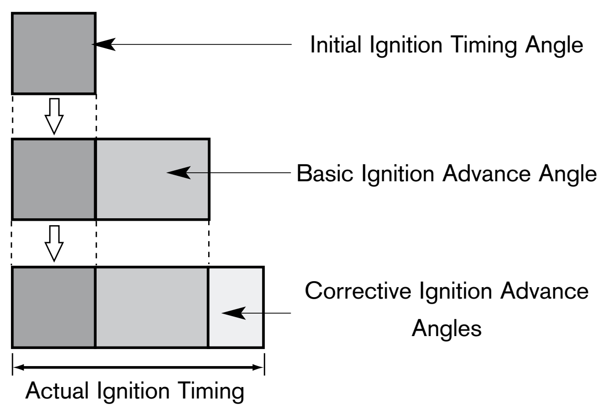


Fig. 3-17

T852f146

Basic Ignition Advance Control

The ECM selects the basic ignition advance angle from memory based on engine speed, load, throttle valve position, and engine coolant temperature.

Relevant Signals:

- Intake air volume (VS, KS, or VG) (Intake manifold pressure (PIM)).
- Engine speed (NE).
- Throttle position (IDL).
- Engine Coolant Temperature (THW).

Corrective Ignition Advance Control

The Corrective Ignition Advance Control makes the final adjustment to the actual ignition timing. The following corrective factors are not found on all vehicles.

Warm Up Correction

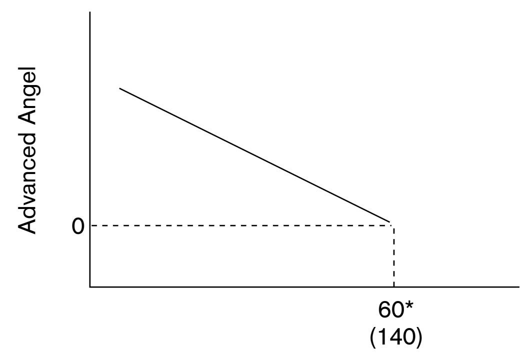


Fig. 3-18

T852f147

Warm-Up Correction

The ignition timing is advanced to improve driveability when the coolant temperature is low. In some engine models, this correction changes the advance angle in accordance with the intake air volume (intake manifold pressure) and can advance approximately 15° (varies with engine model) by this correction during extremely cold weather.

Over Temperature

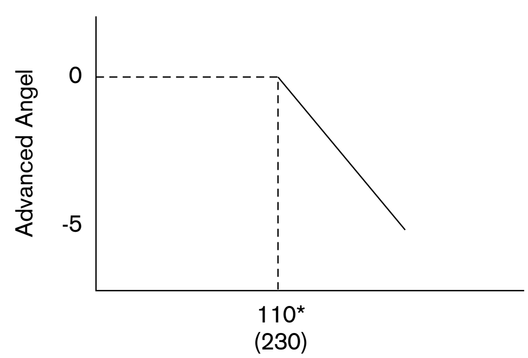


Fig. 3-19

T852f148

Over Temperature Correction

To prevent knocking and overheating, the ignition timing is retarded when the coolant temperature is extremely high. The timing may be retarded approximately 5° by this correction.

Relevant Signals:

- Engine Coolant Temperature (ECT) - THW.

The following may also be used on some engine models:

- MAF (VS, KS, or VG).
- Engine Speed - NE signal.
- Throttle position VTA or (IDL).

Stable Idling Correction

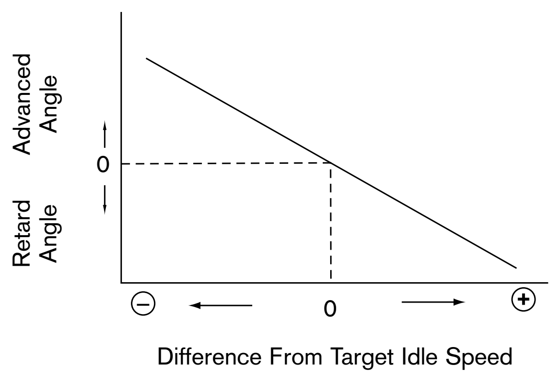


Fig. 3-20

T852f149

Stable Idling Correction

When the engine speed during idling has fluctuated from the target idle speed, the ECM adjusts the ignition timing to stabilize the engine speed. The ECM is constantly calculating the average engine speed. If the engine speed falls below the target speed, the ECM advances the ignition timing by a predetermined angle. If the engine speed rises above the target speed, the ECM retards the ignition timing by a predetermined angle.

This correction is not executed when the engine exceeds a predetermined speed.

In some engine models, the advance angle changes depending on whether the air conditioner is on or off. In other engine models, this correction only operates when the engine speed is below the target engine speed.

Relevant Signals:

- Engine Speed (NE)
- TPS (VTA or IDL)
- Vehicle Speed (SPD)

EGR Correction

When EGR is operating, the ignition timing is advanced according to intake air volume and engine RPM to improve driveability. EGR has the effect of reducing engine knocking, therefore the timing can be advanced.

Relevant Signals:

- Engine Speed (NE)
- TPS (VTA or IDL or PSW)
- Intake air volume (VS, KS, or VG) (Intake manifold pressure (PIM))

Torque Control Correction

This correction reduces shift shock and the result is that the driver feels smoother shifts. With an electronically-controlled transaxle, each clutch and brake in the planetary gear unit of the transmission or transaxle generates shock to some extent during shifting. In some models, this shock is minimized by delaying the ignition timing when gears are upshifted. When gear shifting starts, the ECM retards the engine ignition timing to reduce the engine torque. As a result, the shock of engagement and strain on the clutches and brakes of the planetary gear unit is reduced and the gear shift change is performed smoothly. The ignition timing angle is retarded a maximum of approximately 20° by this correction. This correction is not performed when the coolant temperature or battery voltage is below a predetermined level.

Relevant Signals:

- Engine Speed (NE)
- TPS (VTA or IDL or PSW)
- ECT (THW)
- Battery voltage (+B)

Knock

When the spark plug ignites the air/fuel mixture, cylinder pressure increases. If the increase in heat and pressure is high enough, the air/fuel mixture will ignite at a location other than the spark plug. This is referred to as spontaneous combustion and produces engine knock.

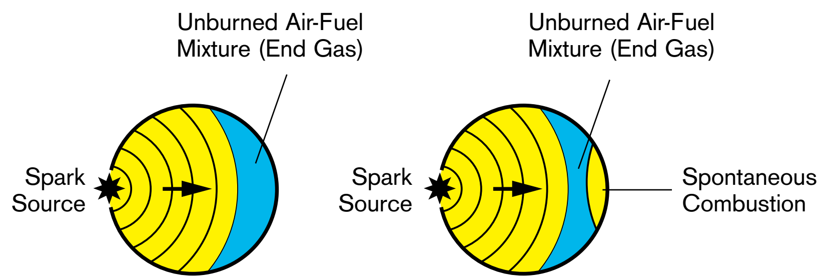


Fig. 3-21

T852f150

Knock Correction

Engine knock, if severe enough, can cause engine damage. Combustion chamber design, gasoline octane, air/fuel ratio, and ignition timing all affect when knock will occur. Under most engine conditions, ignition timing needs to be near the point when knock occurs to achieve the best fuel economy, engine power output, and lowest exhaust emissions. However, the point when knock occurs will vary from a variety of factors. For example, if the gasoline octane is too low, and ignition takes place at the optimum point, knock will occur. To prevent this, a knock correction function is used.

Engine Knock Control Loop

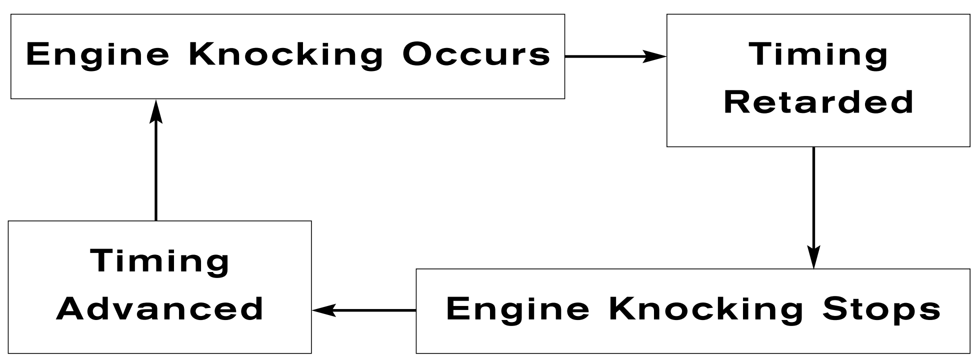


Fig. 3-22

Engine Knock Control

The ECM retards the timing in fixed steps until the knock disappears. When the knocking stops, the ECM stops retarding the ignition timing and begins to advance the timing in fixed steps.

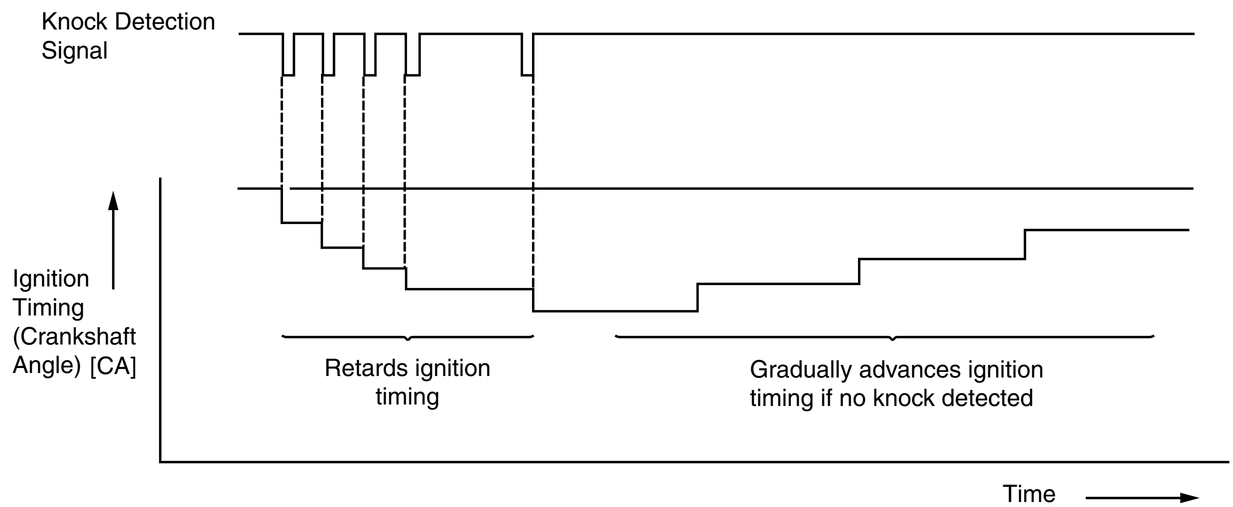


Fig. 3-23

T852f151

When engine knocking occurs, the knock sensor converts the vibration from the knocking into a voltage signal that is detected by the ECM. According to its programming, the ECM retards the timing in fixed steps until the knock disappears. When the knocking stops, the ECM stops retarding the ignition timing and begins to advance the timing in fixed steps. If the ignition timing continues to advance and knocking occurs, ignition timing is again retarded.

Knock Signal Identification

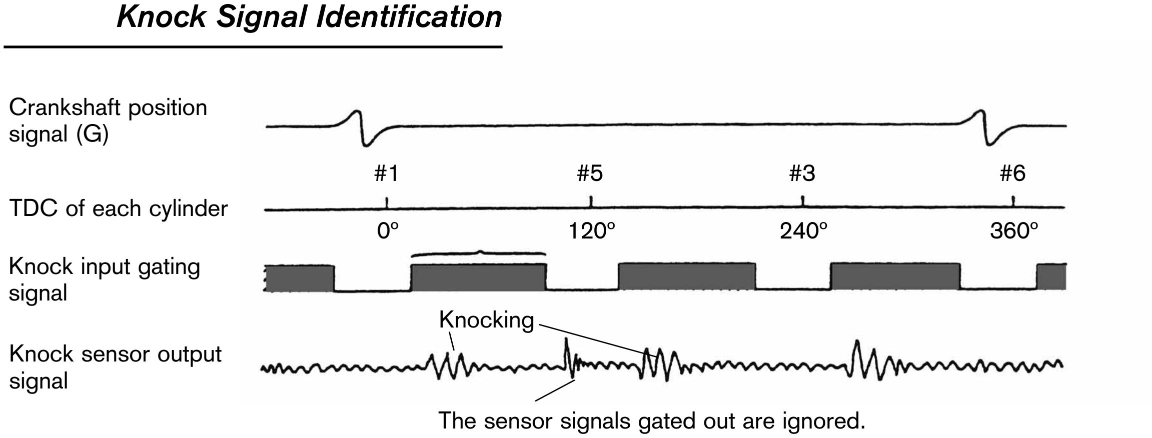


Fig. 3-24

T852f152

The ECM is able to determine which cylinder is knocking by when the knock signal is received. The ECM knows the cylinder that is in the power stroke mode based on the NE and G signals. This allows the ECM to filter any false signals.

Some mechanical problems can duplicate engine knocking. An excessively worn connecting rod bearing or a large cylinder ridge will produce a vibration at the same frequency as engine knocking. The ECM in turn will retard the timing.

Air/Fuel Ratio Correction

The engine is especially sensitive to changes in the air - fuel ratio when it is idling, so stable idling is ensured by advancing the ignition timing at this time in order to match the fuel injection volume of air - fuel ratio feedback correction.

This correction is not executed while the vehicle is being driven.

Relevant Signals:

- Oxygen or A/F sensor.
- TPS (VTA or IDL).
- Vehicle Speed (SPD).

Other Corrections

Engines have been developed with the following corrections added to the ESA system (in addition to the various corrections explained so far), in order to adjust the ignition timing with extremely fine precision.

Transition Correction - During the transition (change) from deceleration to acceleration, the ignition timing is either advanced or retarded temporarily in accordance with the acceleration.

Cruise Control Correction - When driving downhill under cruise control, in order to provide smooth cruise control operation and minimize changes in engine torque caused by fuel cut-off because of engine braking, a signal is sent from the Cruise Control ECU to the ECM to retard the ignition timing.

Traction Control Correction - This retards the ignition timing, thus lowering the torque output by the engine, when the coolant temperature is above a predetermined temperature and the traction control system is operating.

Acoustic Control Induction System (ACIS) Correction - When the engine speed rises above a predetermined level, the ACIS operates. At that time, the ECM advances the ignition timing simultaneously, thus improving output.

Maximum and Minimum Ignition Advance Control

If the actual ignition timing (basic ignition advance angle + corrective ignition advance or retard angle) becomes abnormal, the engine will be adversely affected. To prevent this, the ECM controls the actual advance so that the sum of the basic ignition and corrective angle cannot be greater or less than preprogrammed minimum or maximum values.

Approximately, these values are:

- MAX. ADVANCE ANGLE: 35°-45°.
- MIN. ADVANCE ANGLE: 10°-0°.

Advance angle = Basic ignition advance angle + Corrective ignition advance angle

Distributor System

There are many variations of distributor ignition systems

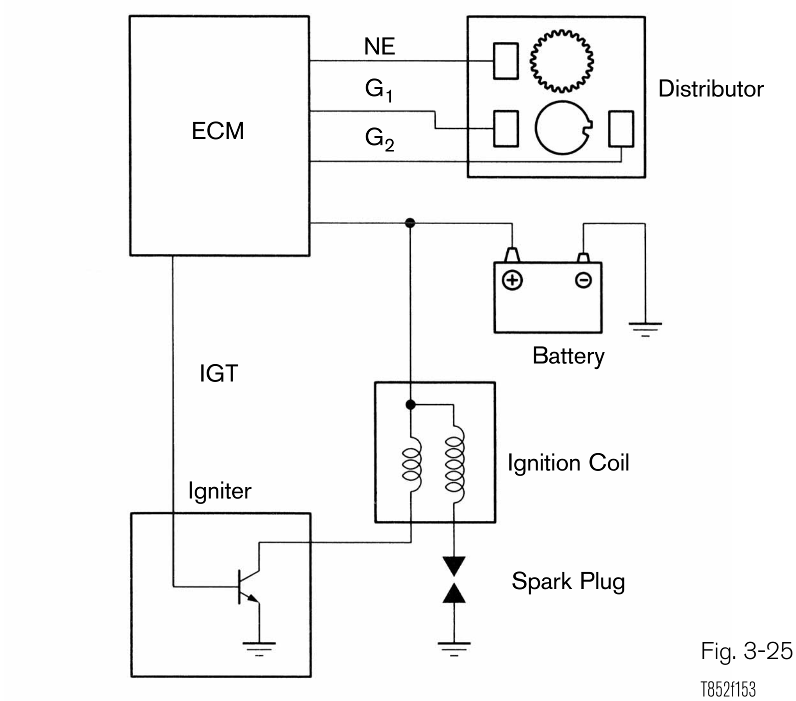


Fig. 3-25

Distributor Ignition (DI) Systems

The NE signal is generated by the Crankshaft Position Sensor (also called engine speed sensor). The G signal is generated by the Camshaft Position sensor that may be located in the distributor or on the engine.

Distributor

This distributor has two G signal pick up coils and an NE signal rotor.

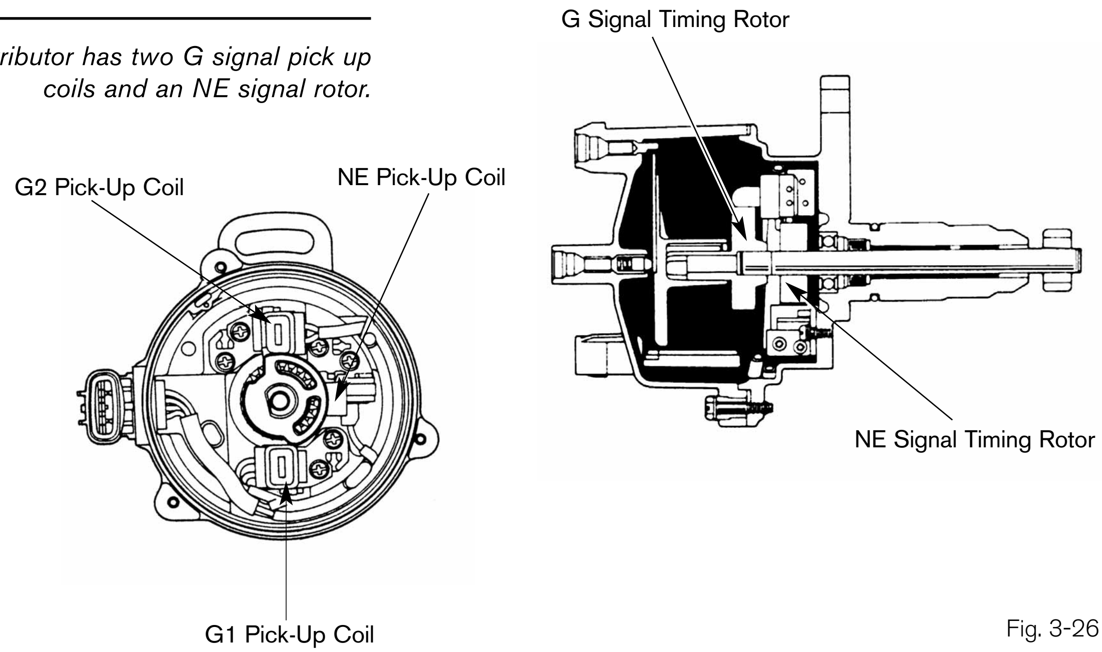


Fig. 3-26

T852f154/T852f155

Distributor System Circuit

The IGT signal turns the igniter on and off at the correct time for ignition to occur.

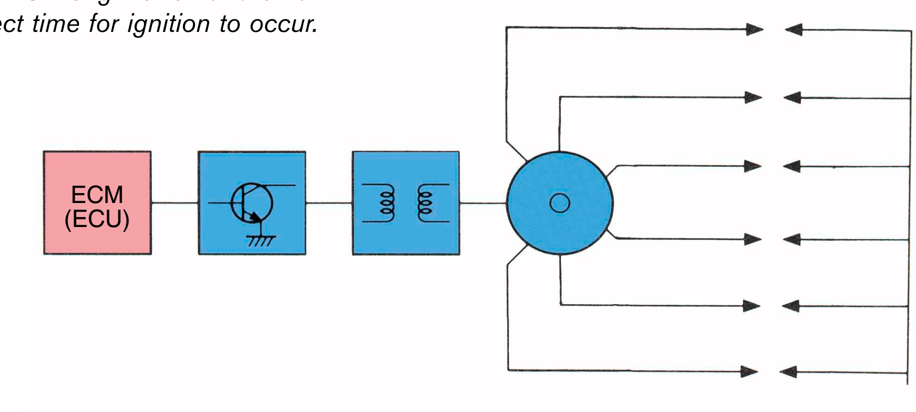


Fig. 3-27

T852f156

At the appropriate time during cylinder compression, the ECM sends a signal called IGT to the igniter. This will turn on the transistor in the igniter sending current through the primary winding of the ignition coil. At the optimum time for ignition to occur, the ECM will turn off IGT and the transistor will turn off current flow through the primary winding. The induced current will travel through the coil wire, to the distributor cap, rotor, to the distributor terminal the rotor is pointing at, high tension wire, spark plug, and ground. The rotor position determines the cylinder that receives the spark.

Firing Order

The firing order can be found in the New Car Features book. The cylinders are identified as follows:

- V-8 engine cylinders are numbered with odd numbered cylinders on the left bank and even numbered cylinders on the right bank.
- V-6 engine cylinders are numbered with even on left bank and odd numbered cylinders on the right bank.
- In-line 6 engines are numbered consecutively 1-6, with the number 1 cylinder at the front.
- Four cylinder engines are numbered consecutively from front to back.

Many times, original equipment distributor caps have the firing order molded into the cap.

Firing Order

Engine Configuration	Firing Order
V-8	1-8-4-3-6-5-7-2
V-6	1-2-3-4-5-6
In-line 6	1-5-3-6-2-4
In-line 4	1-3-4-2

Fig. 3-28

V-6 Cylinder Identification

Note that the cylinder numbering is opposite the V-8.

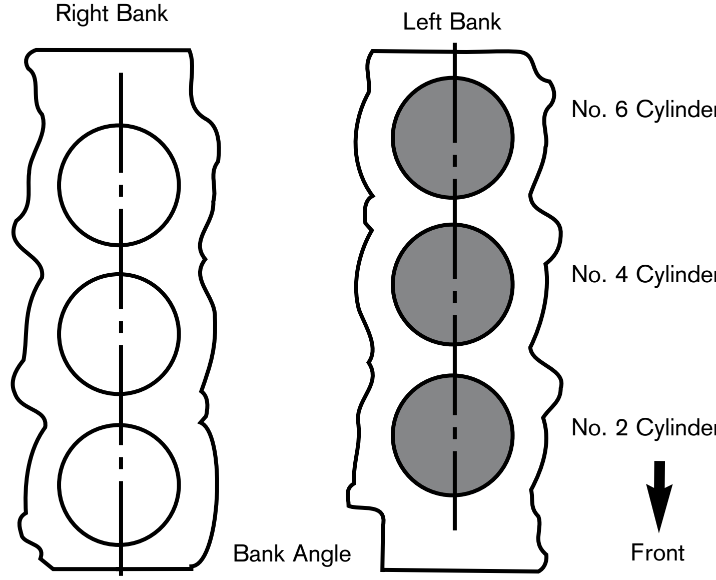


Fig. 3-29

T852f157

V-8 Cylinder Identification

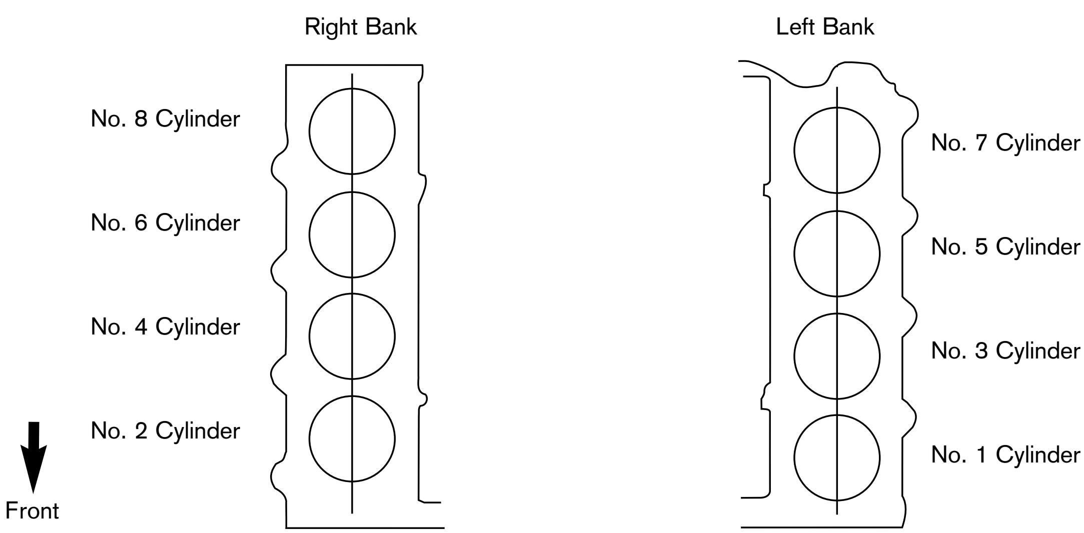


Fig. 30

T852f158

Distributorless & Direct Ignition Systems Overview

Essentially, a Distributorless Ignition System is an ignition system without a distributor. Eliminating the distributor improved reliability by reducing the number of mechanical components. Other advantages are:

- Greater control over ignition spark generation - There is more time for the coil to build a sufficient magnetic field necessary to produce a spark that will ignite the air/fuel mixture. This reduces the number of cylinder misfires.

- Electrical interference from the distributor is eliminated - Ignition coils can be placed on or near the spark plugs. This helps eliminate electrical interference and improve reliability.

- Ignition timing can be controlled over a wider range - In a distributor, if too much advance is applied the secondary voltage would be directed to the wrong cylinder.

All of the above reduces the chances of cylinder misfires and consequently, exhaust emissions.

Distributorless Ignition System

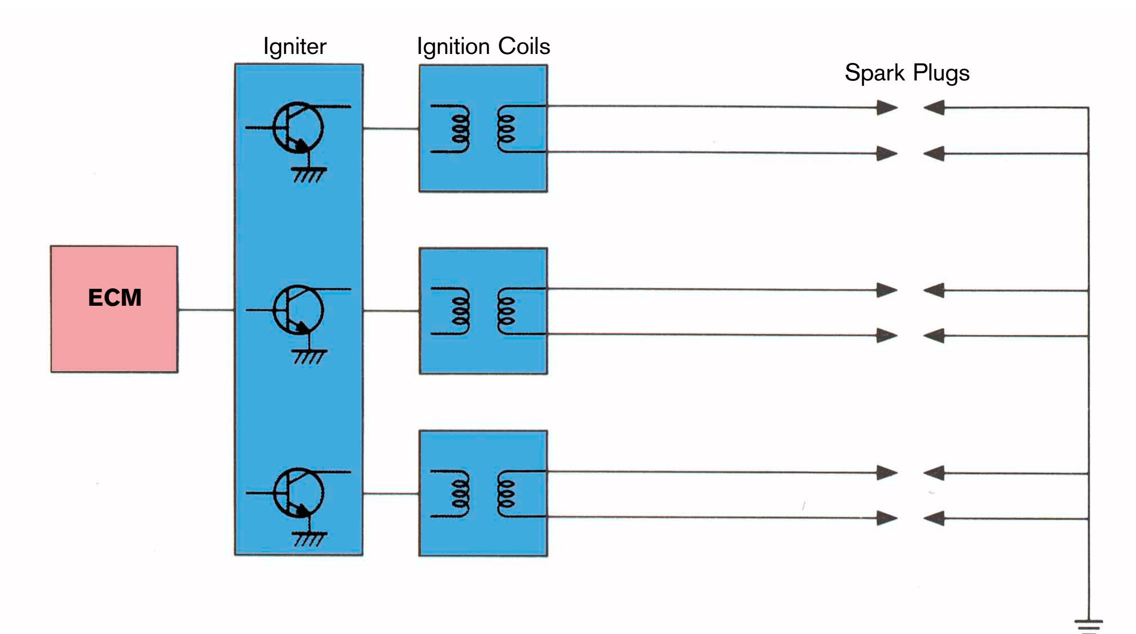


Fig. 3-31
T852f159

Distributorless Ignition systems are usually defined as having one ignition coil with two spark plug wires for two cylinders. Distributorless Ignition Systems use a method called simultaneous ignition (also called waste spark) where an ignition spark is generated from one ignition coil for two cylinders simultaneously.

Direct Ignition System Independent Ignition

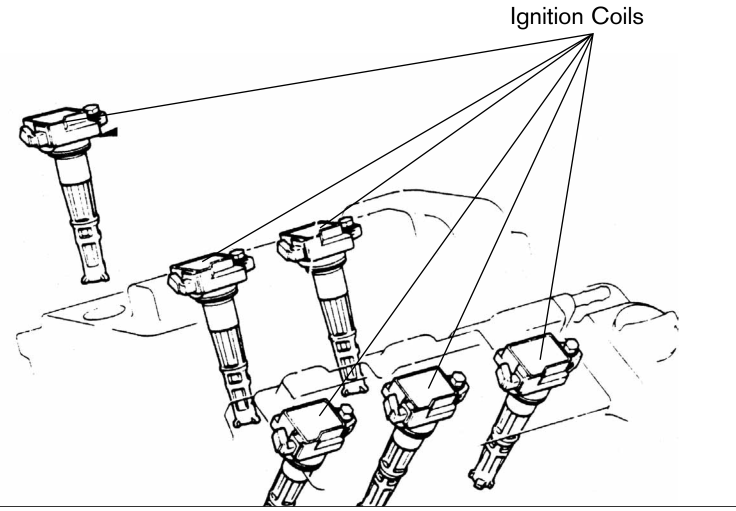


Fig. 3-32

T852f160

Direct Ignition System Circuit

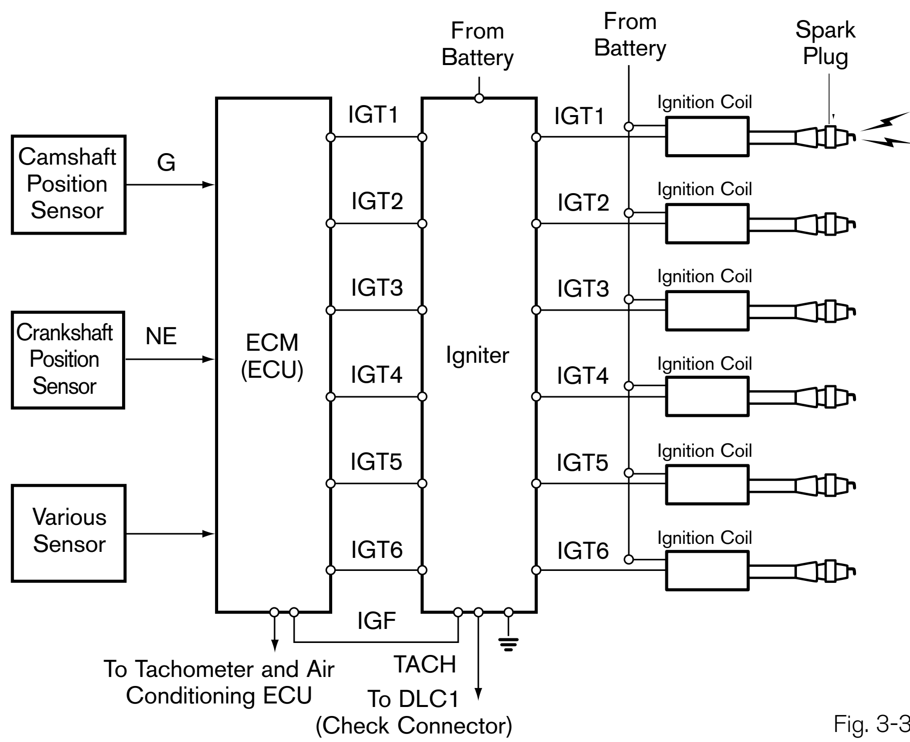


Fig. 3-33

T852f161

Direct Ignition Systems (DIS) have the ignition coil mounted on the spark plug. DIS can come in two forms:

- **Independent ignition** - one coil per cylinder.
- **Simultaneous ignition** - one coil for two cylinders. In this system an ignition coil is mounted directly to one spark plug and a high tension cord is connected to the other spark plug. A spark is generated in both cylinders simultaneously.

Direct Ignition System (DIS) Simultaneous Ignition

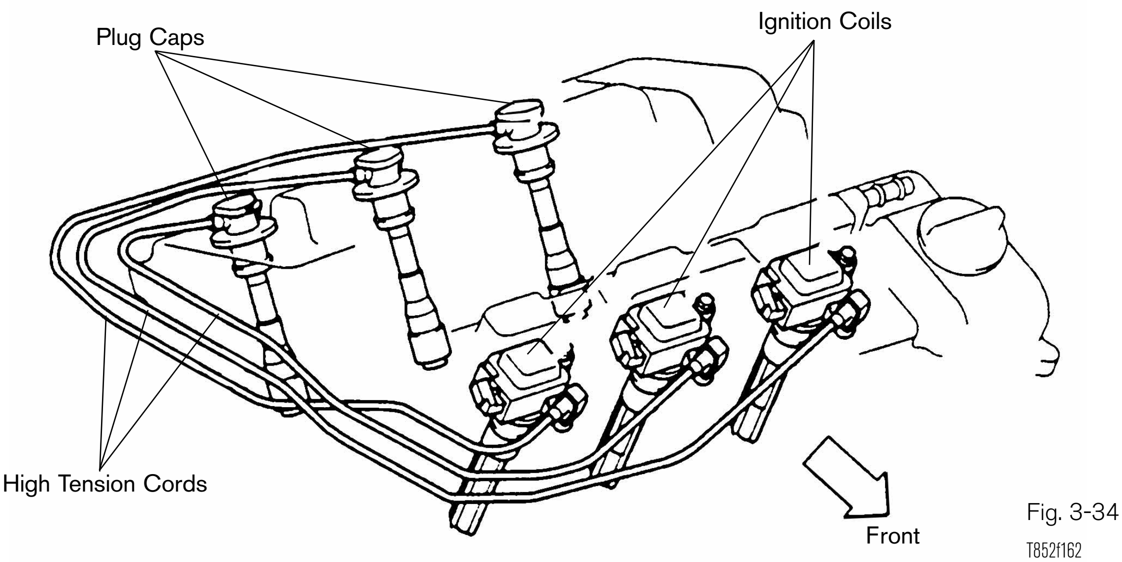


Fig. 3-34
T852f162

Distributorless Ignition System Circuit

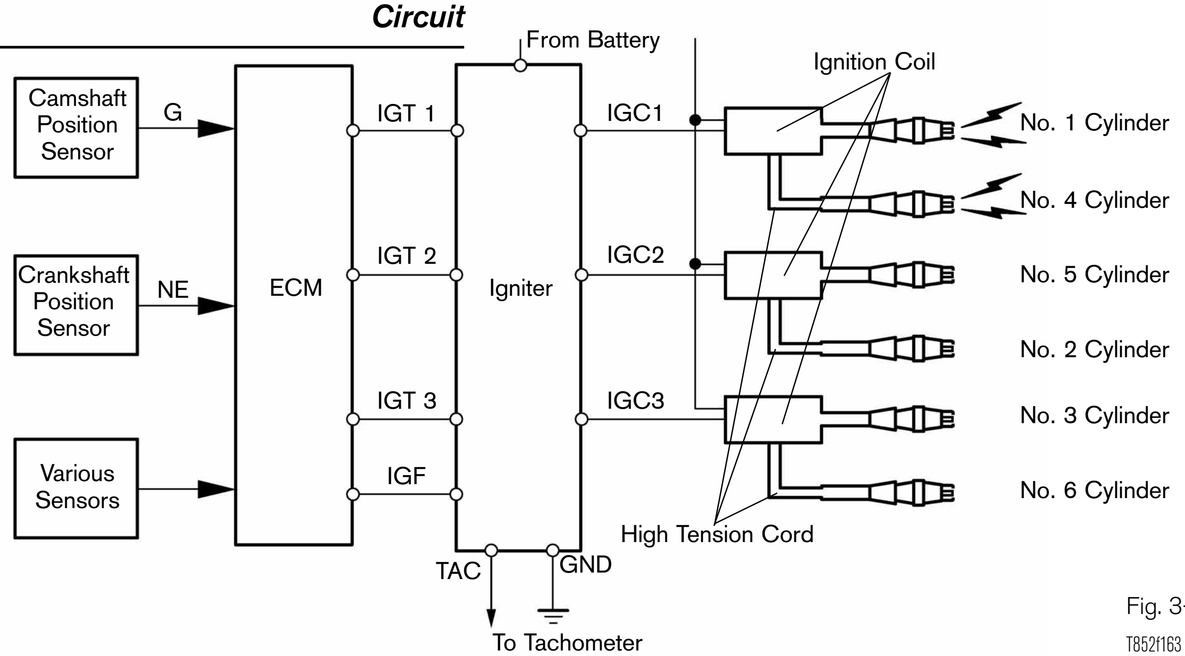


Fig. 3-35
T852f163

Distributorless (Simultaneous Ignition) Operation

Distributorless Ignition Systems and Direct Ignition Systems that use one coil for two cylinders use a method known as simultaneous ignition. With simultaneous ignition systems, two cylinders are paired according to piston position. This has the effect simplifying ignition timing and reducing the secondary voltage requirement.

For example, on a V-6 engine, on cylinders one and four, the pistons occupy the same cylinder position (both are at TDC and BDC at the same time), and move in unison, but they are on different strokes. When cylinder one is on the compression stroke, cylinder four is on the exhaust stroke, and vice versa on the next revolution.

Simultaneous Ignition Sequence

Two cylinders simultaneously will have spark, though only one cylinder will be on the compression stroke. Note that cylinders 2 and 5 both have spark, but cylinder No. 5 is compression. One crankshaft revolution later cylinder No. 3 is on compression.

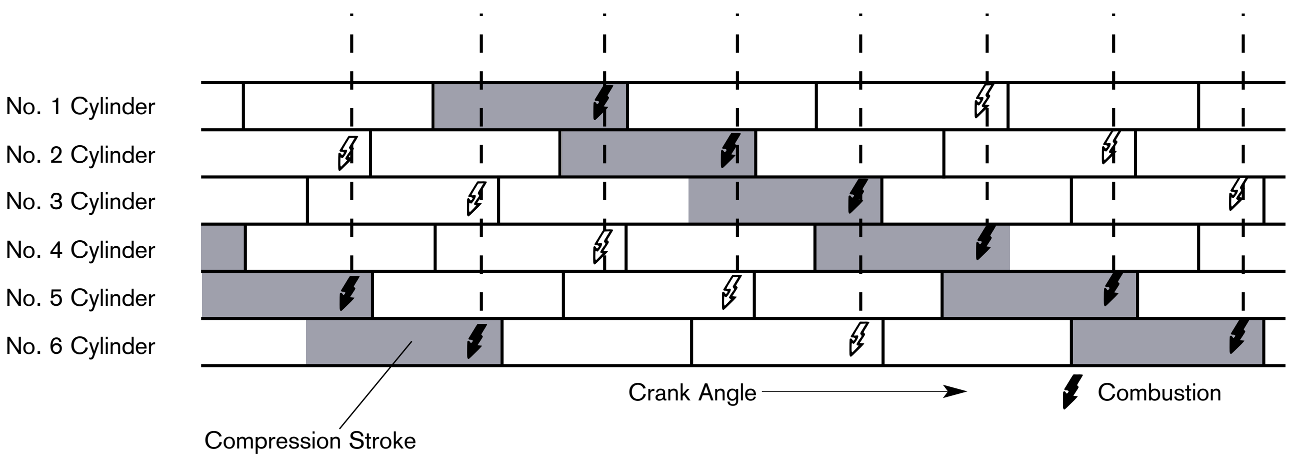


Fig. 3-36

T852f164

The high voltage generated in the secondary winding is applied directly to each spark plug. In one of the spark plugs, the spark passes from the center electrode to the side electrode, and at the other spark plug the spark is from the side to the center electrode.

Simultaneous Ignition Current Flow

One spark plug will always have the spark going from the center to side electrode, the other spark plug from the side to center electrode.

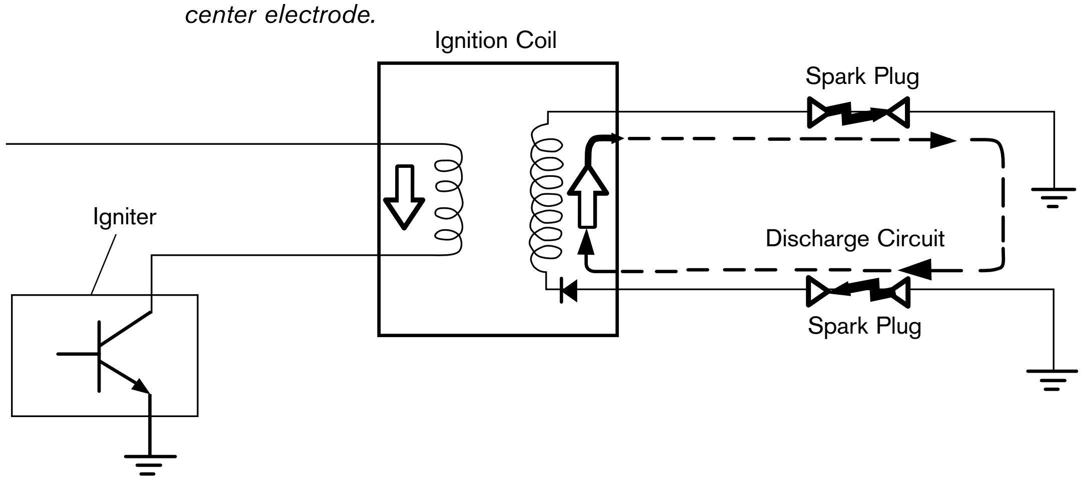


Fig. 3-37

T852f165

Typically, the spark plugs with this style of ignition system are platinum tipped for stable ignition characteristics.

The voltage necessary for a spark discharge to occur is determined by the spark plug gap and compression pressure. If the spark plug gap between both cylinders is equal, then a voltage proportional to the cylinder pressure is required for discharge. The high voltage generated is divided according to the relative pressure of the cylinders. The cylinder on compression will require and use more of the voltage discharge than the cylinder on exhaust. This is because the cylinder on the exhaust stroke is nearly at atmospheric pressure, so the voltage requirement is much lower.

When compared to a distributor ignition system, the total voltage requirement for distributorless ignition is practically the same. The voltage loss from the spark gap between the distributor rotor and cap terminal is replaced by the voltage loss in the cylinder on the exhaust stroke in the Distributorless Ignition System.

Direct Ignition System (DIS)

As DIS has evolved, there have been changes to the function and location of the igniter. With independent ignition DIS, there may be one igniter for all cylinders or one igniter per cylinder. On simultaneous ignition DIS there is one igniter for all coils. The following gives an overview of the different types used on various engines.

1MZ-FE 94 DIS

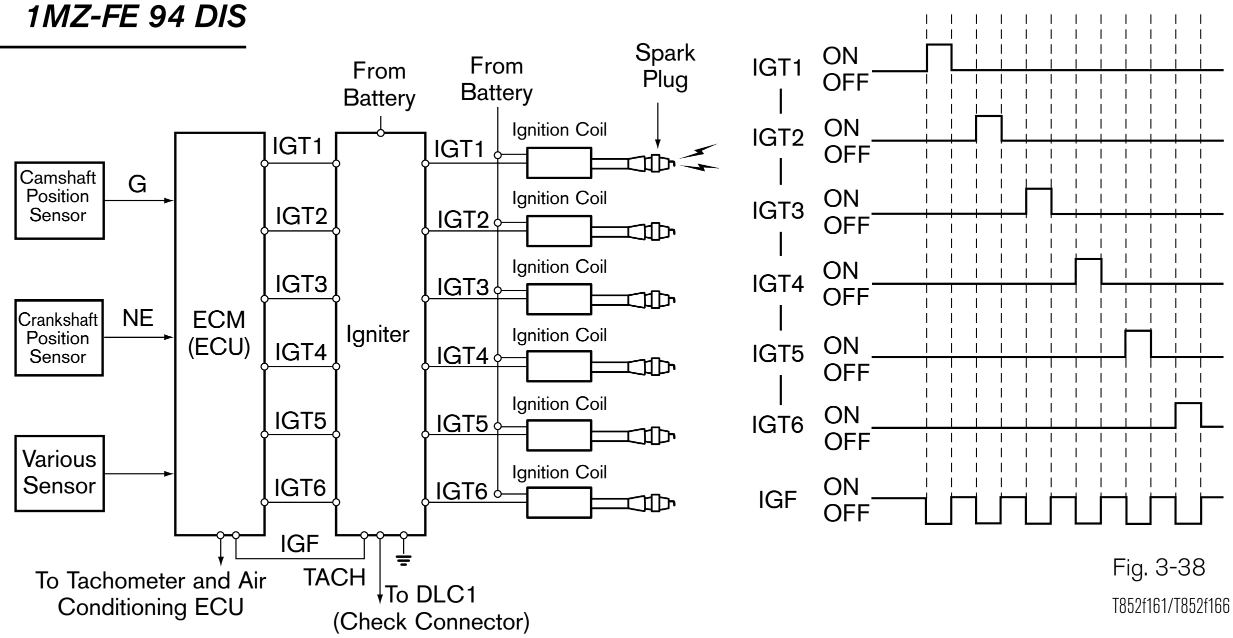


Fig. 3-38

T852f161/T852f166

1MZ-FE 94 DIS

This DIS uses one igniter for all coils. The IGF signal goes low when IGT is turned on. The coils in this system use a high voltage diode for rapid cutoff of secondary ignition. If a coil is suspected of being faulty, swap with another coil.

1MZ-FE 94 DIS Igniter

With one igniter for all coils, there are 6 IGT signal wires used to signal the igniter. Primary current flows through the IGC wires.

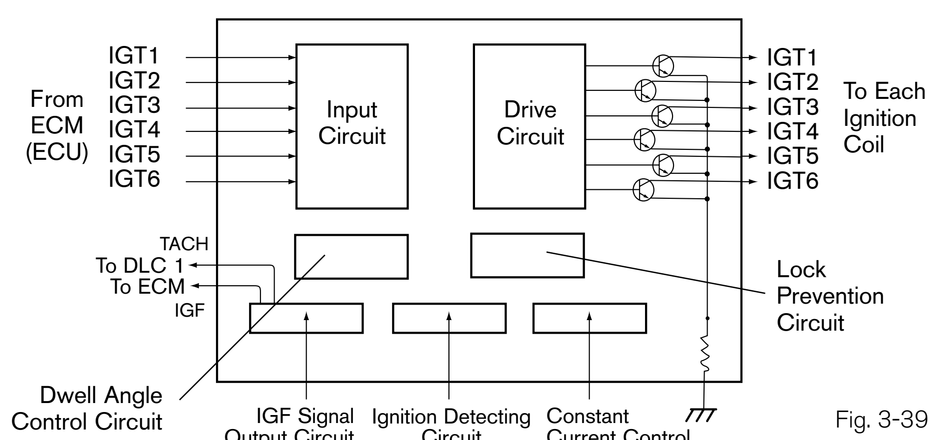


Fig. 3-39

T852f167

Ignition Coil with Diode

With the diode in the circuit, it is recommended to swap coils to test for a faulty coil.

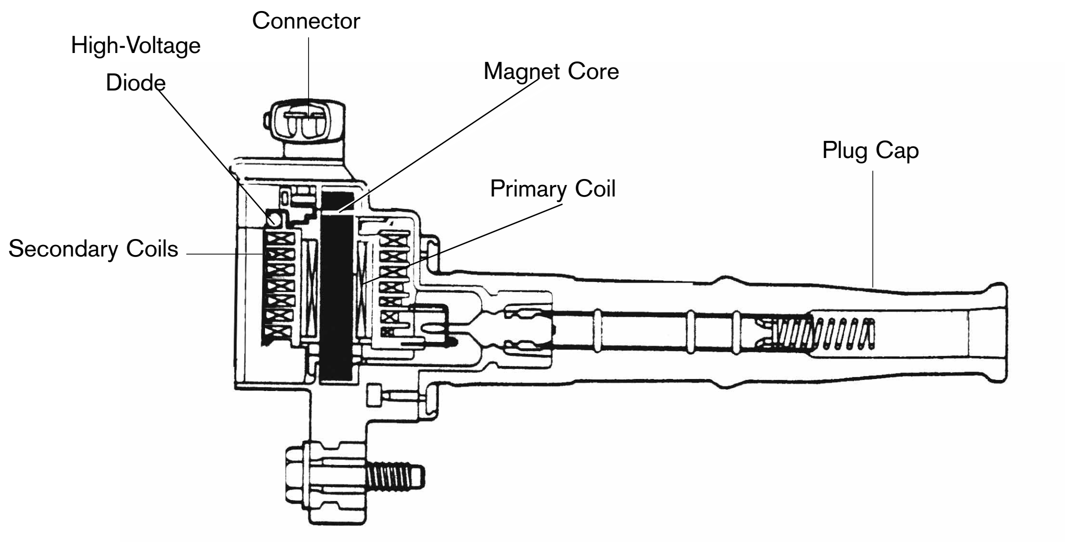


Fig. 3-40
T852f168

High Voltage Diode

The diode is in the secondary circuit.

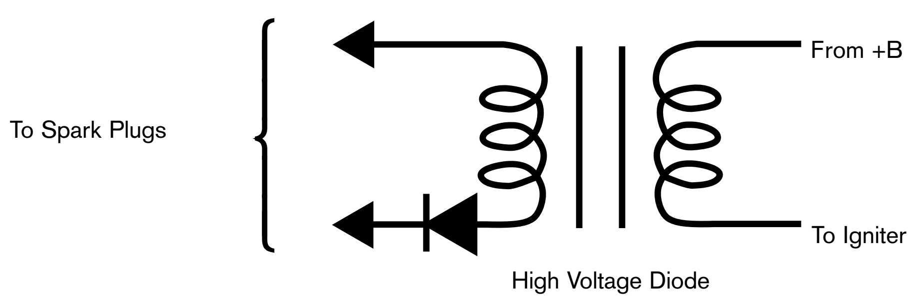


Fig. 3-41
T852f169

1MZ-FE with DIS Simultaneous Ignition

This system uses three IGT signals to trigger the ignition coils in the proper sequence. When a coil is turned on, IGF goes low.

1MZ-FE with DIS Simultaneous Ignition

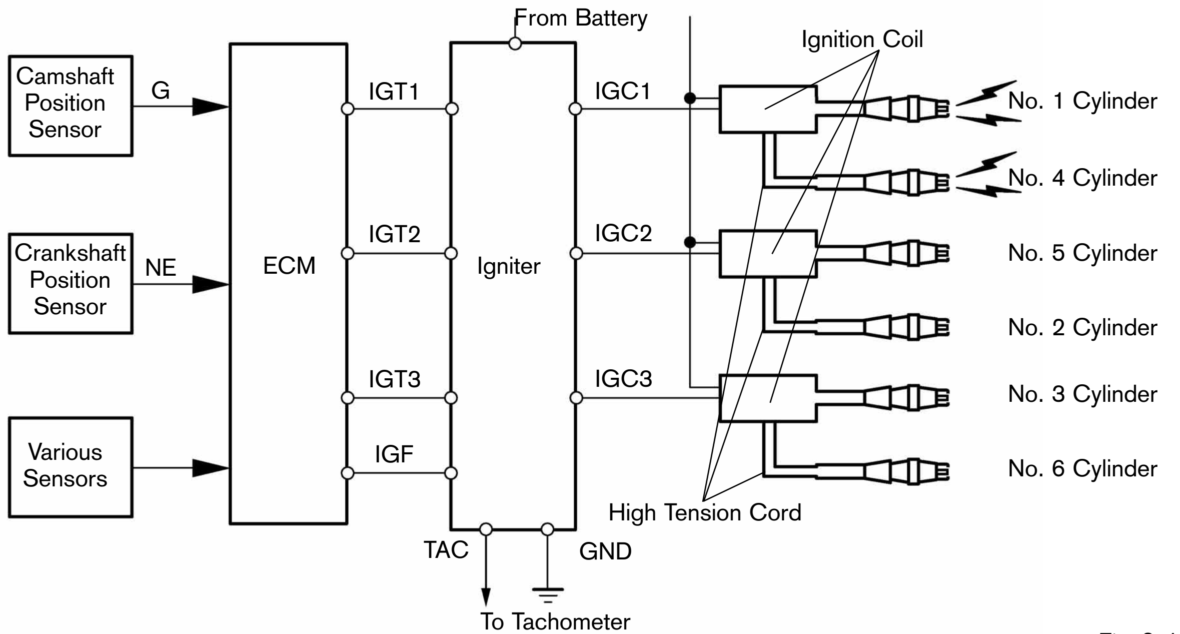


Fig. 3-42

T852f163

Igniter

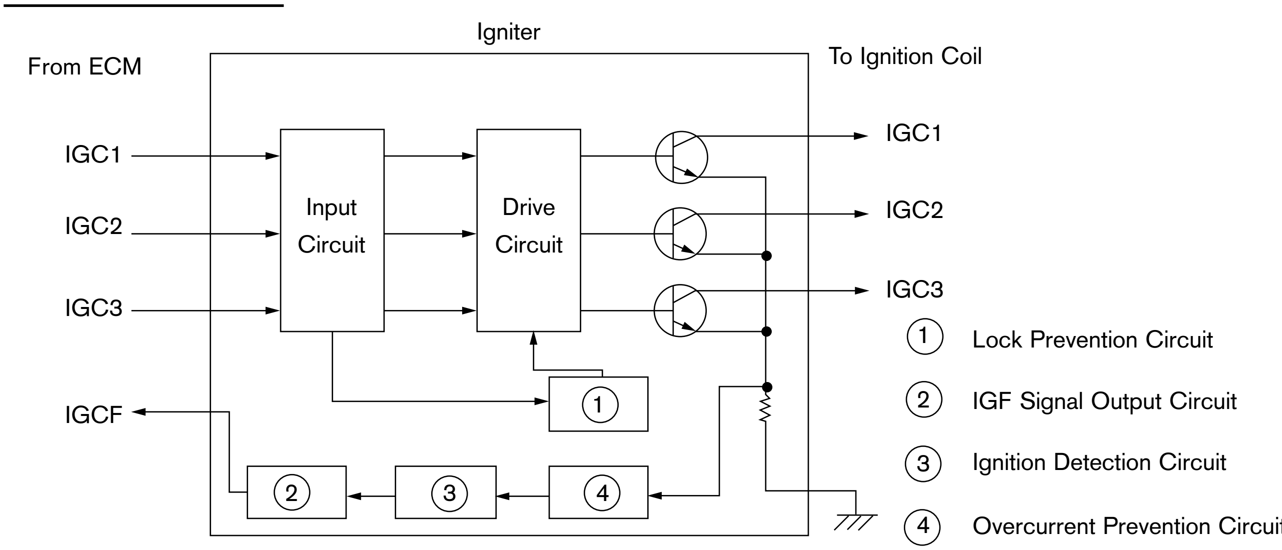


Fig. 3-43

T852f170

V-6 Igniter Sequence

When a coil is turned on, IGF goes low.

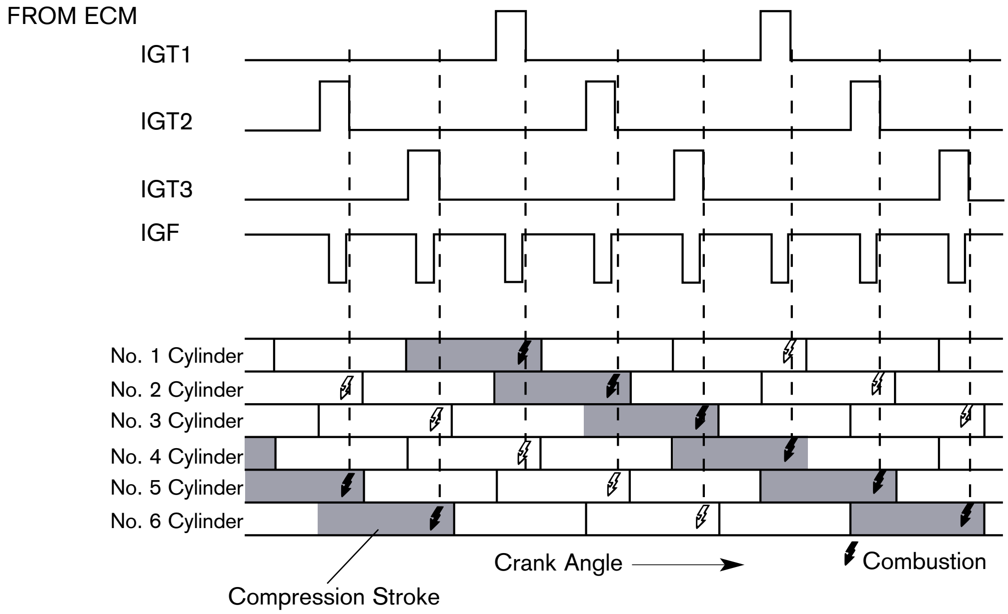


Fig. 3-44

T852f164

In-Line 6 Cylinder

The in-line 6 has a different firing order and cylinders are paired differently.

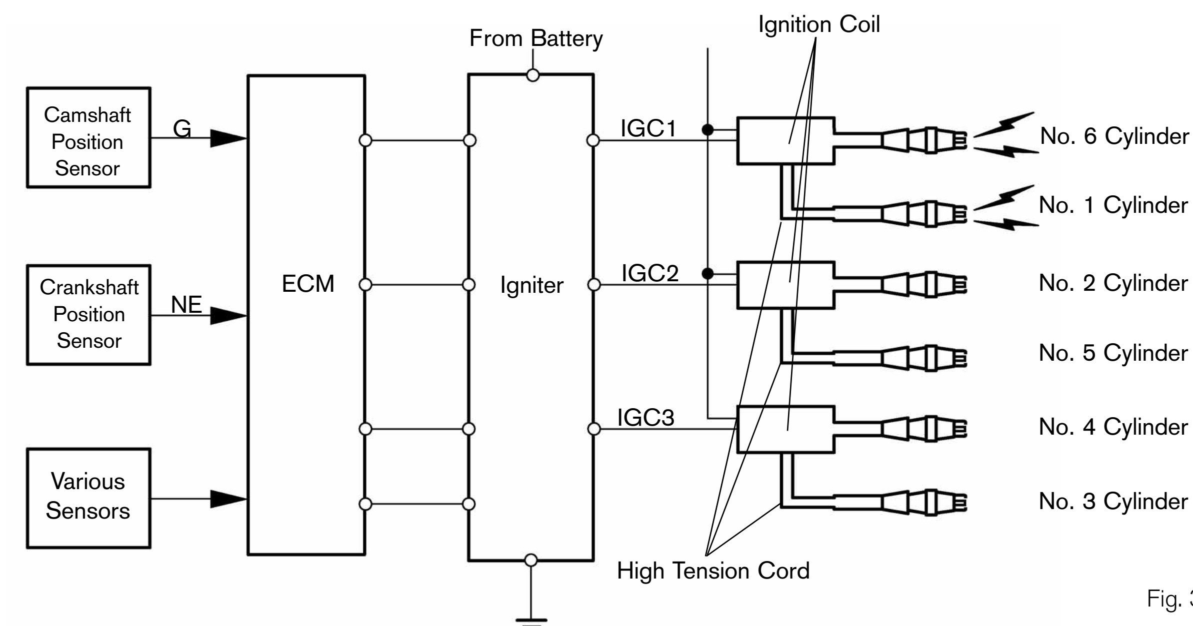
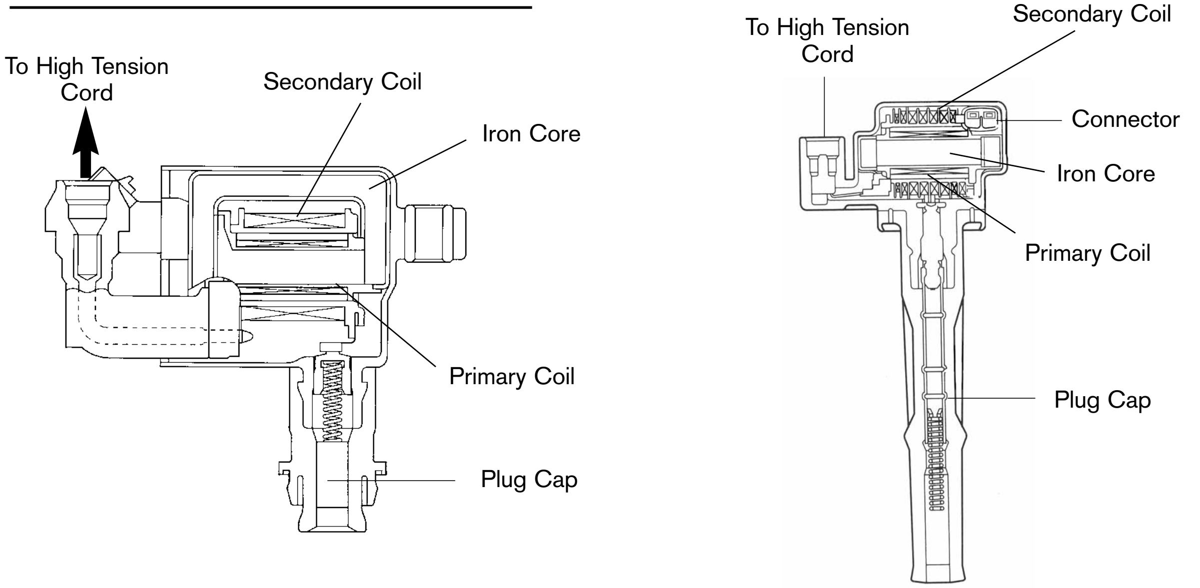


Fig. 3-45

T852f172/T852f173

Simultaneous Ignition Coils



Ignition Coil Cross Section

Ignition Coil Cross Section

Fig. 3-46

T852f174/T852f175

DIS with Independent Ignition

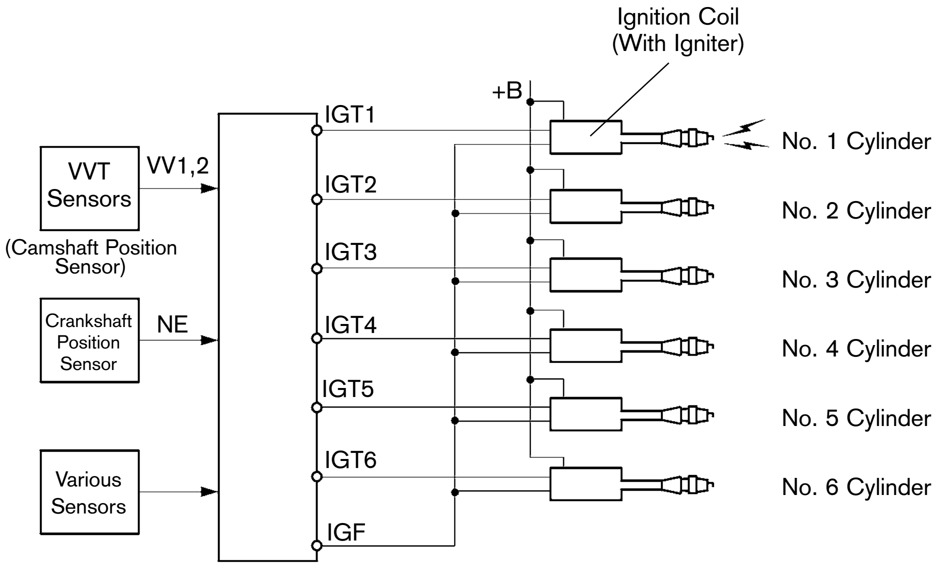
The DIS with independent ignition has the igniter built into the coil. Typically, there are four wires that make up the primary side of the coil:

- +B.
- IGT signal.
- IGF signal.
- Ground.

The ECM is able to distinguish which coil is not operating based on when the IGF signal is received. Since the ECM knows when each cylinder needs to be ignited, it knows from which coil to expect the IGF signal.

The major advantages of DIS with independent ignition are greater reliability and less chance of cylinder misfire.

V-6 1MZ-FE with DIS



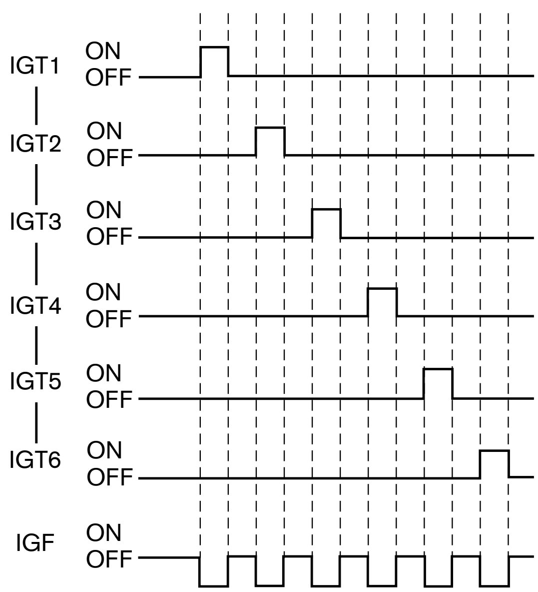
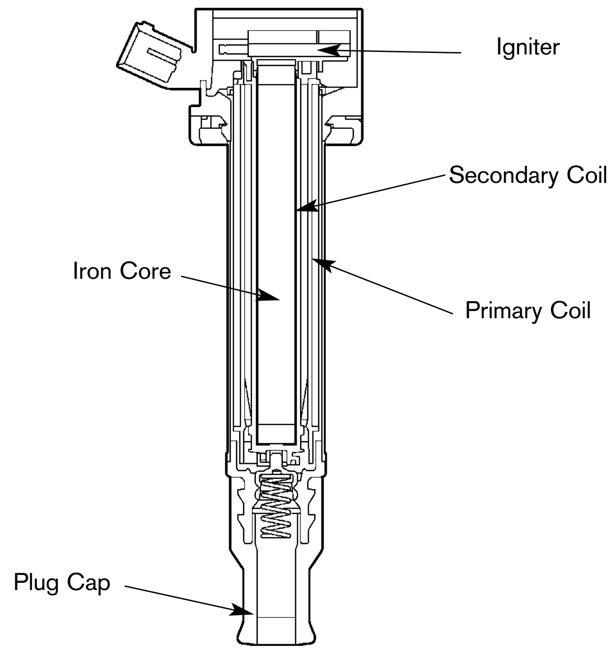


Fig. 3-47

T852f176/T852f166

Ignition Coil with Integrated Igniter

This style is used on DIS with independent ignition.



Ignition Coil Cross Section

Fig. 3-48

T852f171

V-8 with DIS

Each coil is controlled by the IGT signal.

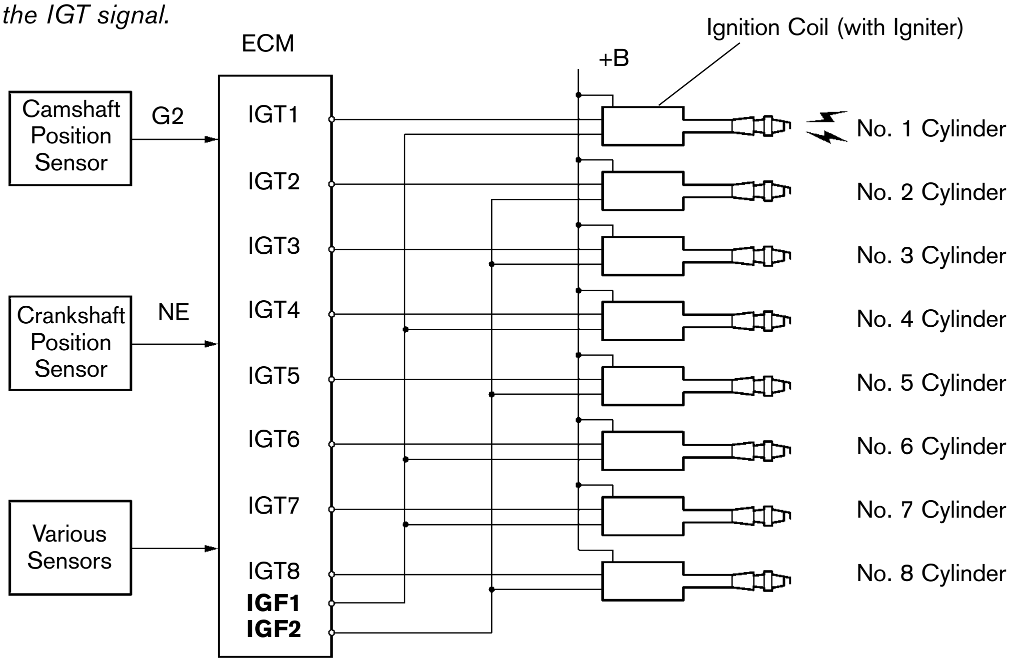


Fig. 3-49

T852f138

V-8 Ignition Chart

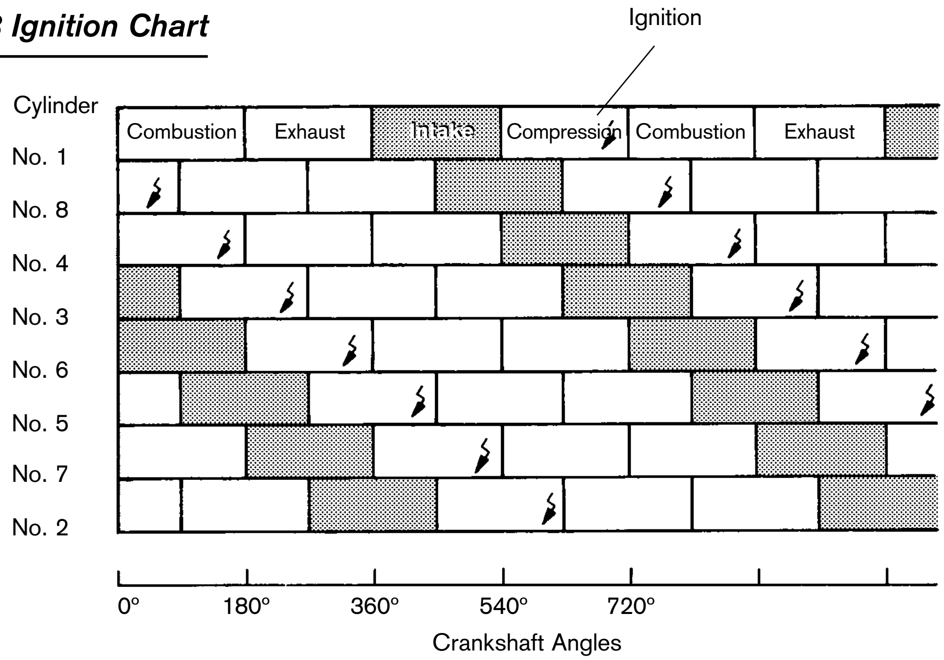


Fig. 3-50
T852f177

Ignition Advance Service

Though the Diagnostic Tester shows the computed ignition, advance, using a timing light confirms that advance took place and the timing marks are in the correct position.

With Distributor Ignition Systems, the point at which ignition occurs may vary because the base reference point can be moved. It is critical that the base reference point be set to factory specifications.

With DLI and DIS, the base reference point is determined by the Crankshaft Position Sensor and rotor, which is non-adjustable.

Standard Ignition Timing Angle

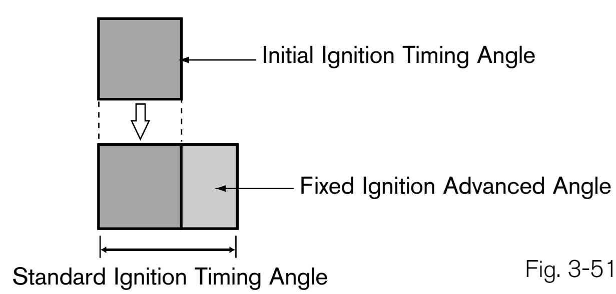


Fig. 3-51
T852f178

The angle to which the ignition timing is set during ignition timing adjustment is called the "standard ignition timing." It consists of the initial ignition timing, plus a fixed ignition advance angle (a value that is stored in the ECM and output during timing adjustment regardless of the corrections, etc., that are used during normal vehicle operation).

Ignition Timing Adjustment

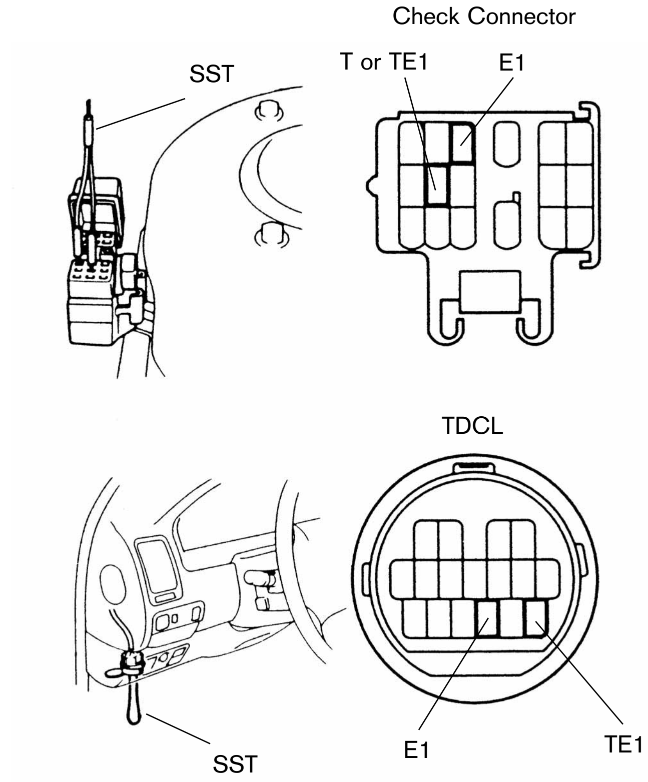


Fig. 3-52

Ignition timing adjustment is initiated by connecting terminal T1 (or TE1) of the check connector or TDCL with terminal E1, with the idle contacts on. This will cause the standard ignition timing signal to be output from the back-up IC in the same way as during after-start ignition control.

The standard ignition timing angle differs depending on the engine model. When tuning up the engine, refer to the repair manual for the relevant engine.

NOTE

Even if terminal T1 or TEl and terminal El are connected, the ignition timing will not be fixed at the standard ignition timing unless the idle contacts are on.

Where the G and NE signal generators are in a fixed position (distributorless or direct ignition systems), ignition timing cannot be adjusted.

Diagnostics

When the igniter is built into the ignition coil, it is not possible to do a resistance check of the primary coil winding. A bad primary winding will have to be determined by checking other functions of the coil and the ignition circuit.

DTC 1300 series will set, depending on the engine and type of ignition system, when the ECM does NOT receive the IGF signal. IGF confirms the primary circuit of the ignition system is working. Lack of IGF signal indicates a malfunction in the primary circuit or IGF signal related components.

If the DTC 1300 is set based on IGF, visually check the ignition system and then check for spark. If spark is present, the engine will start then stall when the ECM does not detect IGF (EXCEPT on some engines equipped with DIS with integrated igniter). In addition, when spark is present this confirms the secondary and primary circuits are good. The problem is most likely with the IGF circuitry.

Notes

WORKSHEET 3–1
Ignition System

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to locate and test ignition power and ground circuits, igniter, secondary ground circuits, and timing using the required tools and equipment, retrieve and apply the needed service information, and retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set

Section 1

1. What is the engine firing order?

____

2. According to the EWD, match the ignition coil to the engine cylinder(s) and IGT wire color (may be called IGC on some older ignition systems).

____

Ignition Coil	Cylinder	IGT Wire Color

3. List any fuses and relays that supply the igniter and ignition coil(s).

____

Section 2

1. According to the Repair Manual, perform an ignition timing check. Use the Diagnostic Tester for readings. What happened to ignition timing?

    ____

Section 3

1. If the ignition coil puts out a spark, but there is a DTC 1300, what part of the ignition circuit do you need to check?

    ____

2. For no spark coming from all ignition coils condition, list four possible components.

    ____

3. What method is used to determine if the coil is defective?

    ____

4. For OBD II vehicles. Disconnect the injector connector from any cylinder. Start the engine. With the DT, use Data List to bring up cylinder misfire. Does the DT show the cylinder misfire? What indicates a misfiring cylinder?

    ____

Section 4

IGT & IGF Signals

1. Set the Diagnostic Tester to the Oscilloscope function, refer to Repair Manual for settings. Start the engine and draw or print the waveform at between IDLE and 1500 RPM, whichever provides the best signal.

IGT

IGF

2. Does the waveform match the Repair Manual waveform?

____

3. With a DVOM, what is the voltage specification for checking IGF?

____

Ignition System

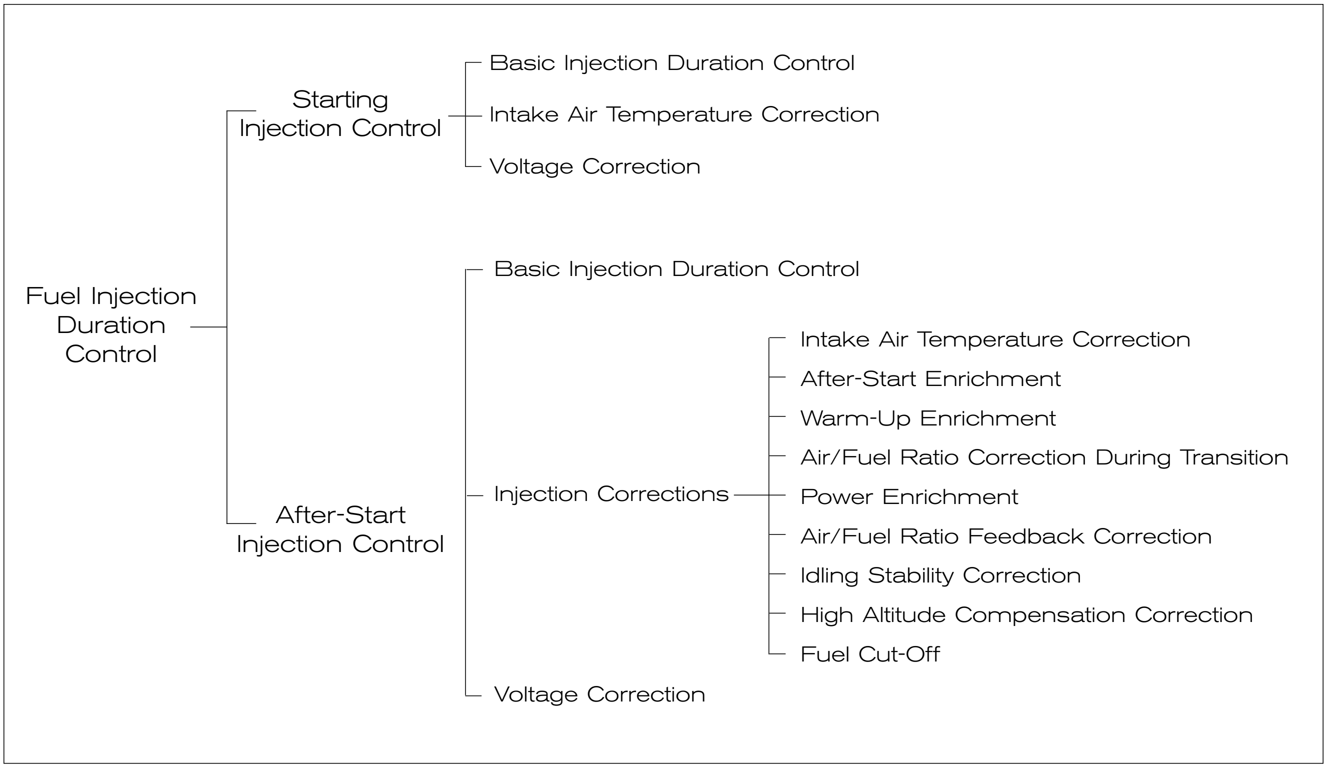
Name ____ Date ______________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the ignition system using the EWD and RM			
Find wire colors, pin numbers in the ignition system using the EWD and RM			
Locate the ignition system components readings from the Data List			
Measure the IGF voltage signal with a DVOM			
Check base ignition timing and adjust if applicable			
Observe the IGF and IGT voltage signal pattern with an oscilloscope			
Test ignition system power circuits for voltage and ground side for continuity			
Test wires for continuity/resistance and compare to specifications to determine condition			
Test ignition coil(s) and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Describe purpose of IGT and IGF signal			

Section 4

Fuel Systems



Lesson Objectives

1. Determine the condition of the fuel delivery system based on fuel pressure
2. Determine the root cause of a failure(s) in the fuel delivery system using appropriate diagnostic procedures
3. Determine the condition of the fuel injection system based on engine data
4. Determine the root cause of a failure(s) in the fuel injection system using the appropriate diagnostic procedures

Fuel Systems

Fuel Injection System

The purpose of the fuel injection system is to precisely inject a metered amount of fuel at the correct time. Based on the input sensor signals, the ECMs programming will decide when to turn each injector on and off.

Fuel Delivery System

The purpose of the fuel delivery system is to quietly deliver the proper volume of fuel at the correct pressure. The fuel delivery system must also meet emission and safety regulations. Major components are:

- Fuel Pump.
- Fuel Pump ECU.
- Pressure Regulator.
- Fuel Pressure Control Circuit.
- Fuel Lines.
- Fuel Tank.
- Fuel Filter.
- Pulsation Damper.
- Fuel Injectors.
- Inertia Switch.

Return Fuel Delivery System

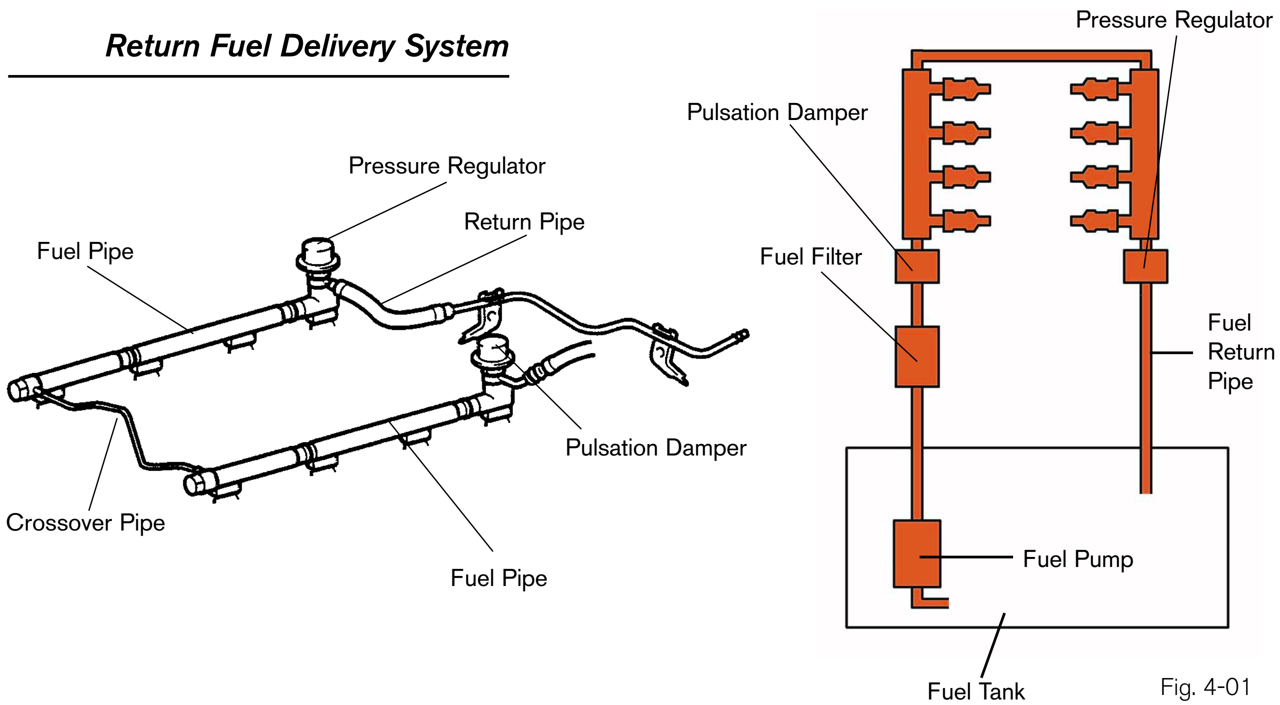


Fig. 4-01

T852f180/T852f181

Return Fuel Delivery System

When the fuel pump is activated by the ECM, pressurized fuel flows out of the tank, through the fuel filter to the fuel rail and up to the pressure regulator. The pressure regulator maintains fuel pressure in the rail at a specified value. Fuel in excess of that consumed by engine operation is returned to the tank by a fuel return line. A pulsation damper, mounted on the fuel rail, is used on many engines to dampen pressure variations in the fuel rail. The injectors, when turned on by the ECM, deliver fuel into the intake manifold. When the fuel pump is turned off by the ECM, a check valve in the fuel pump closes maintaining a residual pressure in the fuel system.

Returnless Fuel Delivery System

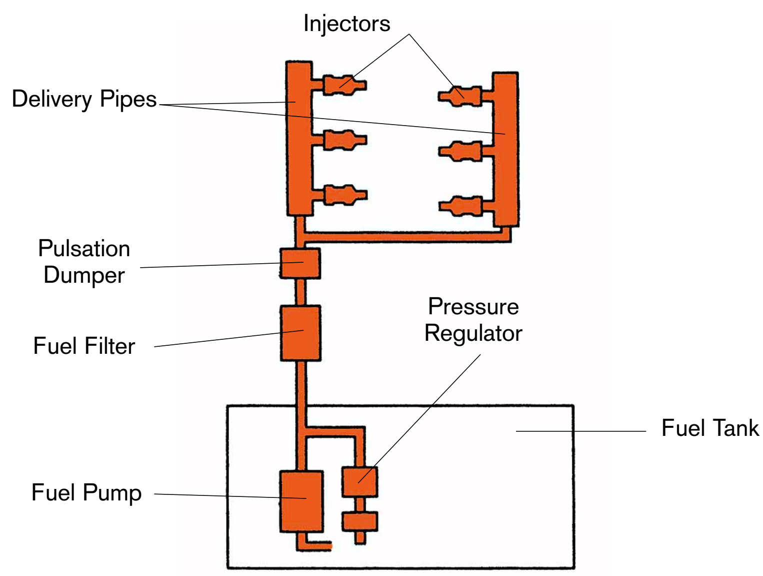


Fig. 4-02
T852f182

Returnless Fuel Delivery System

When the fuel pump is activated by the ECM, pressurized fuel flows from the pump to the pressure regulator. At the pressure regulator excess fuel is directed to the bottom of the fuel tank and pressurized fuel is sent out of the fuel tank, through the fuel filter, pulsation damper, and into the fuel rail. When the ECM turns on the injectors fuel is delivered into the intake manifold.

Fuel pressure in this system is maintained at a constant and higher pressure, 44-50 psi (301-347 kPa) than the return fuel system. ECM programming and a higher fuel pressure eliminates the need for a vacuum modulated pressure regulator.

The returnless fuel delivery system was adopted because it lowers evaporative emissions since no heated fuel is returned to the fuel tank. On the return fuel delivery system, fuel heated by the engine returns to the fuel tank and has warmer fuel creating more fuel vapors.

Fuel Pump

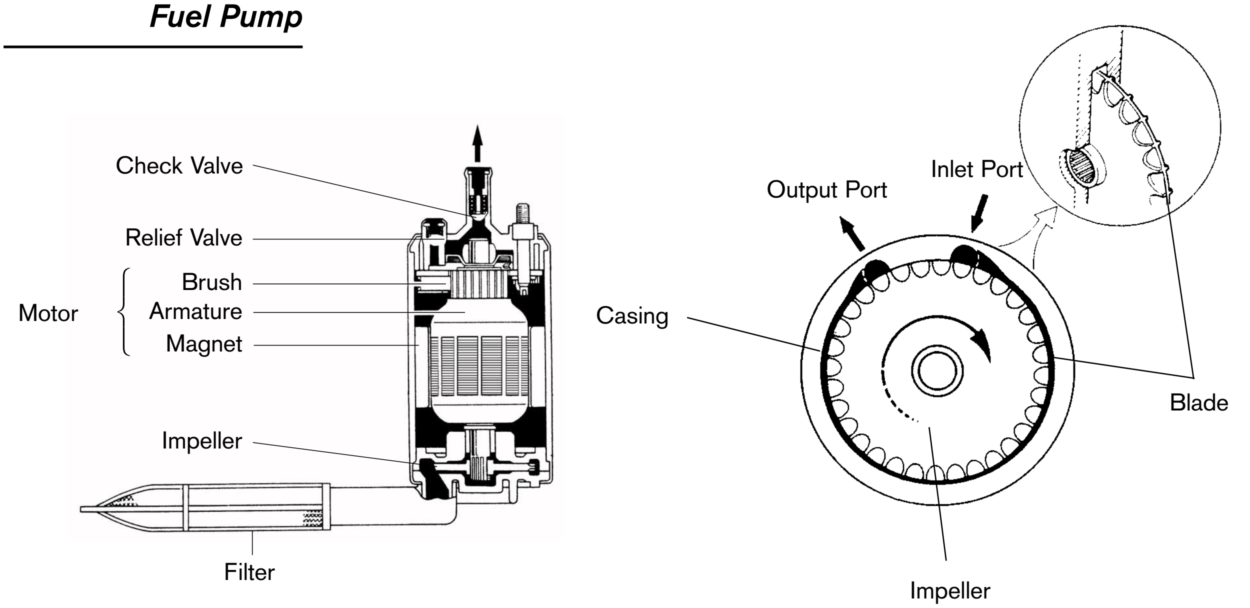


Fig. 4-03

T852f183/T852f184

Fuel Pump The fuel pump is mounted in the tank and immersed in fuel. The fuel cools and lubricates the pump. When current flows through the motor, the armature and impeller rotate. The impeller draws fuel in through a filter and discharges pressurized fuel through the outlet port. The fuel pump's pumping capacity is designed to exceed engine requirements. This insures that there will always be enough fuel to meet engine demands.

An outlet check valve, located in the discharge outlet, maintains a residual fuel pressure in the fuel system when the engine is off. This improves starting characteristics and reduces vapor-lock. Without residual fuel pressure, the system would have to be pressurized each time the engine was started and this would increase engine starting (cranking) time. When a hot engine is shut off, fuel temperature in the lines around the engine increases. Keeping the system pressurized increases the boiling point of the fuel and prevents the fuel from vaporizing.

A pressure relief valve will open if the fuel system becomes restricted. This is a safety device to prevent the fuel lines from rupturing and damage to the pump.

On many models the fuel pump is part of the fuel pump assembly. This assembly contains the filters, pressure regulator (returnless fuel system only), sending unit, and fuel pump. Many of the components can be serviced separately.

Typical Fuel Pump Assembly

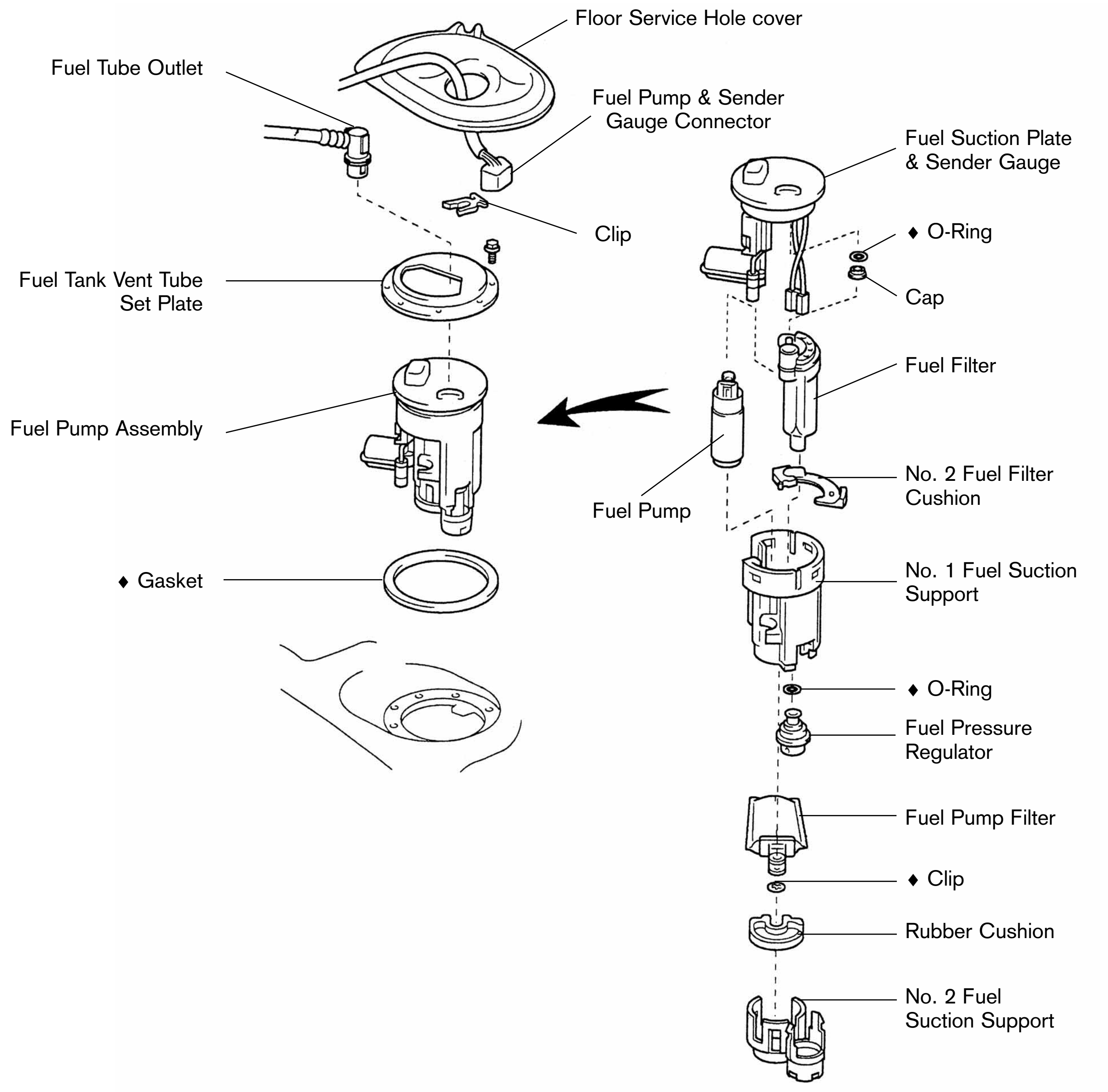
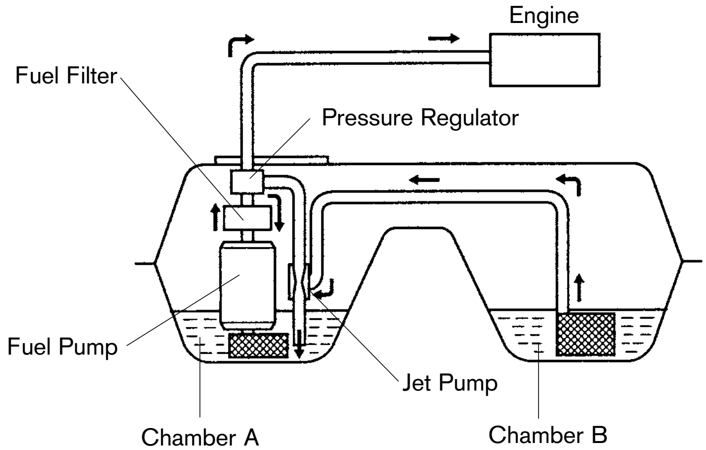
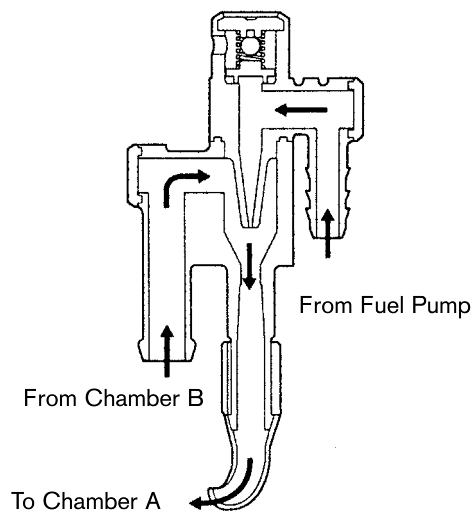


Fig. 4-04

T852f185

Jet Pump





Jet Pump

Fig. 4-05

T852f186/T852f187

Jet Pump The jet pump is an additional pump used when the fuel tank bottom is divided into two chambers. Excess fuel flowing through the fuel return passes through a venturi. This creates a low pressure area around the venturi, and this action will draw the fuel out of Chamber B, and sends it into Chamber A.

Fuel Pump Control

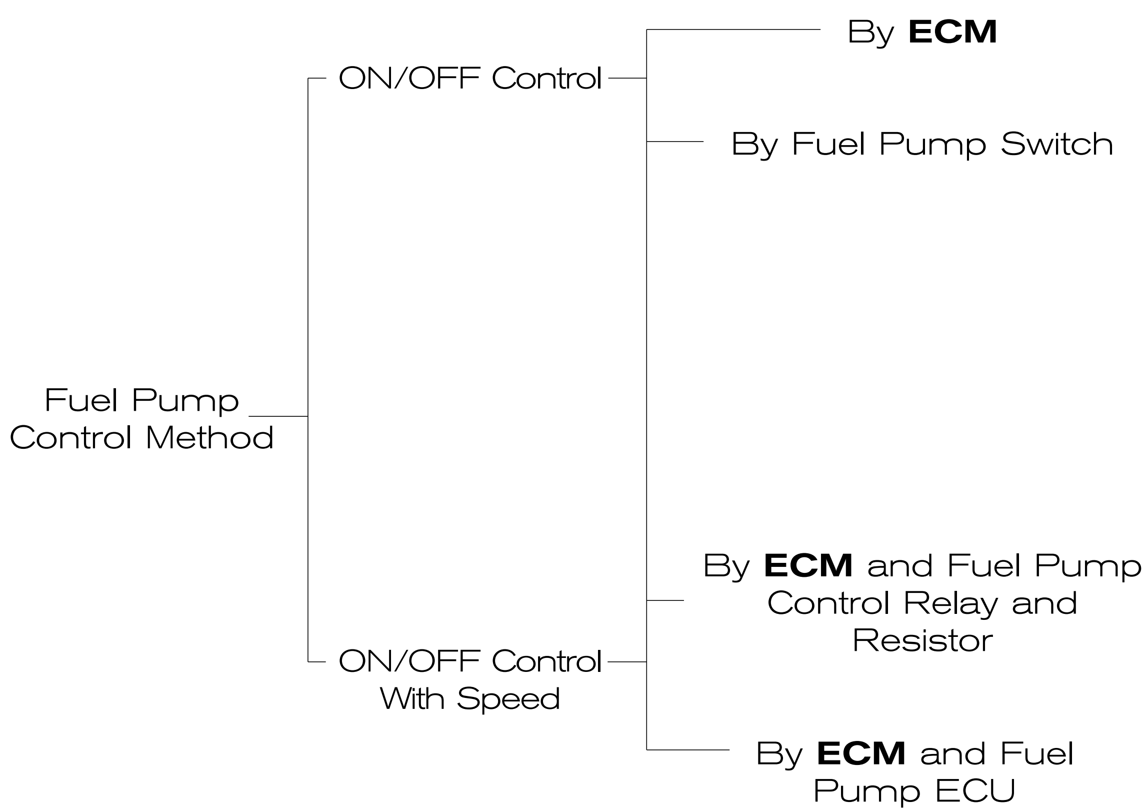


Fig. 4-06

Fuel Pump Controls

A variety of fuel pump control circuits and controls have been used over the years. The following basic methods are:

- ON/OFF Control by ECM.
- ON/OFF Control by Fuel Pump Switch.
- ON/OFF Two Speed Control with a Resistor.
- ON/OFF Two Speed Control with Fuel Pump ECU.
- ON/OFF Three Speed Control with Fuel Pump ECU.

The most accurate way of determining the type of fuel control circuit is to look up the circuit in the appropriate EWD.

The following describes the basic methods of fuel pump control. An essential point to remember is that the fuel pump operates only when the engine is cranking or running.

Engine Start

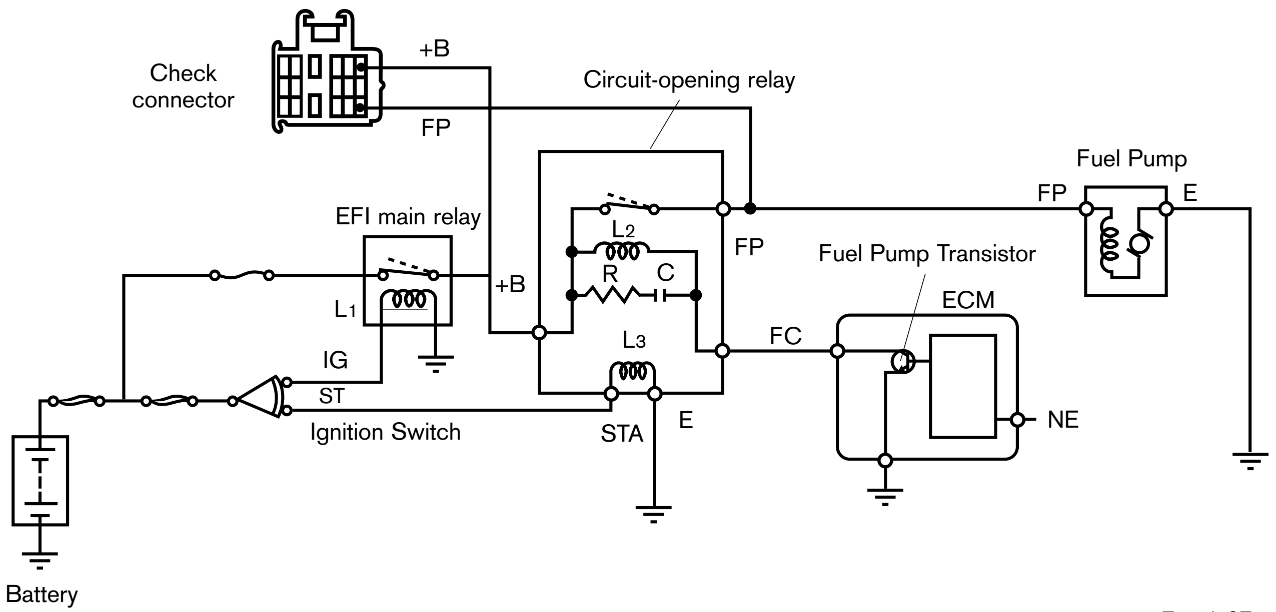


Fig. 4-07

T852f188

ON/OFF Control by ECM

The following is an explanation of how the fuel pump circuit is activated.

Engine Start

When the engine is cranking, current flows from the IG terminal of the ignition switch to the L1 coil of the EFI main relay, turning the relay on. At the same time, current flows from the ST terminal of the ignition switch to the L3 coil of the circuit opening relay, turning it on to operate the fuel pump. The fuel pump is now supplying fuel to the fuel injection system.

NOTE The circuit opening relay in this example is ground side switched.

Engine Running

Once the engine starts and the ignition key is moved to the ON (IG) position, current to the L3 coil is shut off, but the ECM will keep the fuel pump on through coil L2 as long as the ECM receives an NE signal. If the NE signal is lost at any time after starting, the ECM turns the fuel pump off.

Engine Stopped

When the engine stops, the NE signal to the ECM stops. This turns off the transistor, thereby cutting off the flow of current to the L2 coil of the circuit opening relay. As a result, the circuit opening relay opens turning off the fuel pump.

NOTE

The resistor R and the capacitor C in the circuit-opening relay are for the purpose of preventing the relay contacts from opening when current stops flowing in coil L2 due to electrical noise (fuel pumps controlled by the ECM) or to sudden drops in the intake air volume (fuel pumps controlled by fuel pump switch). They also serve to prevent sparks from being generated at the relay contacts. On some models, an L3 coil is not provided in the circuit-opening relay.

Fuel Pump Control Switch

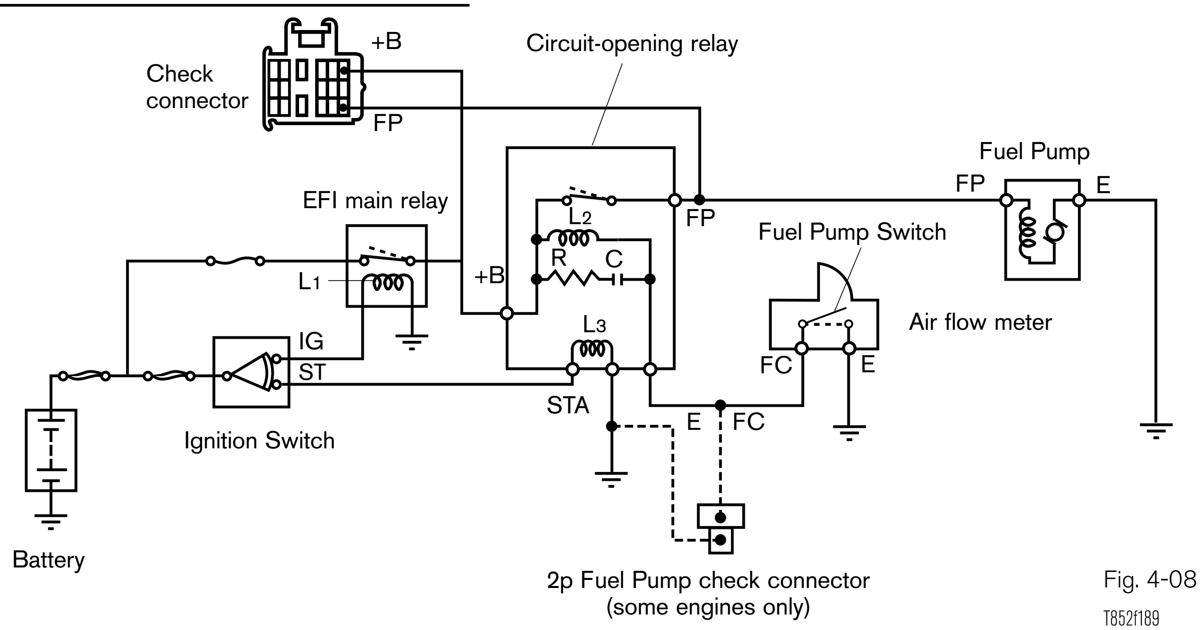


Fig. 4-08

ON/OFF Control by Fuel Pump Switch

The fuel pump switch is found on older vehicles using a Vane Air Flow Meter. The air moves the vane when the engine is running closing the fuel pump switch. The following is an explanation of circuit operation.

Engine Start

When the engine is cranking, current flows from the IG terminal of the ignition switch to the L1 coil of the EFI main relay, turning the relay on. Current also flows from the ST terminal of the ignition switch to the L3 coil of the circuit-opening relay, turning it on to operate the fuel pump. After the engine starts, the cylinders begin drawing in air, causing the measuring plate inside the air flow meter to open. This turns on the fuel pump switch, which is connected to the measuring plate, and current flows to the L2 coil of the circuit-opening relay.

Engine Running

After the engine starts and the ignition switch is turned from ST back to IG, current flowing to the L3 coil of the circuit-opening relay is cut off. However, current continues to flow to the L2 coil while the engine is running due to the fuel pump switch inside the air flow meter being on. As a result, the circuit-opening relay stays on, allowing the fuel pump to continue operating.

Engine Stopped

When the engine stops, the measuring plate completely closes and the fuel pump switch is turned off. This cuts off the flow of current to the L2 coil of the circuit-opening relay. As a result, the circuit-opening relay goes off and the fuel pump stops operating.

Two Speed Fuel Pump Control

Large displacement engines require a higher volume of fuel during starting and heavy load conditions than small displacement engines. High capacity fuel pumps are used to meet the demand, but they produce more noise and consume more power. To overcome these disadvantages and increase pump life, a two speed fuel pump control is used.

ON/OFF Two Speed Control with a Resistor

This type uses a double contact relay and a series limiting resistor.

Two Speed Fuel Pump Control with Resistor at Low Speed

When the engine is idling, or under normal driving conditions (when a small amount of fuel is required), the ECM turns on the fuel pump control relay. The relay switches to contact B, sending current through the resistor. This reduces the available current and voltage to the fuel pump, causing it to run at low speed.

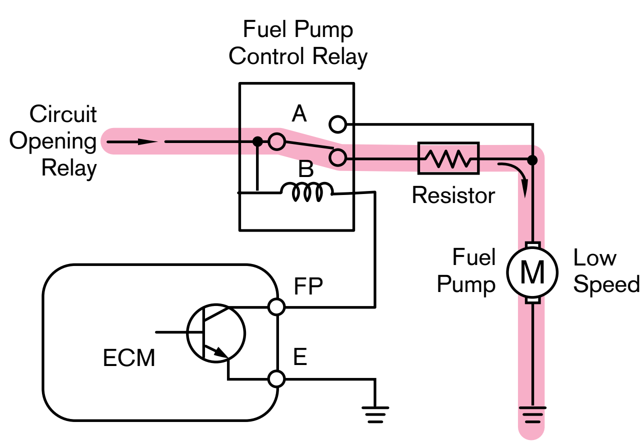


Fig. 4-09

T852f190

High Speed

When the engine is operating at high speeds or under heavy loads, the ECM turns off the fuel pump control relay. The relay switches to contact A, and the current to the fuel pump flows directly to the pump bypassing the resistor, causing the fuel pump to run at high speed.

The fuel pump also runs at high speed while the engine is starting.

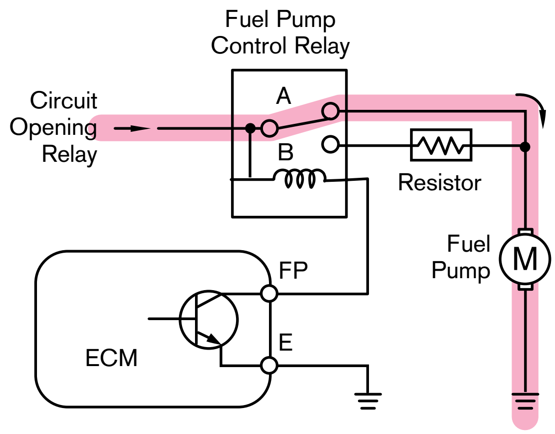


Fig. 4-10
T852f191

Two Speed Control with Fuel Pump ECU

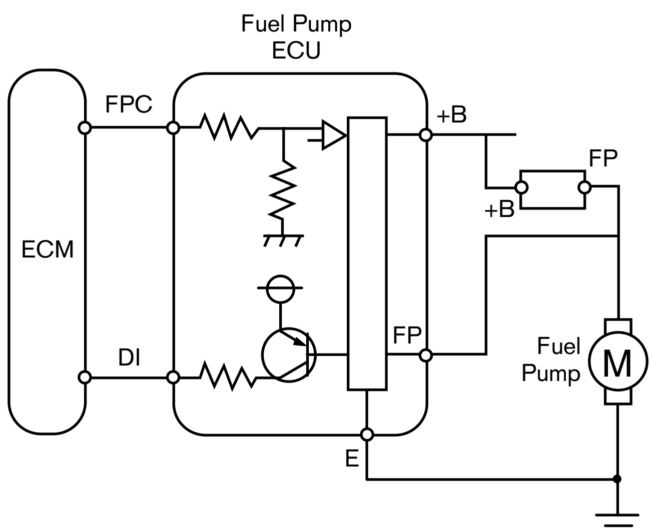


Fig. 4-11
T852f192

ON/OFF Two Speed Control with Fuel Pump ECU

This type is similar to other systems, but uses a Fuel Pump ECU. In this system, however, ON-OFF control and speed control of the fuel pump is performed entirely by the Fuel Pump ECU based on signals from the ECM. In addition, the Fuel Pump ECU is equipped with a fuel pump system diagnosis function. When trouble is detected, signals are sent from the Dl terminal to the ECM.

High Speed During starting and heavy load condition, the ECM sends a HI signal (about 5 volts) to the FPC terminal of the Fuel Pump ECU. The Fuel Pump ECU then supplies full battery power to the fuel pump.

Low Speed After the engine starts, during idle and light loads, the ECM outputs a low signal (about 2.5 volts) to the Fuel Pump ECU. Then, the Fuel Pump ECU supplies less voltage (about 9 volts) to the fuel pump.

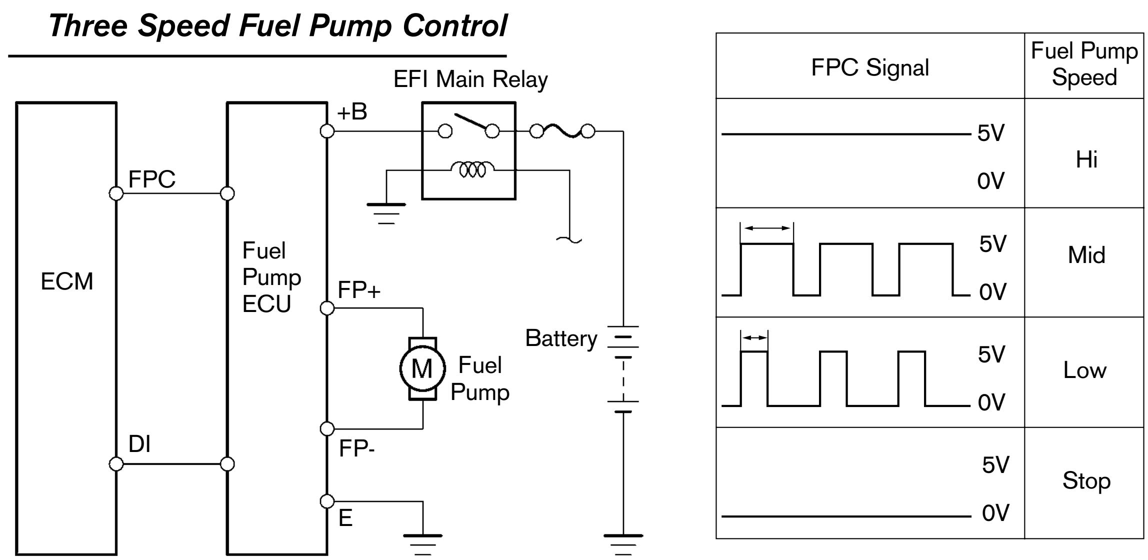


Fig. 4-12

T852f193/T852f194

Three Speed Fuel Pump Control

With this system, the fuel pump is controlled in 3 steps (high speed, medium speed, and low speed).

High Speed When the engine is operating under a heavy load at high RPM or starting, the ECM sends a 5 volt signal to the fuel pump ECU. The fuel pump ECU then applies battery power to the fuel pump causing the fuel pump to operate at high speed.

Medium Speed Under heavy loads at low speed, the ECM sends a 2.5 volt signal to the fuel pump control. The fuel pump ECU applies about 10 volts to the fuel pump. This is considered medium speed.

Low Speed When idling or under light loads, the ECM sends a 1.3 volt signal to the fuel pump ECU. The fuel pump ECU applies 8.5 volts to the fuel pump, preventing excessive noise and decreasing power consumption.

Fuel Pump Inertia Switch

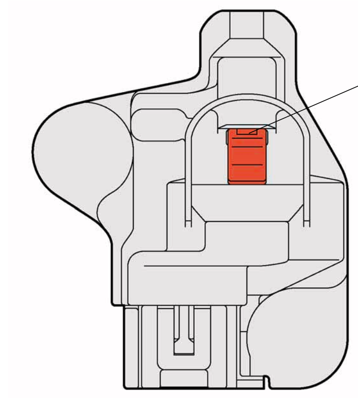


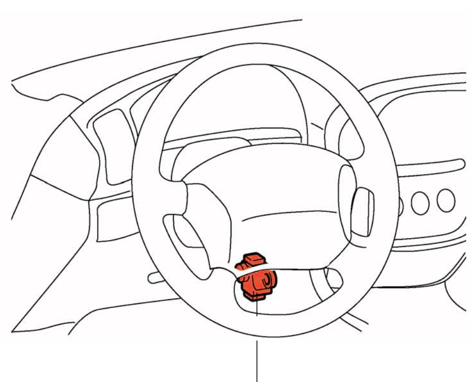
Fig. 4-13

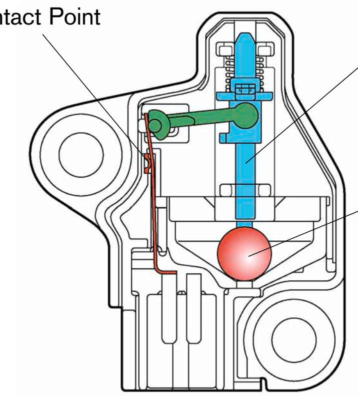
T852f195

Inertia Switch The fuel pump inertia switch shuts off the fuel pump when the vehicle is involved in a collision, minimizing fuel leakage.

Inertia Switch Location

The inertia switch is mounted on the floor pan.





Cross Section

Fig. 4-14

T852f196/T852f197

Fuel Pump Inertia Circuit

Electrically, the fuel pump inertia switch is located between the ECM and Fuel Pump ECU.

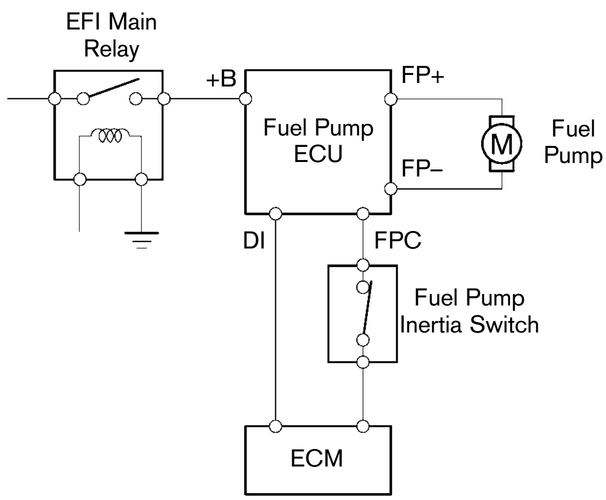


Fig. 4-15
T852f198

Inertia Switch Operation

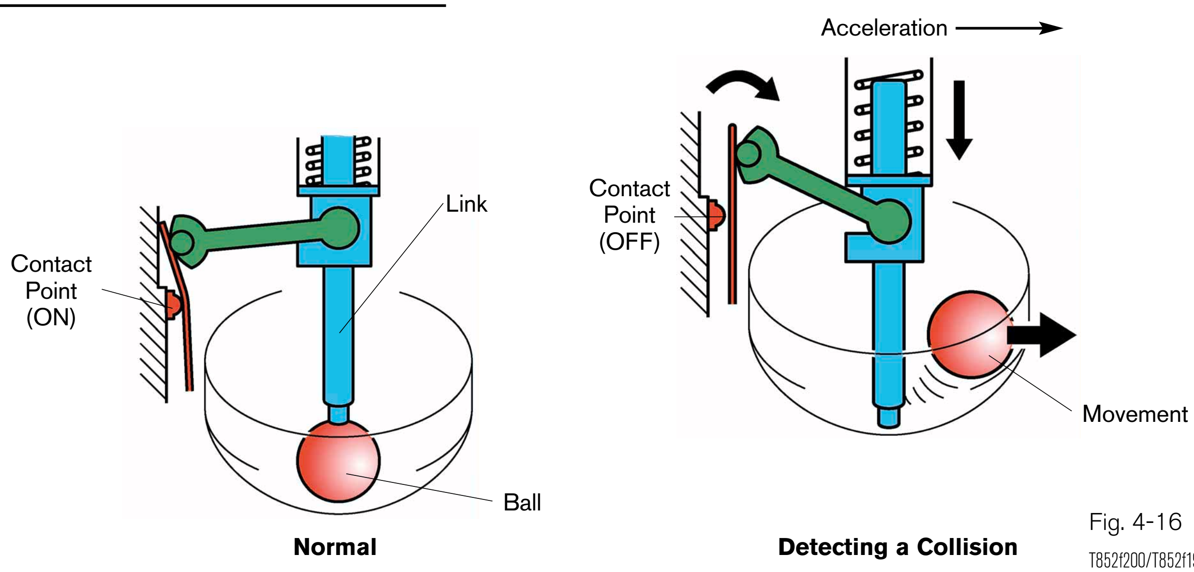


Fig. 4-16
T852f200/T852f199

Operation The inertia switch consists of a ball, spring loaded link, contact point, and reset switch. If the force of the collision exceeds a predetermined value, the ball will move causing the spring loaded link to drop opening the contact point. This opens the circuit between the ECM and Fuel Pump ECU causing the fuel pump to turn off. If the fuel pump inertia switch has been tripped, it can be reset by pushing up on the reset switch for at least 1 second.

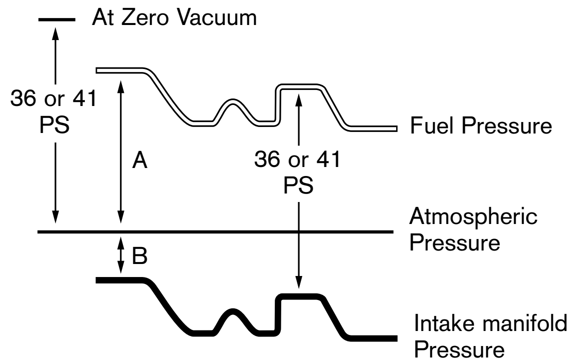
Pressure Regulators

The pressure regulator must consistently and accurately maintain the correct fuel pressure. This is important because the ECM does not measure fuel system pressure. It assumes the pressure is correct. There are two basic types of pressure regulators.

Modulated Pressure Regulators

The return fuel delivery system uses a pressure regulator located on the fuel pressure rail between the fuel pressure rail and the return line to the fuel tank. There are two types of pressure regulators. One type is modulated by vacuum, the other by atmospheric pressure.

Vacuum Modulated Pressure Regulator



Intake Manifold Pressure	**Low**	**HIgh**
Effective Spring Tension	**Small**	**Large**
Fuel Pressure	**Low**	**High**
Injection Volume	**Same**	**Same**

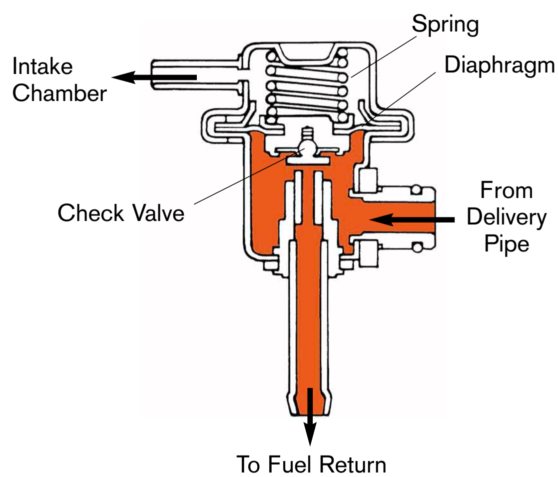


Fig. 4-17
T852f201/T852f202

Vacuum Modulated Pressure Regulator

To maintain precise fuel metering, the vacuum modulated pressure regulator maintains a constant pressure differential across the fuel injector. This means that fuel rail pressure will always be at a constant value above manifold absolute pressure.

Low intake manifold pressure (idle for example) pulls on the diaphragm decreasing spring pressure. This allows more fuel to return to the fuel tank decreasing pressure in the fuel rail. Opening the throttle increases manifold pressure. With less vacuum on the diaphragm spring pressure will increase restricting fuel flow to the fuel tank. This increases pressure in the fuel rail.

Atmospheric Modulated Pressure Regulator

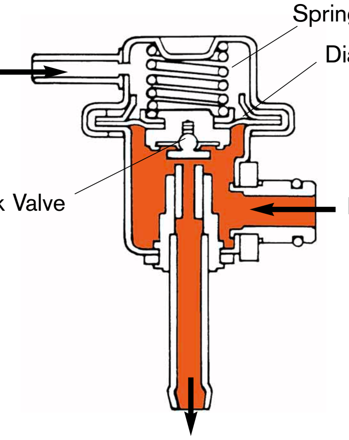


Fig. 4-18
T852f202

Atmospheric Modulated Pressure Regulator

The atmospheric modulated pressure regulator modifies fuel pressure with changes in atmospheric pressure. A hose is connected from the pressure regulator to the air intake hose between the air filter and throttle plate. Spring pressure and atmospheric pressure keep the fuel pressure at a constant value, 226-265 kPa (38-44 psi). As air pressure changes, such as climbing from low to high altitude, fuel rail pressure decreases because there is less force on the diaphragm.

Constant Pressure Regulator

The O-Ring must be properly seated to prevent leakage.

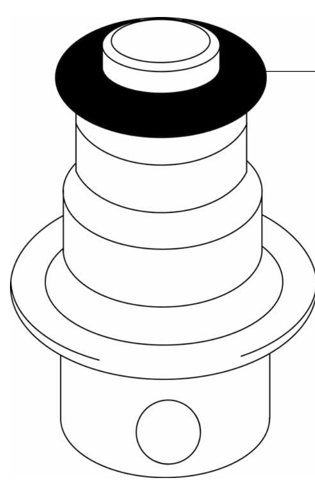
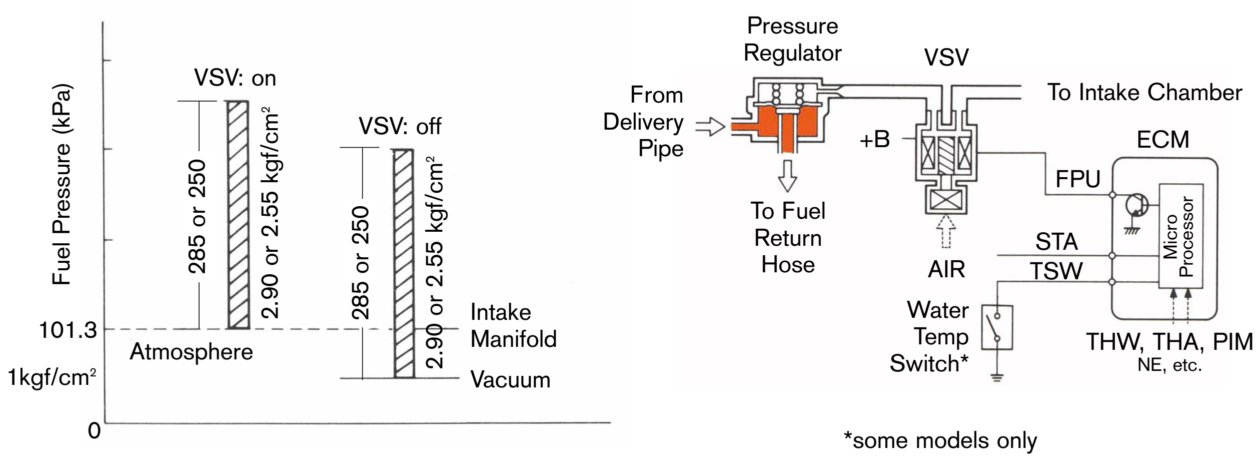


Fig. 4-19
T852f203

Constant Pressure Regulator (Returnless Fuel Delivery System)

The Returnless Fuel Delivery System uses a constant pressure regulator located above the fuel pump in the fuel tank. This type of regulator maintains a constant fuel pressure regardless of intake manifold pressure. Fuel pressure is determined by the spring inside the regulator. Fuel from the fuel pump overcomes spring pressure and some fuel is bypassed into the fuel tank. Fuel pressure is non-adjustable.

High Temperature (Pressure Up) Fuel Pressure Control



*some models only

Fig. 4-20

T852f204/T852f205

High Temperature (Pressure Up) Fuel Pressure Control

Some engines are equipped with a high temperature fuel pressure control to prevent vapor lock for easier starting and better driveability. A three way VSV is connected to the fuel pressure regulator vacuum line. Under normal conditions, the VSV is off and engine vacuum regulates the pressure regulator. If the engine is started when the coolant temperature is 85°C (185°F) or higher and the intake air temperature is above predetermined level, the ECM will turn on the VSV. Engine vacuum is closed off and atmospheric pressure is applied to the pressure regulator diaphragm. This increases fuel pressure preventing vapor lock. Once the engine is started, the VSV may remain on for about 120 seconds.

Fuel Delivery Components

Fuel Lines And Connectors

Today's vehicles use a variety of materials and connectors for fuel lines. Steel and synthetic materials are used, depending on location and model year. It is critical that the correct procedures be followed when servicing the fuel lines.

Connectors can be the threaded type or the quick connector style.

Styles of Quick Connectors

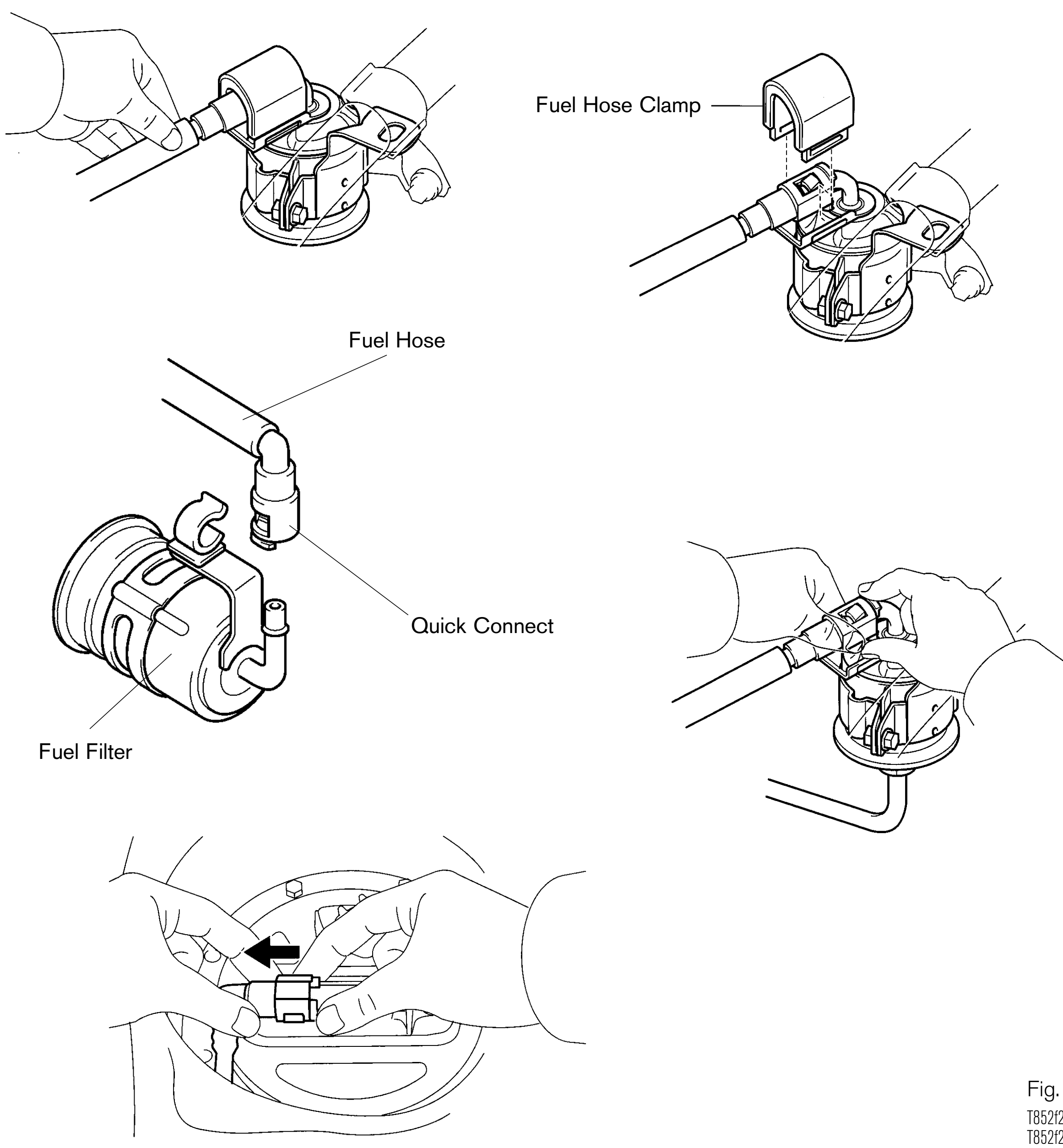
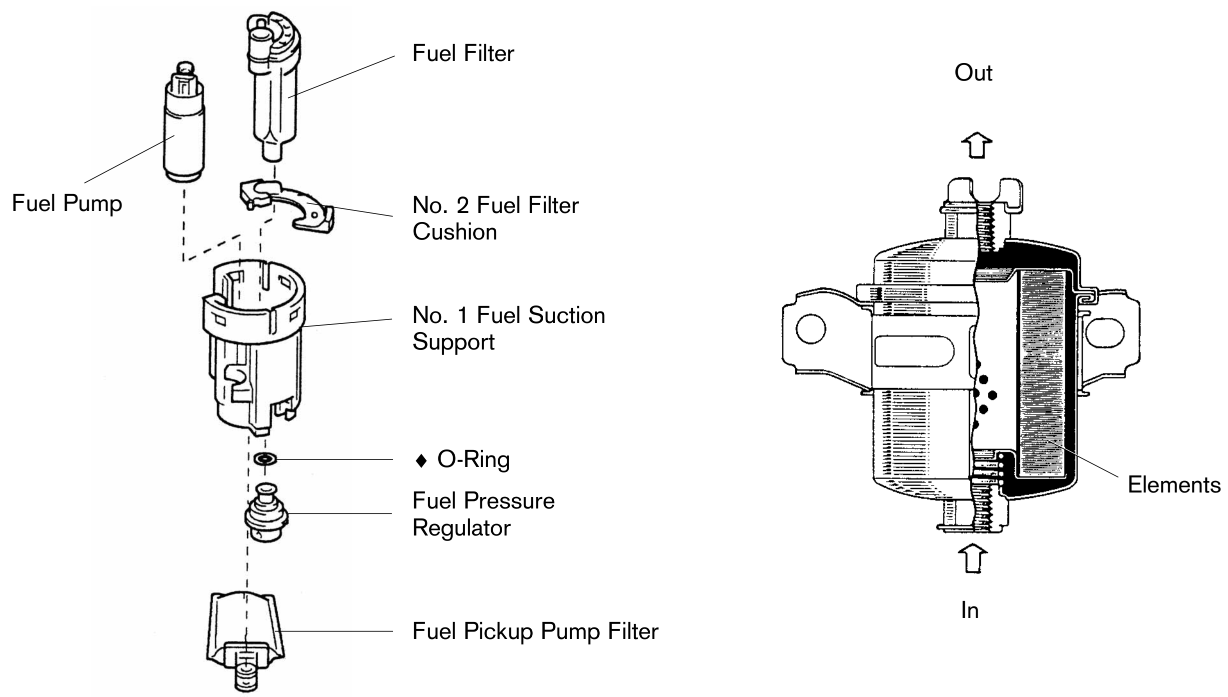


Fig. 4-21
T852f206/T852f207
T852f208/T852f209
T852f210

Fuel Tank

The fuel tank is designed to safely contain the fuel and evaporative emissions. Typically, it houses the fuel pump assembly and rollover protection valves.

Fuel Filters



Discharge External Style Fuel Filter

Fig. 4-22

T852f211/T852f212

Fuel Filters

Typically, there are two fuel filters in the fuel delivery system. The first filter is the fuel pump filter located on the suction side of the fuel pump. This filter prevents debris from damaging the fuel pump. The second filter, located between the pump and fuel rail, removes dirt and contaminates from the fuel before it is delivered to the injectors. This filter removes extremely small particles from the fuel, the injectors require extremely clean fuel.

The filter may be located in the fuel tank as part of the fuel pump assembly or outside the tank in the fuel line leading to the fuel rail. The filter is designed to be maintenance-free with no required service replacement.

A restricted fuel filter will prevent fuel from reaching the injectors. Therefore, the engine may be hard starting, surge, or have low power under loads. A completely clogged filter will prevent the engine from starting.

Pulsation Damper

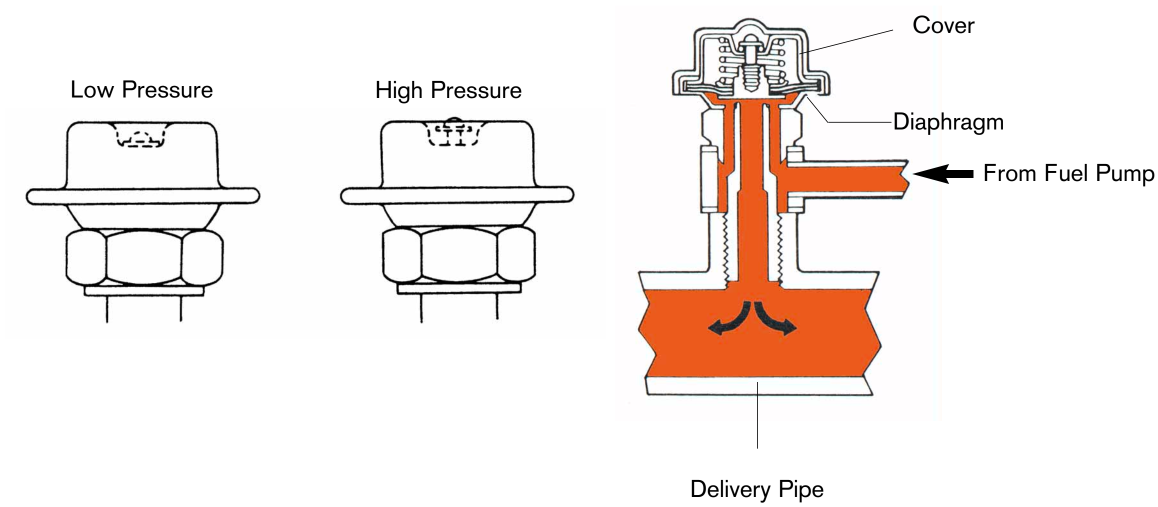


Fig. 4-23

T852f213/T852f214

Pulsation Damper

The rapid opening and closing of the fuel injectors cause pressure fluctuations in the fuel rail. The result is that the amount of injected fuel will be more or less than the desired amount. Mounted on the fuel rail, the pulsation damper reduces these pressure fluctuations. When pressure suddenly begins to increase the spring loaded diaphragm retracts slightly increasing fuel rail volume. This will momentarily prevent fuel pressure from becoming too high. When pressure suddenly begins to drop, the spring loaded diaphragm extends, slightly decreasing effective fuel rail volume. This will momentarily prevent fuel pressure from becoming too low. Not all engines require the use of a pulsation damper.

The screw mounted at the top of the damper provides an easy check for fuel system pressure. When the screw is up it means the fuel rail is pressurized. Under most conditions, this check is adequate. The screw is non-adjustable and it is used to calibrate the damper at the factory.

Fuel Injector

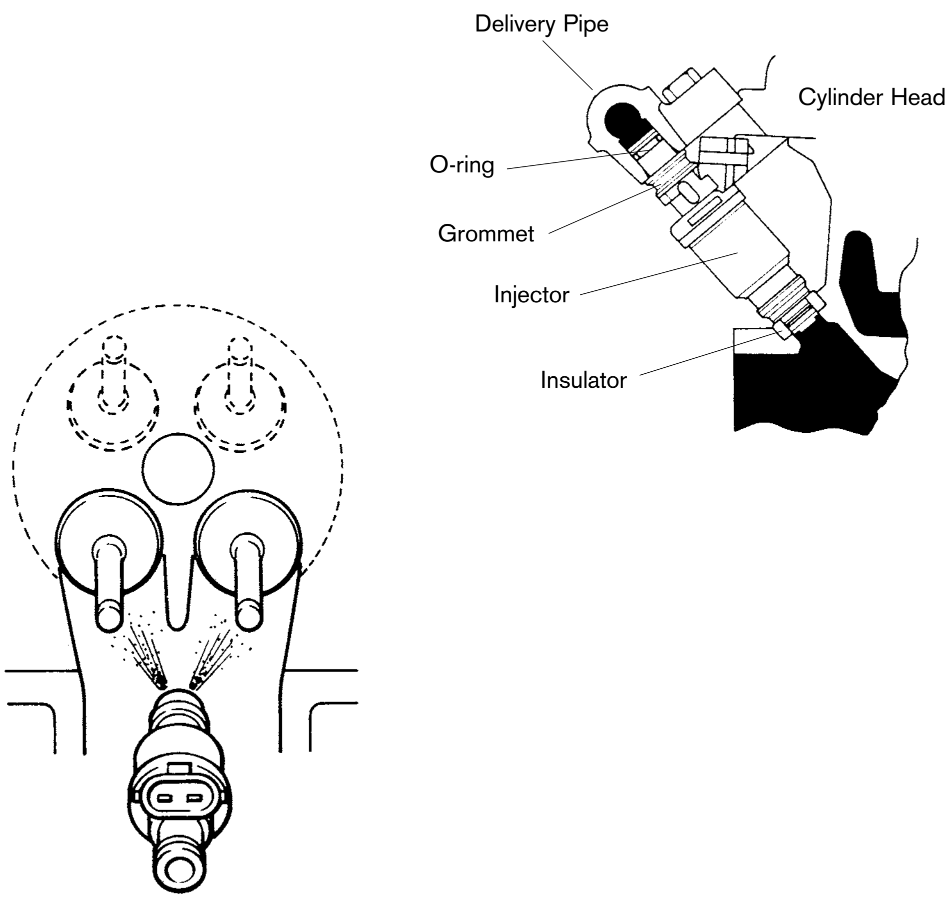


Fig. 4-24

T852f215/T852f216

Fuel Injection Operation

The fuel injector, when turned on by the ECM, atomizes and directs fuel into the intake manifold.

Fuel Injectors

There is one injector per cylinder mounted in the intake manifold before the intake valve(s). The injectors are installed with an insulator/seal on the manifold end to insulate the injector from heat and prevent atmospheric pressure from leaking into the manifold. The fuel delivery pipe secures the injector. An O-ring between the delivery pipe and injector prevents the fuel from leaking.

Different Styles of Fuel Injectors

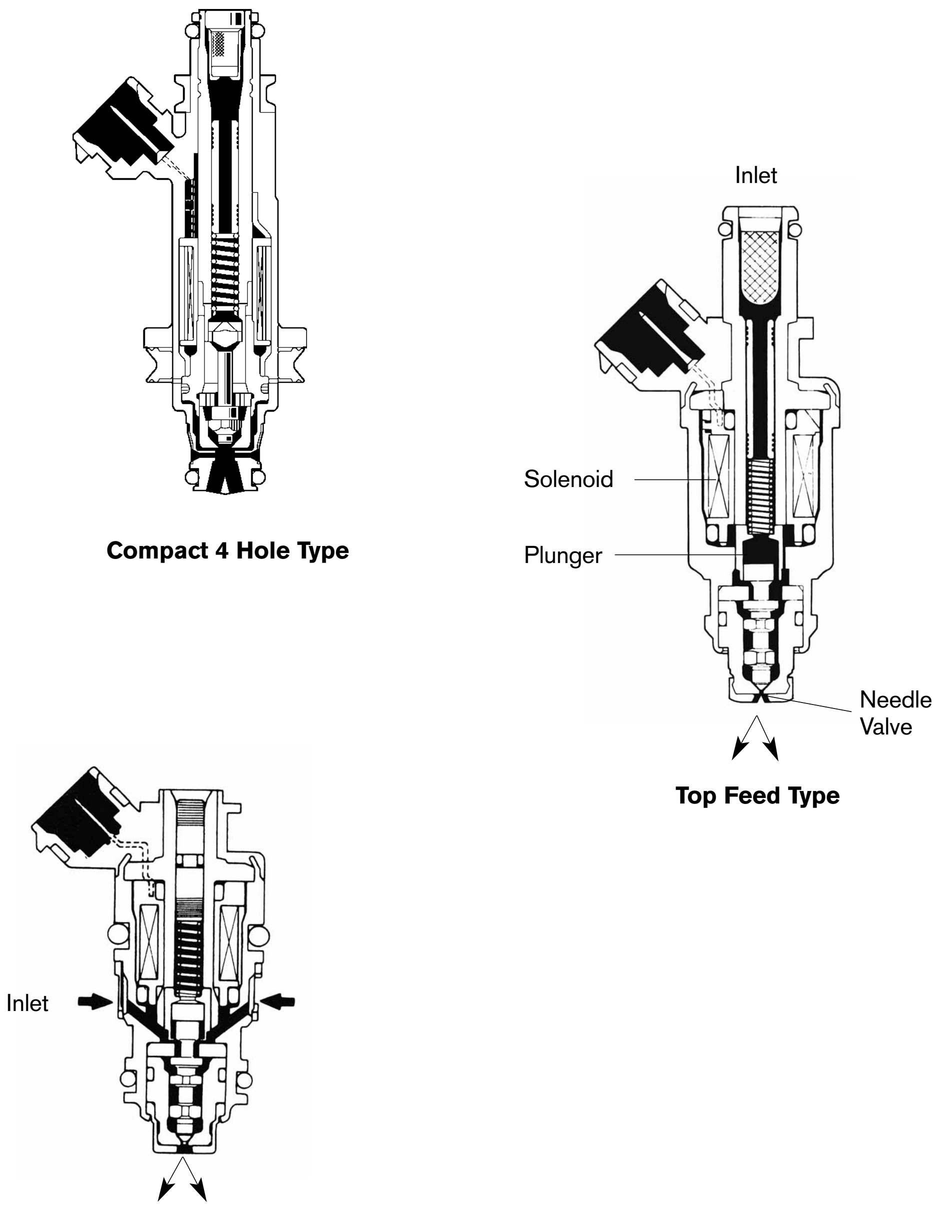


Fig. 4-25

T852f217/T852f218
T852f219

Different engines require different injectors. Injectors are designed to pass a specified amount of fuel when opened. In addition, the number of holes at the tip of the injector varies with engines and model years. When replacing an injector it is critical that the correct injector be used.

Air Assist Fuel Injector

The one on the right is for the air assist system. During idle air is directed Into the air gallery. The smaller tubes increase the air velocity and therefore mixes easily with the fuel for better combustion.

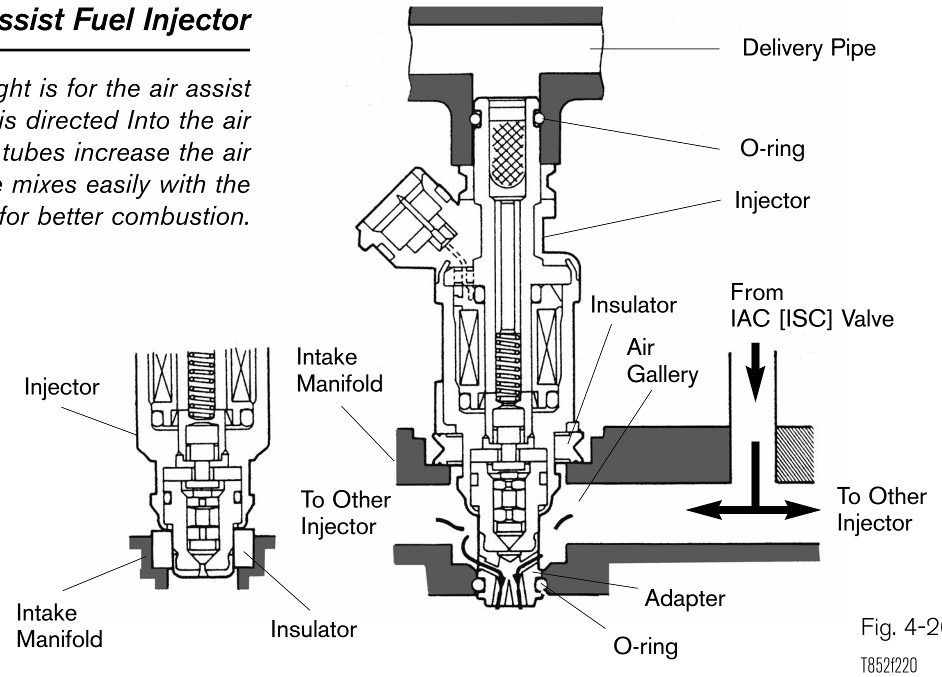


Fig. 4-26

T852f220

Inside the injector is a solenoid and needle valve. The fuel injector circuit is a ground switched circuit. To turn on the injector, the ECM turns on a transistor completing a path to ground. The magnetic field pulls the needle valve up overcoming spring pressure and fuel now flows out of the injector. When the ECM turns off the circuit, spring pressure will force the needle valve onto its seat, shutting off fuel flow.

Grouped Injection

This is one style of grouped injection.

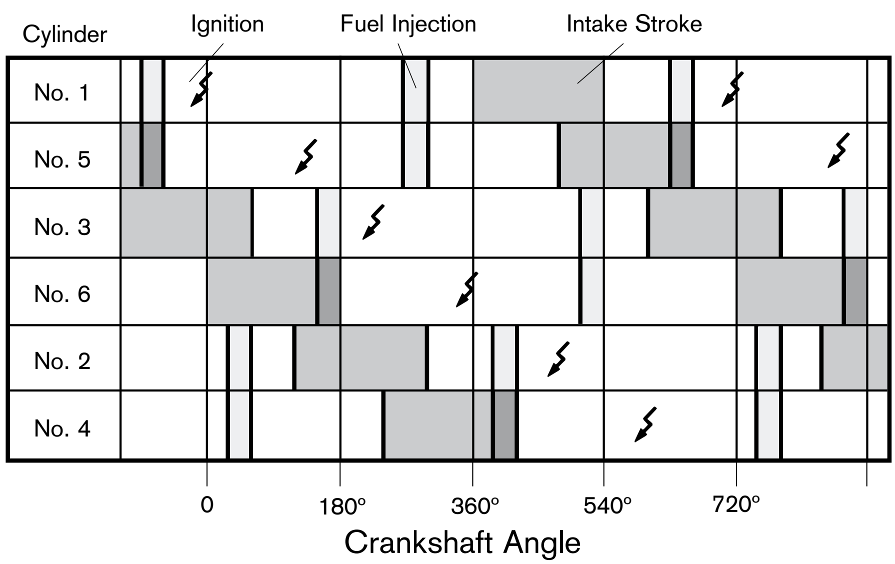


Fig. 4-27

T852f221

Sequential Injection

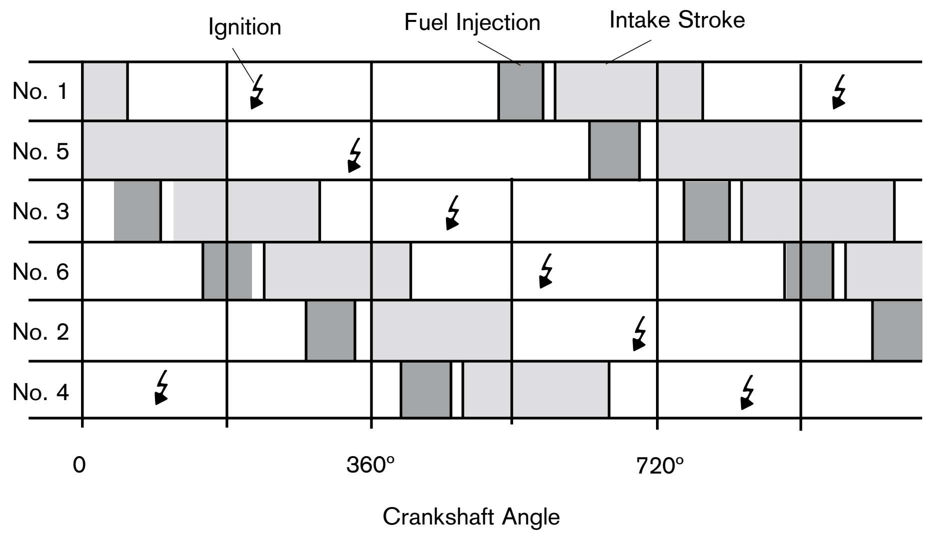


Fig. 4-28
T852f222

Injector Timing/Drive Circuits

The design of the injector drive circuit and ECM programming determines when each injector delivers fuel in relation to the operating cycle of the engine. If the injectors are turned on according to the crankshaft position angle, it is called synchronous injection. That is, the injectors are timed to turn on according to crankshaft position. Depending on engine application, the three main types of synchronous injection designs are: Simultaneous, Grouped, or Sequential. In all these types, voltage is supplied to the injectors from the ignition switch or EFI main relay and the ECM controls injector operation by turning on the driver transistor grounding the injector circuit. Simultaneous and grouped are the oldest styles, and are no longer used.

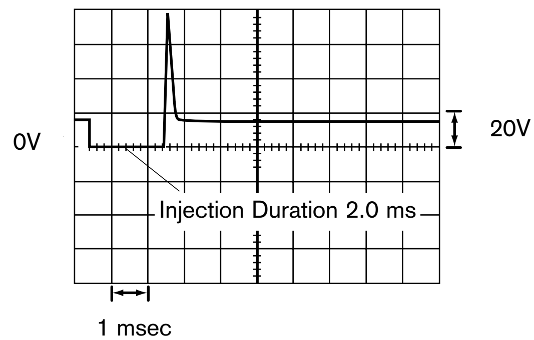
On simultaneous, all injectors are pulsed at the same time by a common driver circuit. Injection occurs once per engine revolution, just prior to TDC No. 1 cylinder. Twice per engine cycle, one-half of the calculated fuel is delivered by the injectors. With grouped drive circuits, injectors are grouped in combinations. There is a transistor driver for each group of injectors. On sequential drive circuits, each injector is controlled separately and is timed to pulse just before the intake valve opens.

There are times when the ECM needs to inject extra fuel into the engine regardless of crankshaft position and this is called asynchronous injection. Asynchronous injection is when fuel is injected into all cylinders simultaneously when predetermined conditions exist without relation to the crankshaft angle. Two common conditions are starting and acceleration.

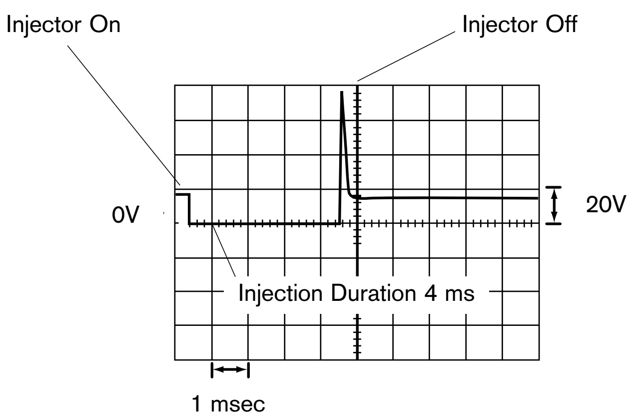
NOTE The EWD injector circuit can identify if the injection system is a grouped or sequential. A sequential system will have one injector per injector driver.

Injector Wave Pattern

Injection duration, when the injector is turned on and off, can be seen on the oscilloscope wave pattern.



• Engine running condition: Idling.



• Engine running condition: Heavy Load.

Fig. 4-29

T852f223/T852f224

Fuel Injection Volume Control

The amount of fuel injected depends on fuel system pressure and the length of time the injector is turned on. Fuel system pressure is controlled by the pressure regulator, and injector on time is controlled by the ECM. The time the injector is on is often called duration or pulse width, and it is measured in milliseconds (ms). Cold starting requires the highest pulsewidth. Pulsewidth is dependent primarily on **engine load and engine coolant temperature**. The higher the engine load and the more the throttle is opened to let air in, the pulsewidth increases. The ECM determines the duration based on the input sensor signals, engine conditions, and its programming.

Fuel Injection Duration Control Modes and Corrections

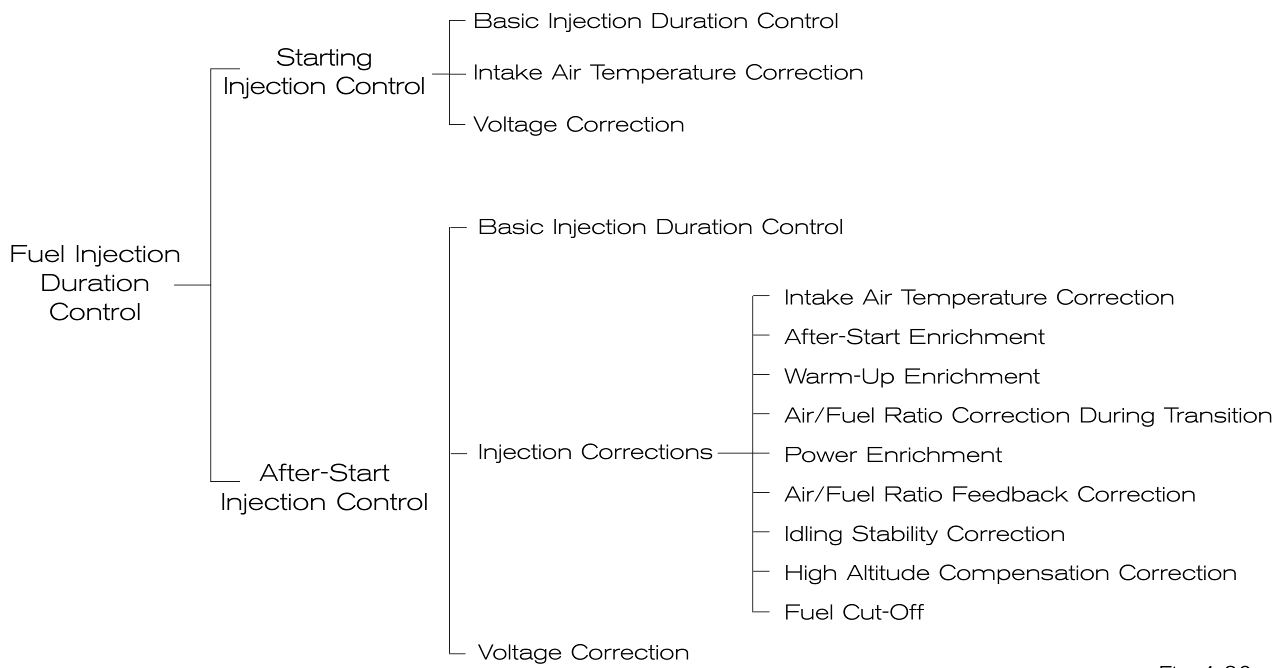


Fig. 4-30

Injection Start Mode

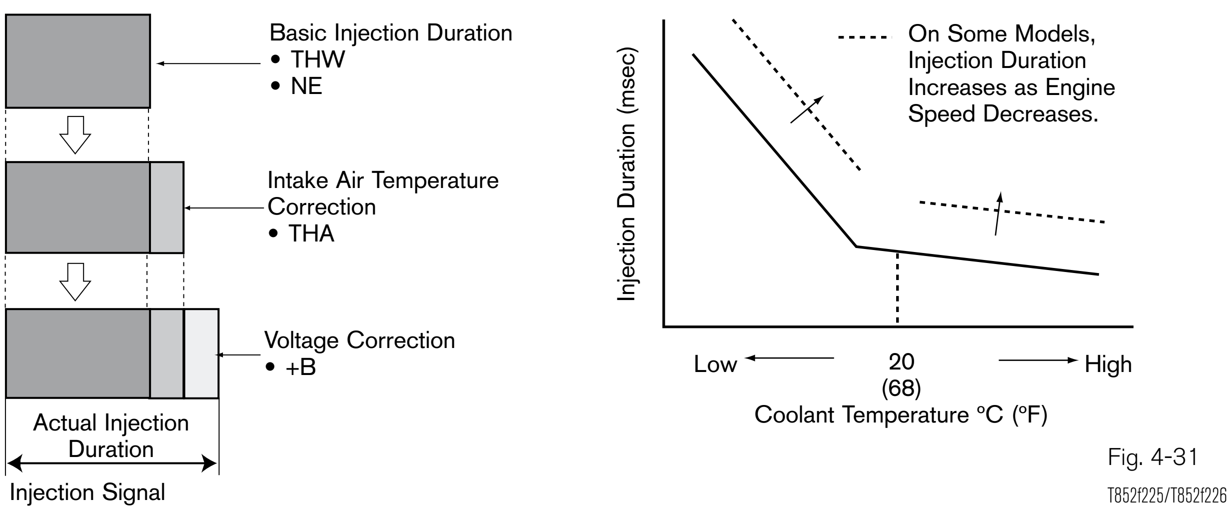


Fig. 4-31

T852f225/T852f226

Start Mode When the ignition switch is in the Start position, the ECM receives a voltage signal at the STA terminal. The ECM determines basic injection duration based on the ECT (THW) signal. On MAP sensor equipped engines the ECM will then modify this duration based on the IAT (THA) signal.

The ECM will adjust the duration based on battery voltage. During cranking, battery voltage is much lower causing the injector valve to lift slowly. The ECM corrects for this by increasing injection duration.

When the ECM receives the NE signal (Crankshaft Position Sensor), all the injectors are turned on simultaneously. This insures there is enough fuel for starting the engine. Note that below freezing, injection duration increases drastically to overcome the poor vaporization characteristics of fuel at these temperatures.

After Start Injection Control Mode

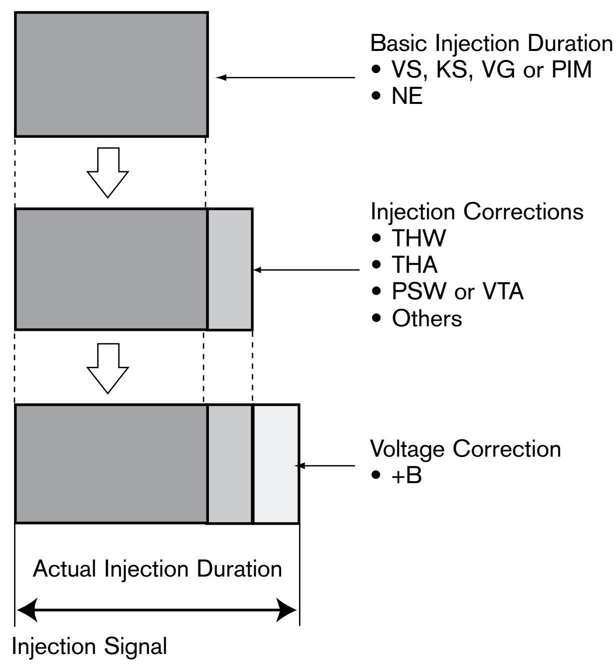


Fig. 4-32

T852f225

Engine Running (After Start) Injection Duration Control

Total fuel injection duration is determined in three basic steps:

- Basic injection duration.
- Injection corrections.
- Voltage correction.

Basic injection duration is based on air volume and engine RPM. Air volume on MAF equipped engines is determined by the MAF voltage signal.

On MAP sensor equipped engines, the ECM calculates air volume based on the PIM signal, engine RPM, THA signal, and volumetric efficiency values stored in the ECM.

Injection corrections adjust the basic injection duration to accommodate different engine modes and operating conditions. It is based on a variety of input signals.

Voltage correction adjusts the injection duration to compensate for differences in the electrical system voltage.

After Start Enrichment & Warm Up Correction

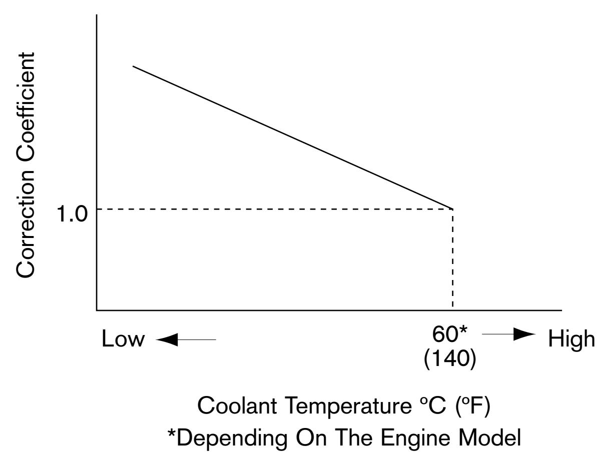


Fig. 4-33
T852f227

After Start Enrichment

Immediately after starting (engine speed above a predetermined level), the ECM supplies an extra amount of fuel for a certain period of time to stabilize engine operation.

This correction volume is highest immediately after the engine has started and gradually decreases. The maximum correction volume value is based on engine coolant temperature. The hotter the engine, the less volume of fuel injected.

Warm-Up Enrichment

A rich fuel mixture is needed to maintain driveability when the engine is cold. The ECM injects extra fuel based on engine coolant temperature. As the engine coolant warms up, the amount of warm-up enrichment decreases. Depending on the engine, warm-up enrichment will end at approximately 50°C–80°C (122°F–176°F).

If the ECM is in Fail-Safe Mode for DTC P0115, the ECM substitutes a temperature value, usually 80°C (176°F).

Correction Based on Intake Air Temperature (MAP Sensor Equipped Engines)

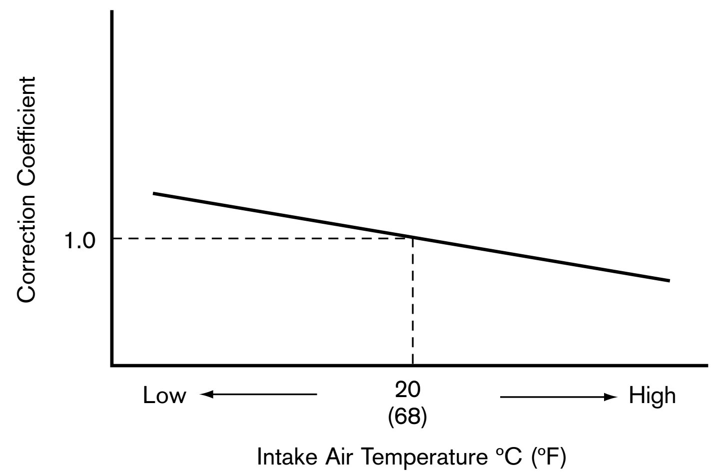


Fig. 4-34

T852f228

Correction Based on Intake Air Temperature (MAP Sensor Equipped Engines)

The density of the intake air decreases as temperature increases. Based on the IAT (THA) signal, the ECM adjusts the fuel injection duration to compensate for the change in air density. The ECM is programmed so that at 20°C (68°F), no correction is needed. Below 20°C (68°F), duration is increased, above 20° (68°F), duration is decreased.

If the ECM is in Fail-Safe Mode for DTC P0110, the ECM substitutes a temperature value of 20°C (68°).

Power Enrichment Correction

When the ECM determines the engine is operating under moderate to heavy loads, the ECM will increase the fuel injection duration. The amount of additional fuel is based on the MAF or MAP sensors, TPS, and engine RPM. As engine load (and air volume) increases, fuel injection duration increases. As engine RPM increases, injection frequency increases at the same rate.

Acceleration Correction

On initial acceleration, the ECM extends the injection duration richening the mixture to prevent a stumble or hesitation. The duration will depend on how far the throttle valve travels and engine load. The greater the throttle travel and engine load, the longer the injection duration.

Deceleration Fuel Cut

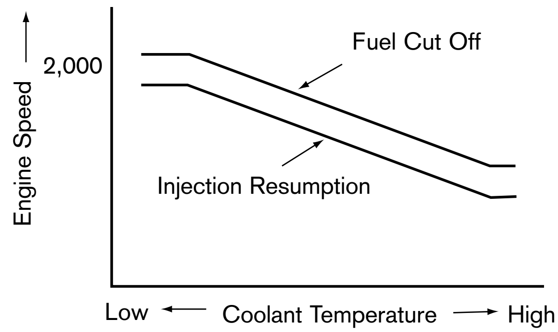


Fig. 4-35

T852f229

Deceleration Fuel Cut

During closed throttle deceleration periods from moderate to high engine speeds, fuel delivery is not necessary or desirable. To prevent excessive decel emissions and improve fuel economy, the ECM will not open the injectors under certain decel conditions. The ECM will resume fuel injection at a calculated RPM.

Referring to the graph, fuel cut-off and resumption speeds are variable, depending on coolant temperature, A/C clutch status, and the STA signal. Essentially, when extra engine loads are present, the ECM will begin fuel injection earlier.

Fuel Tau Cut is a mode employed on some engines during long deceleration time with the throttle valve closed. During these times, excess oxygen would enter the catalytic converter. To prevent this, the ECM will very briefly pulse the injectors.

Engine Over-Rev Fuel Cutoff

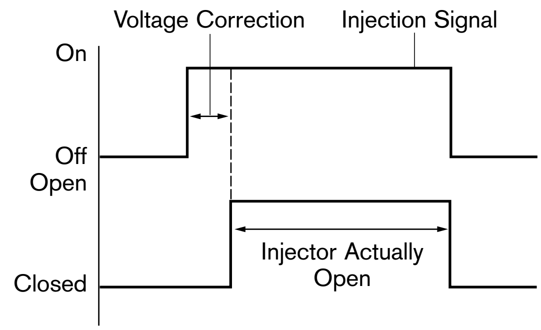
To prevent engine damage, a rev-limiter is programmed into the ECM. Any time the engine RPM exceeds the pre-programmed threshold, the ECM shuts off the injectors. Once RPM falls below the threshold, the injectors are turned back on. Typically, the threshold RPM is slightly above the engine's redline RPM.

Vehicle Over-Speed Fuel Cutoff

On some vehicles, fuel injection is halted if the vehicle speed exceeds a predetermined threshold programmed into the ECM. Fuel injection resumes after the speed drops below this threshold.

Battery Voltage Correction

With lower battery voltage, a longer injector ON time is needed.



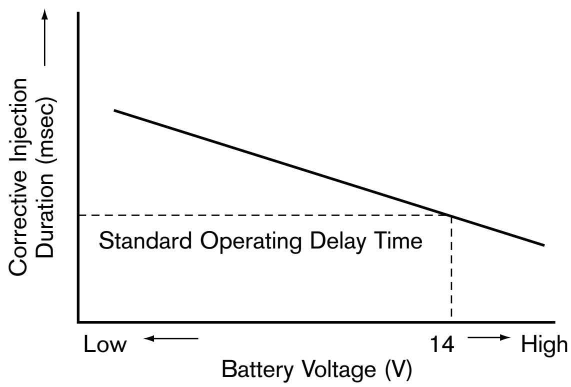


Fig. 4-36

T852f230/T852f231

Battery Voltage Correction

The applied voltage to the fuel injector will affect when the injector opens and the rate of opening. The ECM monitors vehicle system voltage and will change the injection on time signal to compensate. If system voltage is low, the injection on time signal will be longer, but the actual time the injector is open will remain the same (if system voltage were higher).

High Altitude Compensation

To compensate for less air at higher altitudes, fuel injection duration is decreased.

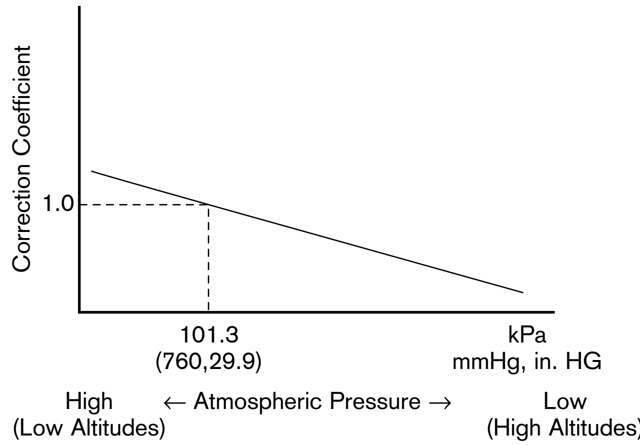


Fig. 4-37

T852f232

EVAP Purge Compensation When the evaporative purge valve is on, fumes from the charcoal canister are drawn into the intake manifold. The ECM will compensate based on the oxygen sensor output and shorten the injector pulse width.

Closed Loop Systems A system that controls its output by monitoring its output is said to be a closed loop system. An example of a closed loop system is the vehicle's charging system. The voltage regulator adjusts the voltage output of the alternator by monitoring alternator voltage output. If voltage is too low, the voltage regulator will increase alternator output. Without the voltage regulator, alternator output could not be adjusted to match the electrical loads. Many systems are closed loop systems. Some other examples are: cruise control, ignition system knock control, idle speed control, and closed loop air/fuel ratio correction control. When the ECM corrects the air/fuel ratio based on the oxygen or air/fuel ratio sensor, the system is said to be in closed loop.

Open Loop Systems An open loop system does not monitor its output and make adjustments based on its output. The temperature control in a vehicle not equipped with automatic air conditioning serves as an example.

Closed Loop Fuel Control The ECM needs to monitor the exhaust stream and adjust the air/fuel ratio so that the catalytic converter will operate at peak efficiency, reducing regulated emission gases. Measuring the amount of oxygen remaining after combustion is a means to indicate the air/fuel ratio. A richer mixture will consume more oxygen during combustion than a leaner mixture. The oxygen sensor or air/fuel ratio sensor measures the amount of oxygen remaining after combustion in the exhaust stream. From this information, the ECM will control the injection duration to achieve the desired, ideal air/fuel ratio of 14.7:1. This is necessary so the catalytic converter will operate at peak efficiency.

NOTE

The engine operation often requires different air/fuel ratios for starting, maximum power, and maximum fuel economy. The 14.7:1 ratio is for catalytic converter efficiency.

Stoichiometry and Catalyst Efficiency

Catalytic converter efficiency is nearly 100% when the air/fuel ratio is approximately 14.7:1.

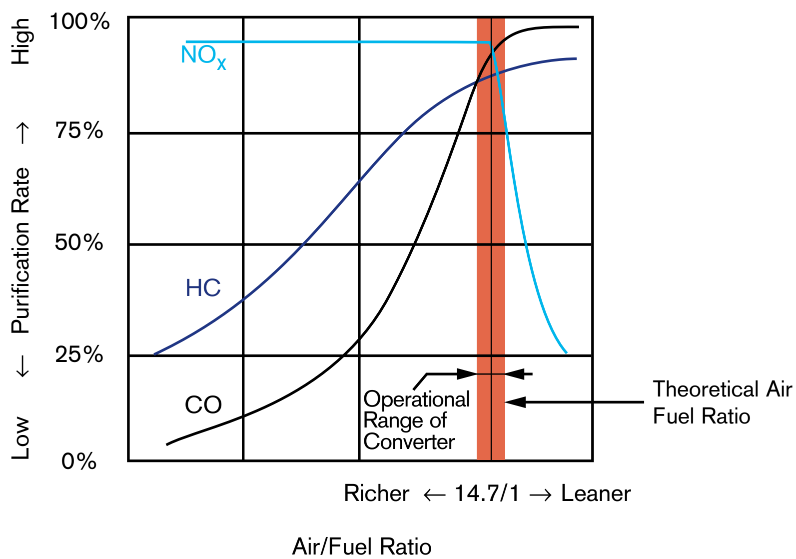


Fig. 4-38

T852f233

Stoichiometry and Catalyst Efficiency

For the catalytic converter to operate at peak efficiency, the air/fuel ratio must be at the ideal stoichiometric ratio of 14.7 parts air to one part fuel as measured by weight. This why the ECM tries to maintain a 14.7 to 1 ratio whenever possible.

Open Loop Mode

When in open loop, the ECM does not use the oxygen sensor or A/F sensor to adjust the injector duration.

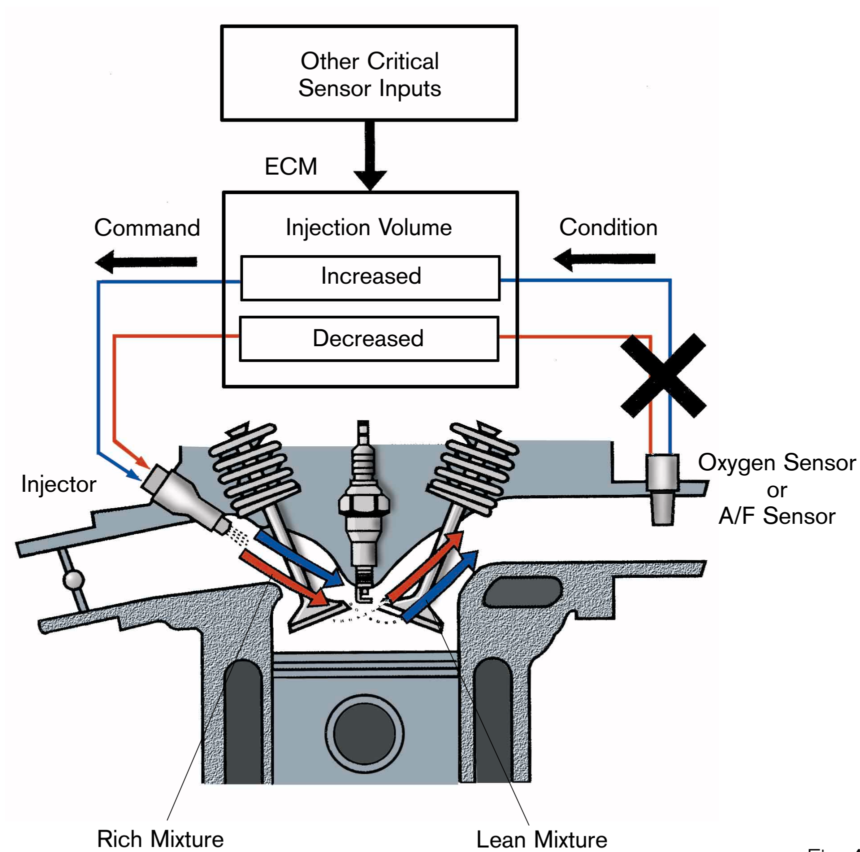


Fig. 4-39

T852f234

Open Loop Mode The ECM will be in open loop mode when:

- starting the engine.
- the engine is cold.
- hard acceleration.
- during fuel cut-off.
- wide open throttle.

If the engine will not go into closed loop mode, the problem may be insufficient engine temperature, no response from the oxygen sensor or air/fuel sensor, or the heater circuit is inoperative. Usually, no response from the oxygen or A/F sensor will set DTC P0125.

If there is a driveability problem only in closed loop, anything that disrupts air/fuel ratio, the oxygen or A/F sensor circuit may be the cause.

Closed Loop Fuel Control

Now, the ECM will adjust injector duration using the oxygen sensor or A/F sensor signal.

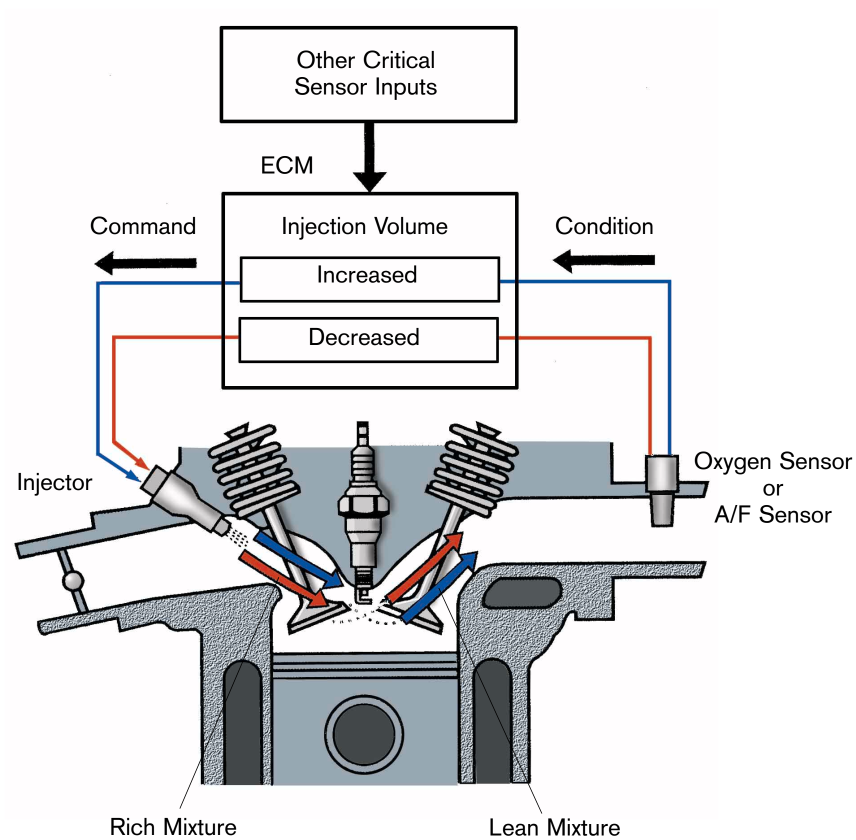


Fig. 4-40

T852f235

Closed Loop Operation/Oxygen Sensor

When in closed loop, the ECM uses the oxygen sensor voltage signal to make minor corrections to the injection duration. This is done to help the catalytic converter operate at peak efficiency.

When the voltage is higher than 450 mV, the air/fuel ratio is judged to be richer than the ideal air/fuel ratio and the amount of fuel injected is reduced at a constant rate. The reduction in the duration continues until the oxygen sensor signal switches to a low voltage (lean air/fuel ratio).

Exhaust Oxygen Content	Oxygen Sensor Output	Air/Fuel Mixture Judged To Be:
Low →	**High, Above 0.45 volts** →	**Rich**
High →	**Low, Below 0.45 volts** →	**lean**

When the voltage signal is lower than 450 mV, the air/fuel ratio is judged to be leaner than the ideal air/fuel ratio so the amount of fuel injected is increased at a constant rate. The increase in duration continues until the oxygen sensor switches to high voltage (rich air/fuel ratio). At this point, the ECM will slowly decrease the amount of fuel, therefore the air/fuel ratio oscillates slightly richer or leaner from the ideal air/fuel ratio. The result is an average of approximately 14.7:1. This produces the proper mixture of exhaust gases so that the catalytic converter operates at its most efficient level.

The frequency of this rich/lean cycle depends on exhaust flow volume (engine RPM and load), the oxygen sensor response time, and the fuel control programming. At idle, exhaust flow volume is low, and the switching frequency of the oxygen sensor is low. As engine speed increases, the switching frequency of the oxygen sensor increases, generally eight or more times at 2,500 RPM in ten seconds.

Closed Loop Operation Air/Fuel Sensor

With an A/F sensor, air/fuel mixture correction is faster and more precise. An oxygen sensor signal voltage abruptly changes at the ideal A/F ratio and changes very little as the air/fuel ratio extends beyond the ideal ratio. This makes fuel control less precise, for the ECM must gradually and in steps change the injection duration until the oxygen sensor signal abruptly switches.

By contrast, the A/F sensor outputs a voltage signal that is relatively proportional to the A/F ratio. The ECM now knows how much the A/F ratio has deviated from the ideal, and thus, the fuel control program can immediately adjust the fuel injection duration. This rapid correction reduces emission levels because the ECM can more accurately maintain the ideal air/fuel ratio for the best catalytic converter efficiency.

Therefore, when observing A/F sensor voltage output, the output is relatively constant because there is no cycling between rich and lean.

Fuel Trim

As the engine and sensors change over time, the ECM needs a method to adjust the injection duration for improved driveability and emission performance. Fuel trim is a program in the ECM designed to compensate for these changes.

When in closed loop, the ECM modifies the final injection duration based on the oxygen sensor. These minor corrections are needed to maintain the correct air/fuel ratio. However, if more correction than normal (as determined by the ECM) is needed, the ECM will use the fuel trim strategy to compensate. Fuel trim allows the ECM to learn and adjust the injection duration quickly by reducing the correction time back to normal. This means that driveability and performance will not suffer.

Fuel trim can be observed on the Diagnostic Tester as a percentage. A positive percentage means that the ECM has increased the duration and a negative percentage means the ECM has decreased the duration.

There are two different fuel trim values that affect final injection duration and can be observed by the technician; short term fuel trim (SHORT FT) and long term fuel trim (LONG FT). SHORT FT is a temporary addition or subtraction to the basic injection duration. LONG FT is part of the basic injection duration calculation and it is stored in the ECM's memory.

SHORT FT

SHORT FT is based on the oxygen sensor, and therefore, it only functions in closed loop. SHORT FT responds rapidly to changes in the oxygen sensor. If SHORT FT is varying close to 0%, little or no correction is needed. When SHORT FT percentage is positive, the ECM has added fuel by increasing the duration. A negative percentage means the ECM has subtracted fuel by decreasing the duration. The SHORT FT value is temporary and not stored when the ignition key is turned off.

SHORT FT is used to modify the long term fuel trim. When the SHORT FT remains higher or lower longer than expected, the ECM will add or subtract this value to the LONG FT.

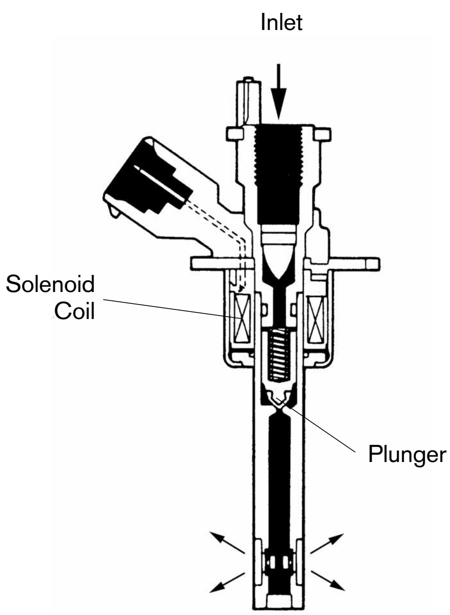
LONG FT

LONG FT is stored in memory because it is part of the basic injection duration calculation. The ECM uses the SHORT FT to modify the LONG FT. The LONG FT does not react rapidly to sudden changes, it only changes when the ECM decides to use the SHORT FT value to modify the LONG FT. LONG FT is stored in the ECM's memory and it is not erased when the ignition key is turned off. Because LONG FT is part of the basic injection duration, it affects injection duration in closed and open loop. Like the SHORT FT, when LONG FT is at 0% there has been no modification to the basic injection duration. A positive percentage means the ECM is adding fuel; a negative percentage, subtracting fuel.

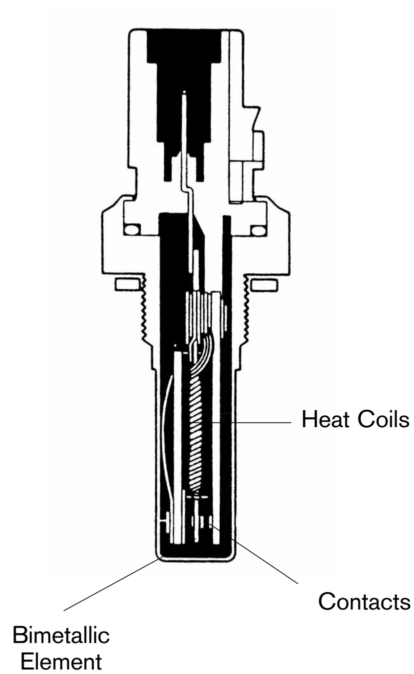
Fuel System Monitor

The fuel system monitor is designed to set a DTC if the fuel injection system is going to exceed emission standards. This monitor uses the fuel trim correction levels for detection. The amount of fuel trim correction that will set a DTC varies with each engine type and model year.

Cold Start Injector and Time Switch



Injector



Time Switch

Fig. 4-42

T852f236/T852f237

Cold Start Injector System

Cold start injector systems are no longer used, but they were very common for many years. The function of the cold start injector is to maintain engine startability when the engine is cold. This injector operates only during cranking when the coolant temperature is low. The function of the start injector time switch is to control the maximum injection duration of the cold start injector.

Non-ECM Controlled Cold Start Timer Circuit

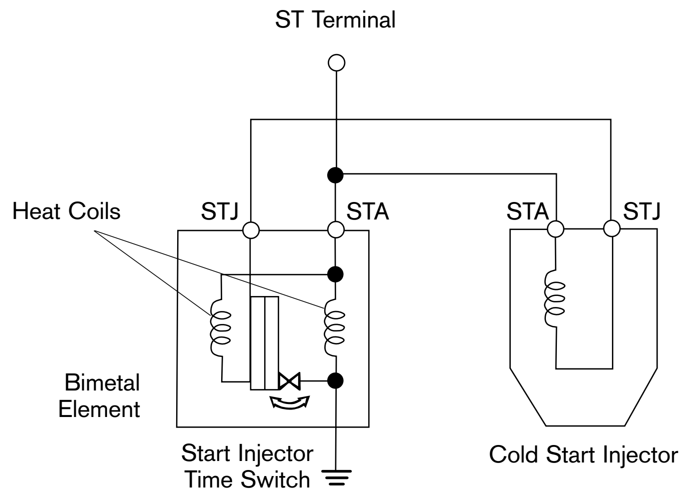


Fig. 4-43

T852f238

Non-ECM Controlled Cold Start Circuit

When the engine is cranked while the engine coolant temperature is low, the duration of cold start injector operation is controlled by the start injector time switch. When the bimetal contacts are closed, current flows through the cold start injector. Simultaneously, current is flowing through the heat coils. Heat will flex the bimetal element opening the contacts. The length of time depends on engine temperature.

Cold Start Injector Duration

Duration is determined by engine coolant temperature. ON or OFF depending on engine model.

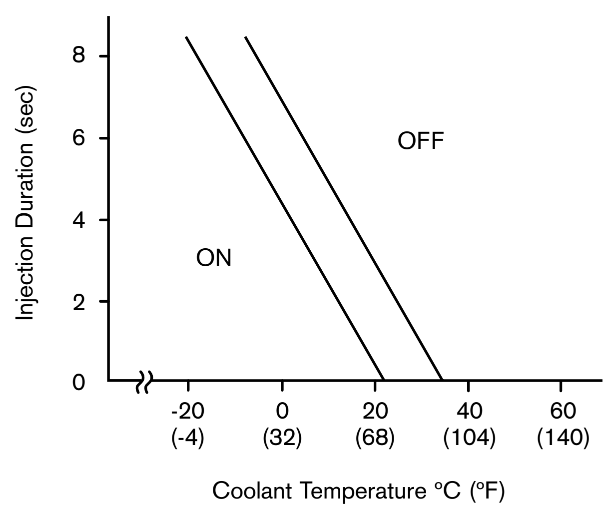


Fig. 4-44

T852f239

Callout

ECM Controlled Cold Start Injector System

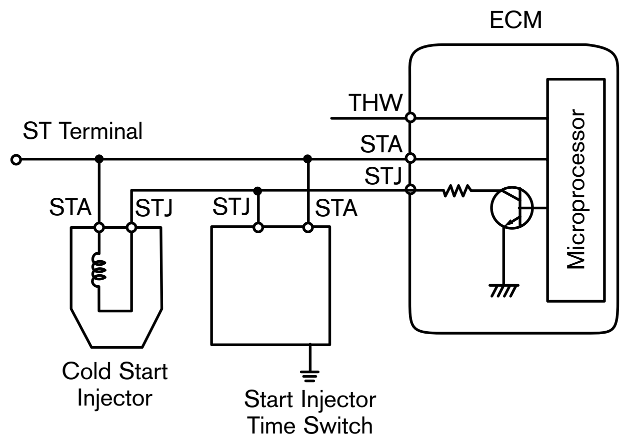
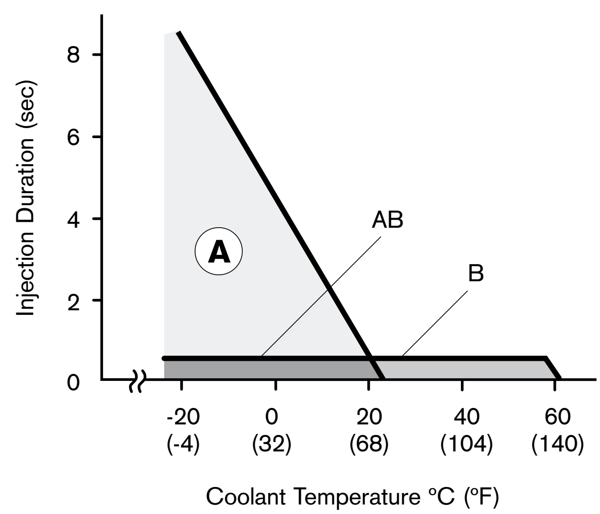


Fig. 4-45
T852f2240

ECM Controlled Cold Start Injector System In order to improve startability when the engine is cold, the injection duration of the cold start injector is controlled not only by the injector time switch but also by the ECM in accordance with the coolant temperature.

ECM and Injector Time Switch

Control of the injection duration of the cold start injector continues to be carried out by the start injector time switch, as shown by shaded area A, but control is also exercised by the ECM, as shown by shaded area B.



A: Controlled By Start Injector Time Switch
B: Controlled By ECM
A,B: Controlled By Start Injector Time Switch and ECM

Fig. 4-46
T852f241

Notes

WORKSHEET 4–1
Fuel Delivery System

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test fuel delivery systems using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set

Section 1

Testing Fuel Delivery System

1. Using a copy of the EWD/RM electrical circuit for the fuel pump, trace the power flow with a marker. Use orange for power side, green/yellow for ground.

2. What relay activates the fuel pump?

3. Is the relay supply side or ground side switched?

4. What fuse(s) feed the fuel pump circuit?

Section 2

1. According to the Repair Manual, use Active Test on the DT to operate the fuel pump. What component can be used to indicate fuel pressure?

2. How could the fuel pump be operated without the DT?

3. What is the recommended method for depressurizing the system?

Section 3

1. On three speed fuel pumps, what signal does the ECM use to vary fuel pump speed? What is the voltage signal level for low, medium, and high?

____

Section 4

Using the Repair Manual and Technician Handbook, answer the following questions.

1. A disconnected hose on a vacuum modulated pressure regulator will cause fuel pressure to:

____

2. If the fuel has no residual fuel pressure, list three possible causes.

____

3. If fuel pressure is too high, list two possible causes:

____

4. List four causes of low fuel pressure.

____

5. If there is no fuel pressure, list six possible causes for this condition.

____

6. List five symptoms lower than normal fuel pressure will have on driveability.

____

Fuel Delivery System

Name ______________________________ Date ______________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the fuel delivery system using the EWD and RM			
Find wire colors, pin numbers in the fuel delivery electrical circuits using the EWD and RM			
Locate the Fuel Pump status in the Data List and compare to specifications to determine condition			
Activate fuel pump with Active Test			
Activate fuel pump using test leads			
Test fuel pump and compare to specifications to determine condition			
Test fuel system pressure and compare to specifications to determine condition			
Test fuel pump relay/ECU and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Properly disconnect and reconnect fuel lines			
Locate in the RM three sections related to fuel delivery system concerns			

Notes

WORKSHEET 4–2
Fuel Injector Systems

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test fuel injection systems using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual & EWD
- Diagnostic Tester & Noid Light
- Hand Tool Set
- Vehicle

Section 1

1. Connect a DT to a vehicle, measure injector pulsewidth and MAF/MAP output with DT using Data List.

Diagnostic Tester	Pulsewidth at Idle	2000 RPM	In Drive at Idle (prk brk set, foot on brake)	In Drive at 1500 RPM (prk brk set, foot on brake)
Fuel Injector Pulsewidth				
MAF/MAP Output				

2. Compare MAF/MAP output to injector pulsewidth. What is your conclusion?

____

Section 2

1. According to the Repair Manual, display the injector waveform on the oscilloscope.

____

2. Does the waveform match the Repair Manual waveform?

____

3. Draw or print the waveform.

IDLE

In Drive at 1500 RPM (prkbrkset, foot on brake)

4. Identify on the waveform injector on time and when the injector is turned off.

Section 3

1. Connect a noid light. Crank the engine. What did the noid light do?

2. Disconnect the crank sensor. Crank the engine. What did the noid light do? Why?

3. Measure injector coil resistance? specifications

4. An open injector coil may set DTC

Section 4

1. List five symptoms a failed injector will have on driveability.

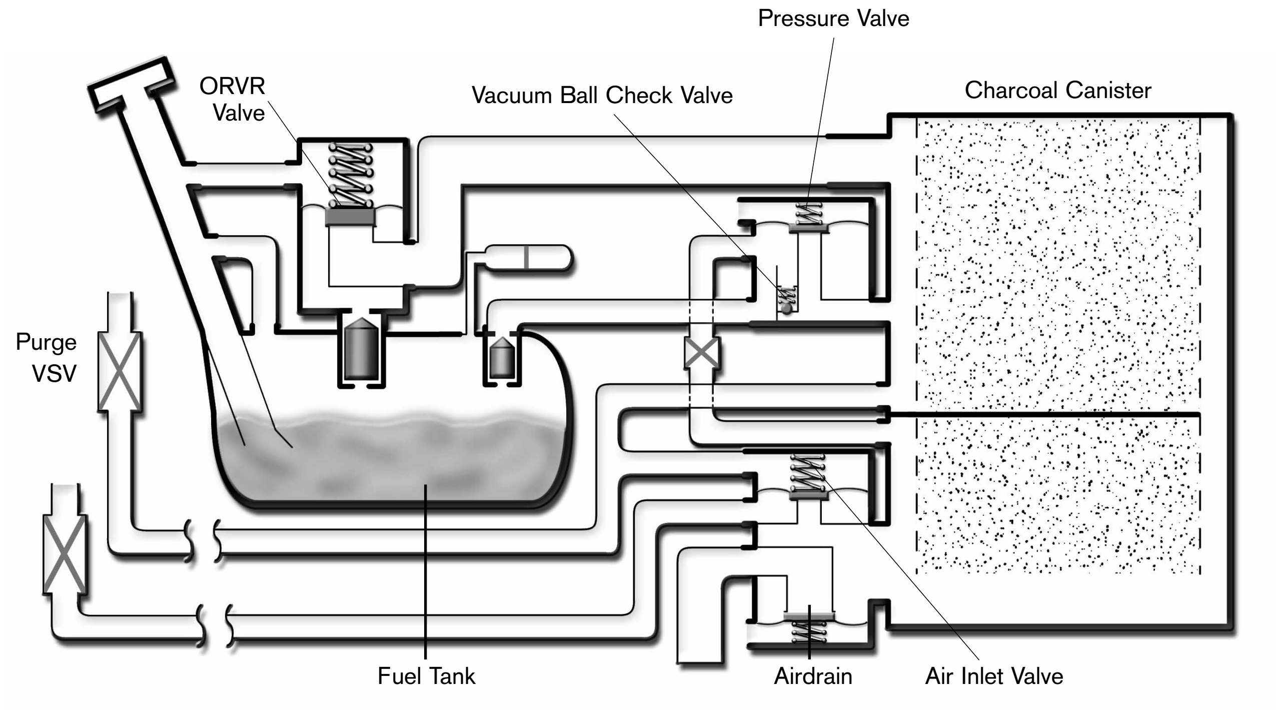
Fuel Injector Systems

Name ______________________________ Date ________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the fuel injection system using the EWD and RM			
Find wire colors, pin numbers in the fuel injection electrical circuits using the EWD and RM			
Locate the Injector on time in the Data List and compare to specifications to determine condition			
Measure injector pulsewidth with DT			
Examine injector pattern with oscilloscope			
Test injector coil resistance and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Properly remove and install fuel injectors			
Locate in the RM three sections related to fuel injection system concerns			

Evaporative Emission Control Systems



Lesson Objectives

1. Determine the condition of the EVAP system operation based on engine data
2. Determine the condition of the EGR system based on engine data
3. Determine the root cause of a failure(s) in the EGR system using appropriate diagnostic procedures

Notes

EMISSION SYSTEMS

Evaporative Emissions Control Systems

Approximately 20% of all hydrocarbon (HC) emissions from the automobile originate from evaporative sources. The Evaporative Emission Control (EVAP) system is designed to store and dispose of fuel vapors normally created in the fuel system and prevent their escape to the atmosphere.

The EVAP system is a fully closed system designed to maintain stable fuel tank pressures without allowing fuel vapors to escape to the atmosphere. Fuel vapor is normally created as fuel temperature rises. It is then transferred to the EVAP system charcoal canister as tank vapor increases. When the engine can tolerate additional enrichment, these stored fuel vapors are purged into the intake manifold and added to the incoming air/fuel mixture.

There are two basic types of evaporative emission control systems: **Non-ECM controlled EVAP systems** use solely mechanical control devices to collect and purge stored fuel vapors. Typically, these systems use a ported vacuum purge port and a Thermo Vacuum Valve (TVV) to prohibit cold engine operation.

ECM controlled EVAP systems use a manifold vacuum purge source in conjunction with a duty cycled Vacuum Switching Valve (VSV). This type of EVAP system has the ability to provide more precise control of purge flow volume and inhibit operation. This is the only type on current models.

Non-ECM Controlled EVAP System

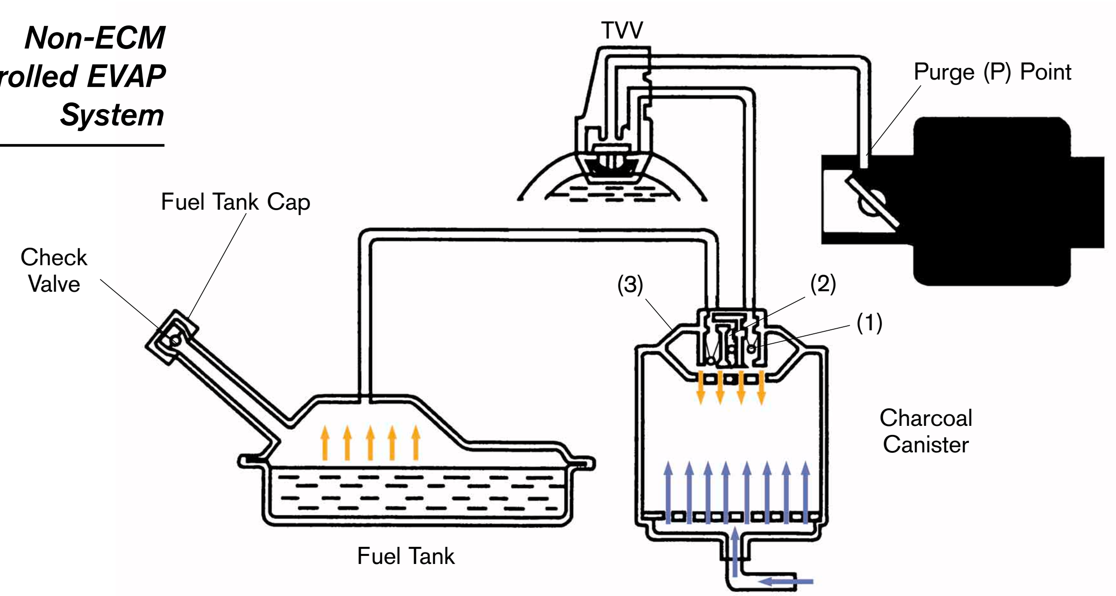


Fig. 5-01

T852f242

Non-ECM Controlled EVAP Systems

Non-ECM controlled EVAP systems typically use the following components:

- Fuel tank.
- Fuel tank cap (with vacuum check valve).
- Charcoal canister (with vacuum & pressure check valves).
- Thermo Vacuum Valve (TVV).
- Ported vacuum purge port (port P; on throttle body).

Under some conditions, the fuel tank operates under a slight pressure to reduce the possibility of pump cavitation due to fuel vaporization. Pressure is created by unused fuel returning to the tank and is maintained by check valve No. 2 in the charcoal canister and the check valve in the fuel tank cap.

Under other conditions; as fuel is drawn from the tank, a vacuum can be created in the tank causing it to collapse. This is prevented by allowing atmospheric pressure to enter the tank through check valve No. 3 in the charcoal canister or the fuel tank cap check valve. The EVAP system is designed to limit maximum vacuum and pressure in the fuel tank in this manner.

When the engine is running, stored fuel vapors are purged from the canister whenever the throttle has opened past the purge port (port P) and coolant temperature is above a certain point (usually around 54°C (129°F)). Fuel vapors flow from the high pressure area in the canister, past check valve No.1 in the canister, through the Thermo Vacuum Valve (TVV), to the low pressure area in the throttle body. Atmospheric pressure is allowed into the canister through a filter located on the bottom of the canister. This ensures that purge flow is constantly maintained whenever purge vacuum is applied to the canister. When coolant temperature falls below a certain point–usually around 35°C (95°F), the TVV prevents purge from taking place by blocking the vacuum signal to check valve No.1.

ECM Controlled EVAP System

The Purge VSV is duty ratio controlled by the ECM.

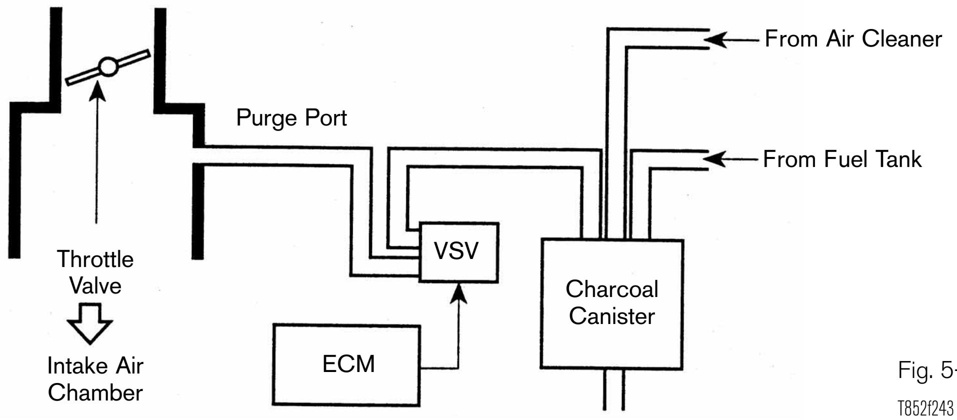


Fig. 5-02

ECM Controlled EVAP Systems

ECM controlled EVAP systems were introduced to provide a more precise control and maintain driveability. The ECM will adjust the fuel injection duration based on oxygen sensor or air/fuel ratio sensor signal.

ECM controlled EVAP systems typically use the following components:

- Fuel tank.
- Fuel tank cap (with vacuum check valve).
- Charcoal canister (with vacuum & pressure check valves).
- Purge VSV (manifold vacuum purge port).
- Early ECM EVAP systems used a ported vacuum purge port with in-line check valve (port A; on throttle body).

When the engine has reached predetermined parameters (closed loop, engine temp. above 52°C (125°F), stored fuel vapors are purged from the canister whenever the purge VSV is opened by the ECM. At the appropriate time, the ECM will turn on the purge VSV. This will allow the low pressure in the intake manifold to draw the fuel vapors out of the charcoal canister. The vapors will then be burned in the combustion chamber.

The ECM will change the duty ratio cycle of the purge VSV thus controlling purge flow volume. Purge flow volume is determined by manifold pressure and the duty ratio cycle of the purge VSV. Atmospheric pressure is allowed into the canister to ensure that purge flow is constantly maintained whenever purge vacuum is applied to the canister.

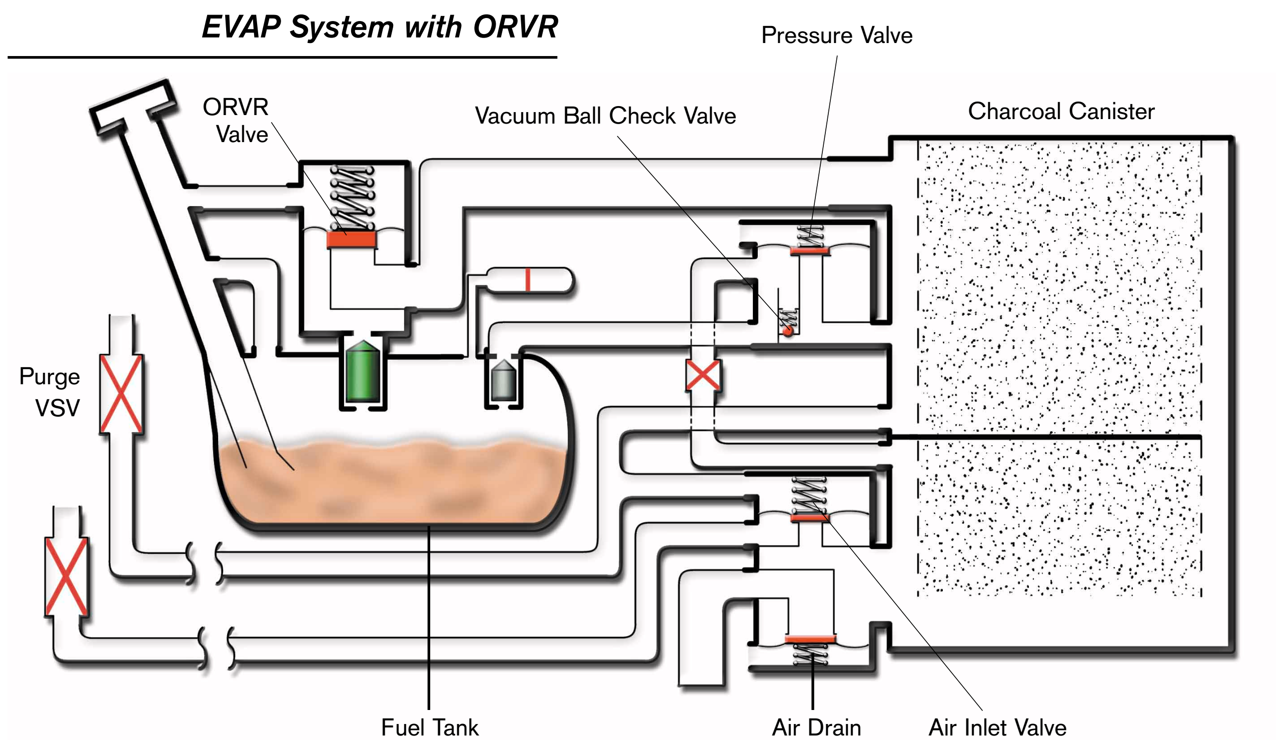


Fig. 5-03

Condition	Purge Port	Air Inlet Valve	Tank Vacuum Ball Check	Tank Pressure Port	Fill Check Valve	Air Drain
VSV Purge Valve On	OPEN (V)	OPEN (V)	CLOSED	CLOSED	CLOSED	CLOSED
VSV Purge Valve Off	CLOSED (NV)	CLOSED (NV)	CLOSED	CLOSED	CLOSED	CLOSED
Pressure In Tank	CLOSED	CLOSED	CLOSED	OPEN	CLOSED	CLOSED
Vacuum In Tank			OPEN	CLOSED	CLOSED	CLOSED
Refill			CLOSED	CLOSED	OPEN	OPEN

Charcoal Canister The charcoal canister is filled with activated charcoal. This charcoal has the ability to absorb gasoline vapors and release these vapors when fresh air passes through the canister. Mounted on the charcoal canister are check valves to control vapor flow. The table on the previous page shows the action of each valve according to engine operation and fuel tank conditions.

Pressure in Fuel Tank

Fuel vapor pressure is vented into the charcoal canister when vapor pressure forces the tank pressure control valve open.

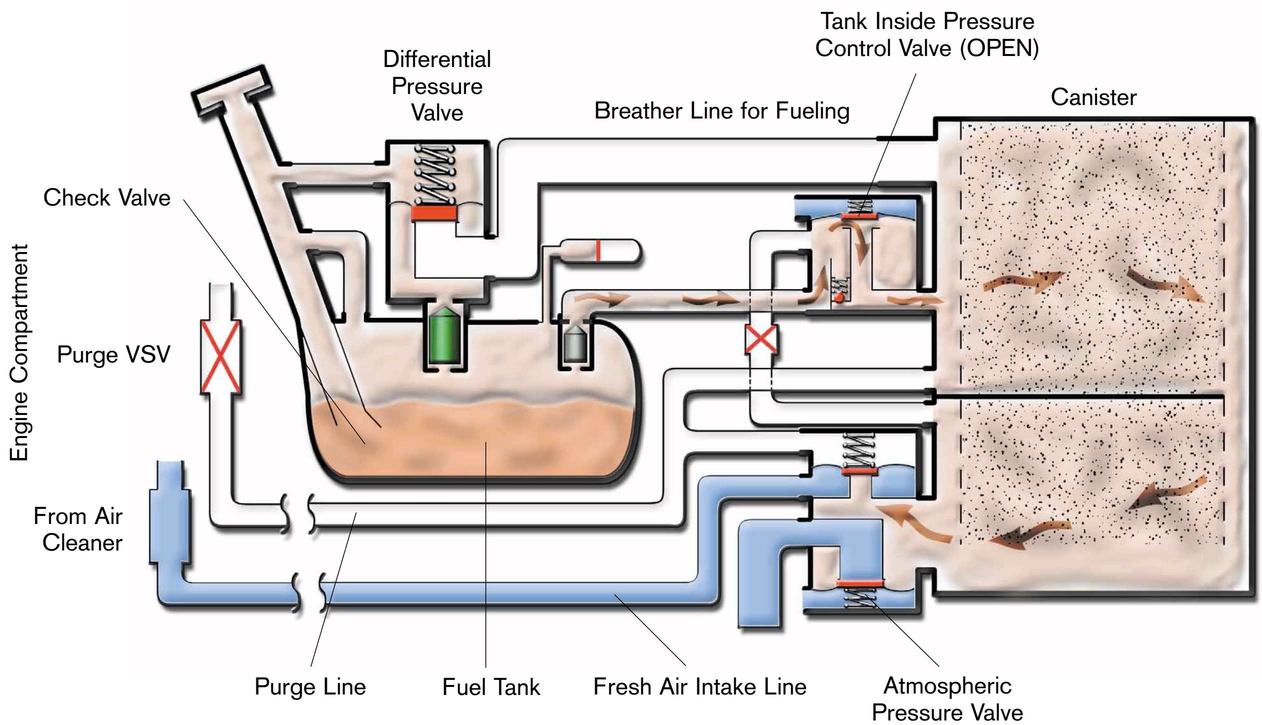
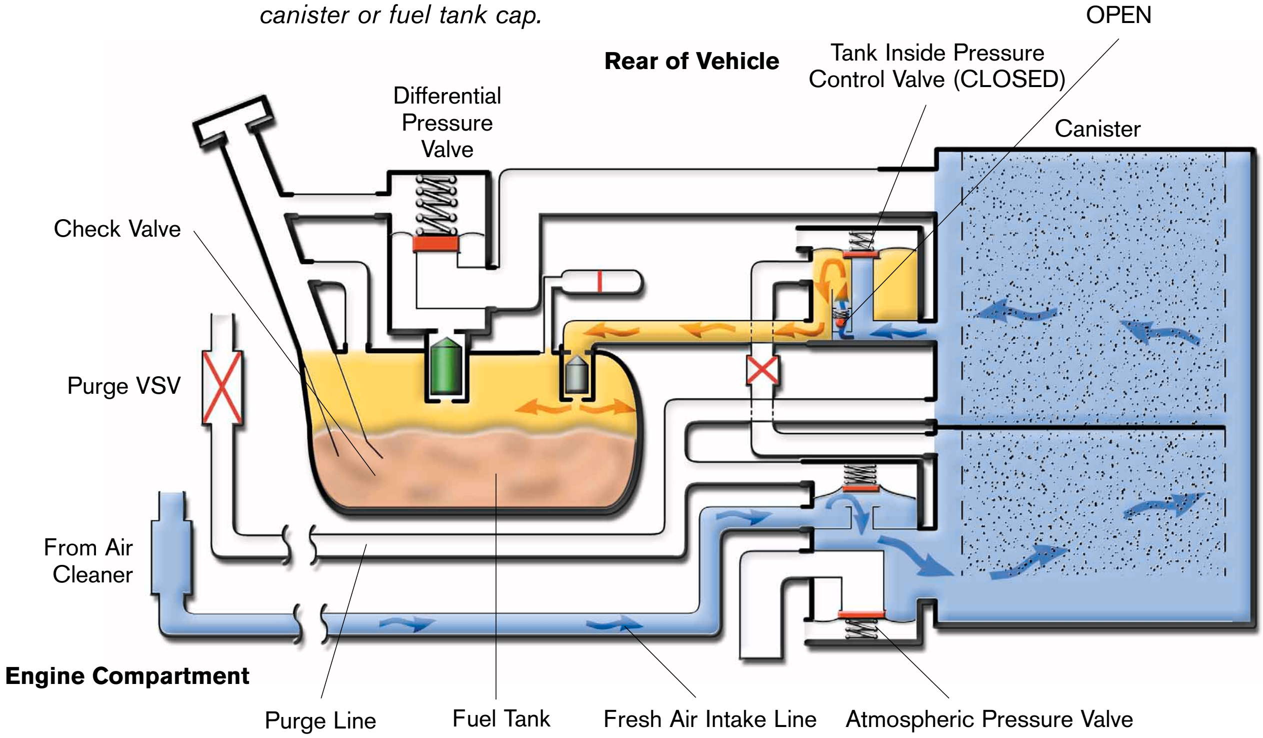


Fig. 5-04

T852f245

Vacuum in Fuel Tank

Vacuum in the tank can be relieved by allowing air to enter through the charcoal canister or fuel tank cap.



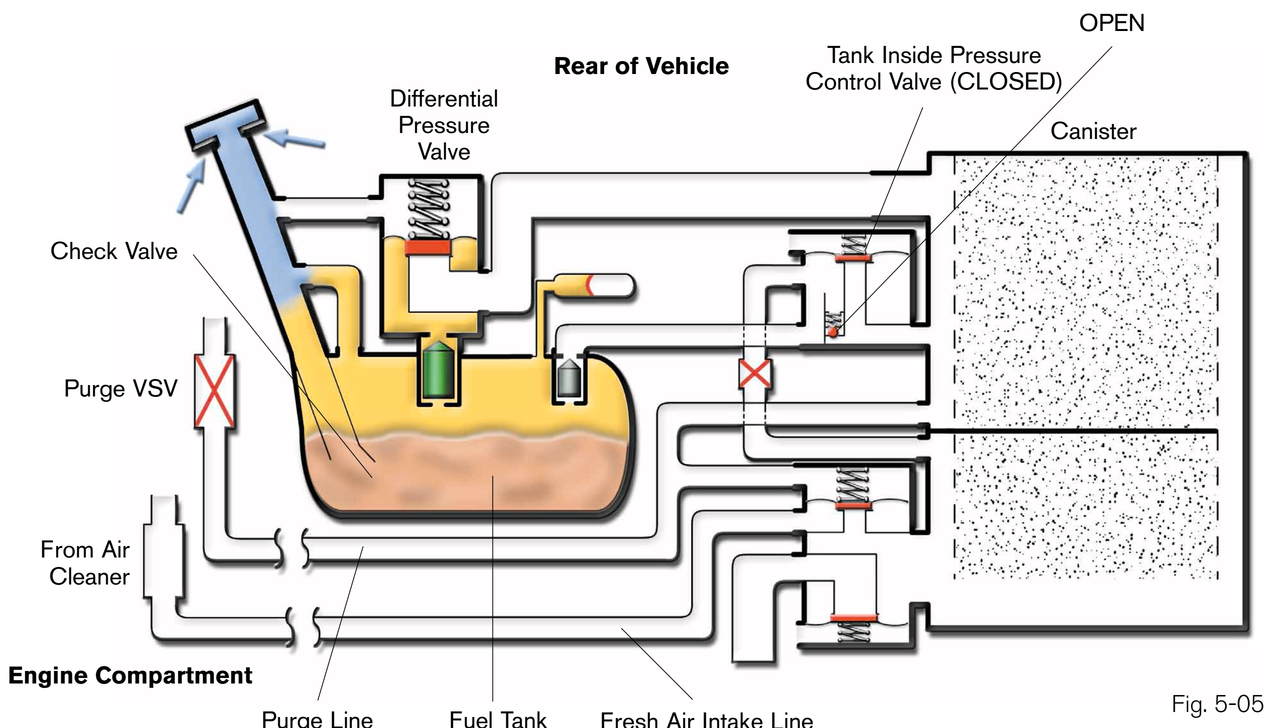


Fig. 5-05

T852f246/T852f334

Purge Mode

During purge, vapors are drawn out of canister and burned in the engine.

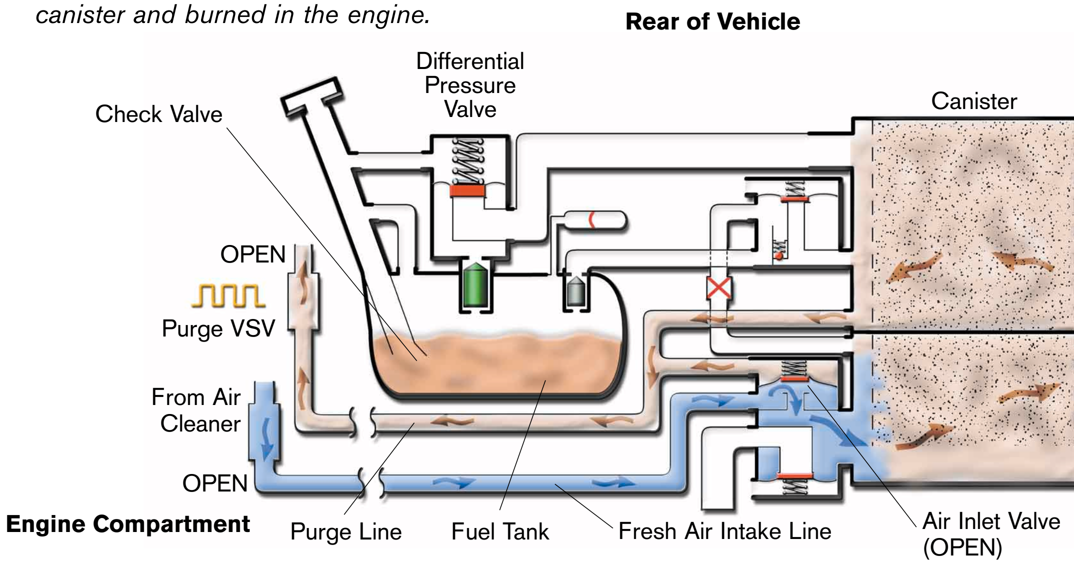


Fig. 5-06

T852f247

Refueling Mode

During refueling, the differential pressure valve and air drain valve are open. Fuel vapors are absorbed by the charcoal canister and excess air is vented to the atmosphere.

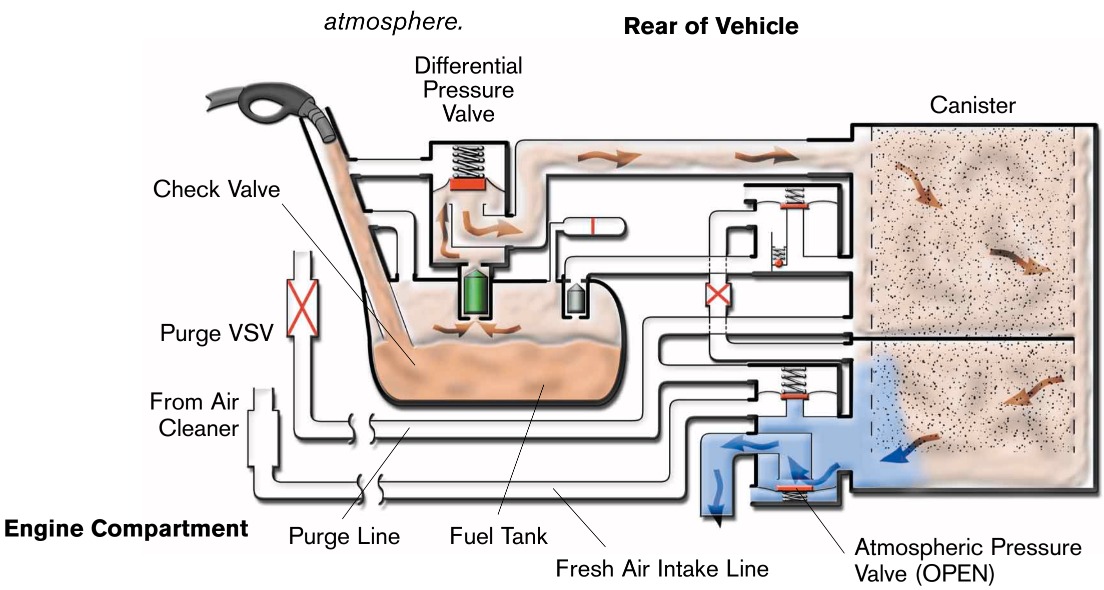


Fig. 5-07

T852f248

EVAP System Service

There is no routine maintenance for the EVAP system. It is critical that the proper diameter hoses and parts are used. Failure to do so can result in driveability problems. There are diagnostic procedures for checking the valves listed in the Repair Manual.

Exhaust Gas Recirculation System

The Exhaust Gas Recirculation (EGR) system is used for reducing oxides of nitrogen and for engine knock control. By recirculating a controlled amount of exhaust gases into the intake air-fuel mixture, combustion temperature is lowered. This, in turn, reduces the amount of NO_X emission.

Basic EGR System

Exhaust gases are directed to the intake manifold to lower oxides of nitrogen emissions.

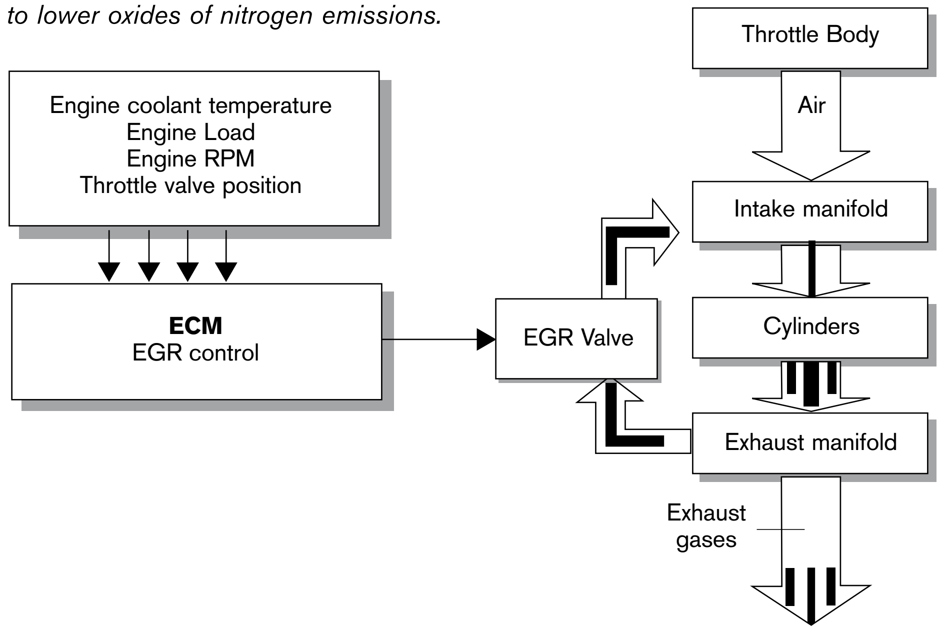


Fig. 5-08

T852f249

EGR Valve

When the EGR valve opens, exhaust gasses enter the intake manifold.

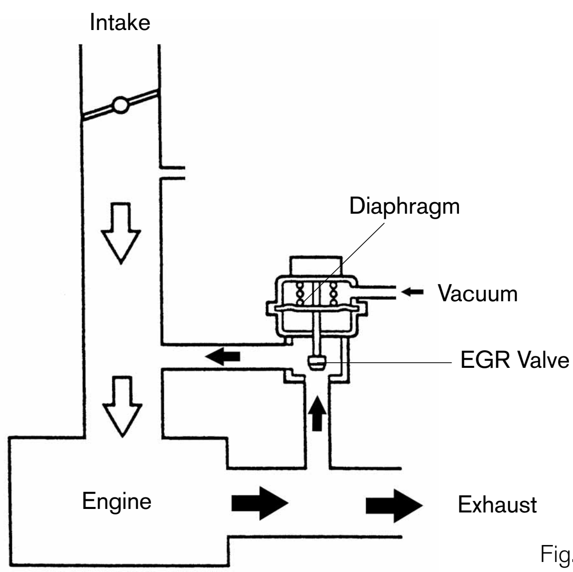


Fig. 5-09

T852f250

EGR Valve

Also, the exhaust gases help prevent engine knock and allow for more advanced ignition timing.

The EGR valve opens and closes the passage between the exhaust manifold and intake manifold. Vacuum is used to move the EGR valves.

Inside the vacuum actuated EGR valve is a valve, diaphragm, and spring. When vacuum is applied to the diaphragm the diaphragm lifts the valve off its seat allowing exhaust gases into the intake air stream. When vacuum is removed the spring forces the diaphragm and valve downward closing the exhaust passage.

For proper engine operation, the EGR valve must open to the proper height, and when closed seal the intake manifold from exhaust gases.

CAUTION The EGR valve can get very hot. Handle with care.

Cut-Off Control EGR System

EGR Operating (VSV OFF)

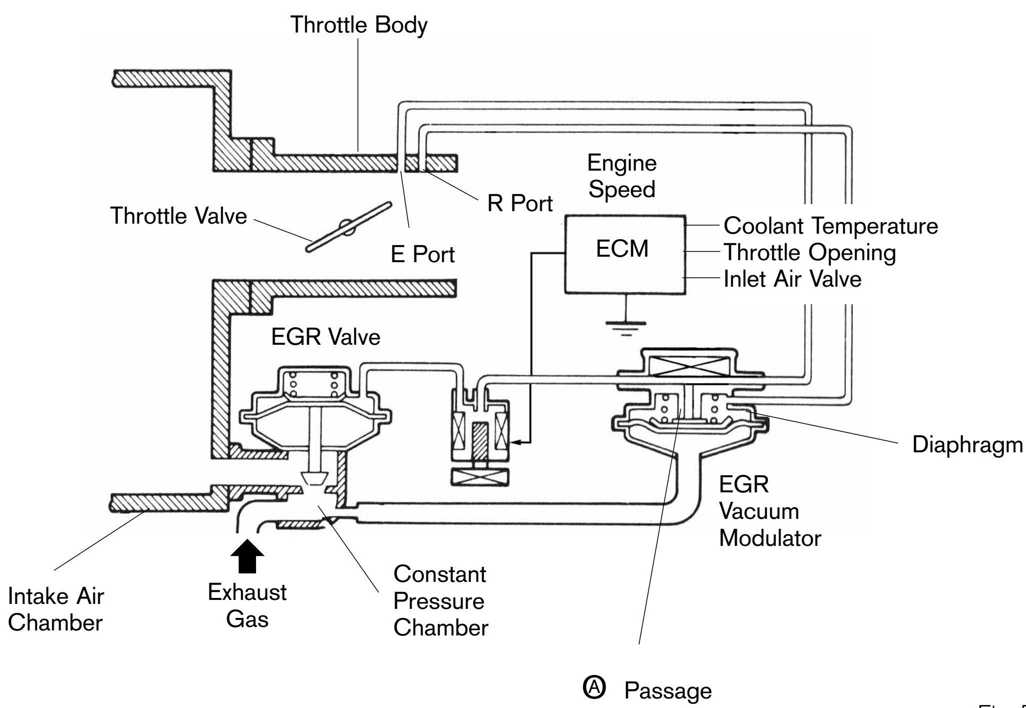


Fig. 5-10

T852f251

Cut-Off Control EGR System Operation

Some EGR valve's are water cooled and this is done to cool the exhaust gases. Cooling the exhaust gases increases the exhaust gases effectiveness in reducing NO_X and engine knock.

In the Cutoff Control EGR system, the amount of exhaust gas to be recirculated is controlled by the EGR vacuum modulator. The EGR modulator is needed because of the changes in engine vacuum and exhaust backpressure. The vacuum available at ports E and R changes with throttle opening. As the throttle valve opens and intake air volume/speed increases, the vacuum signals from ports E and R increases. As engine load increases the amount of exhaust backpressure increases.

For the above reasons, an EGR vacuum modulator controls the amount of vacuum reaching the EGR valve lifting the EGR valve to the correct height.

As determined by the ECM, the EGR VSV is closed to atmospheric pressure allowing the modulated vacuum to reach the EGR valve.

EGR Signal Logic Table

Port	Throttle Valve Opening	Vacuum Signal
E	Position Less than E Port	No Vacuum Present
E	Position More than E Port	Near Manifold Vacuum
R	Position Less than R Port	No Vacuum Present
R	Position More than R Port	Near Manifold Vacuum

Fig. 5-11

EGR Cut-Off

When the EGR VSV is on, the vacuum line is open to atmosphere, preventing the EGR from opening.

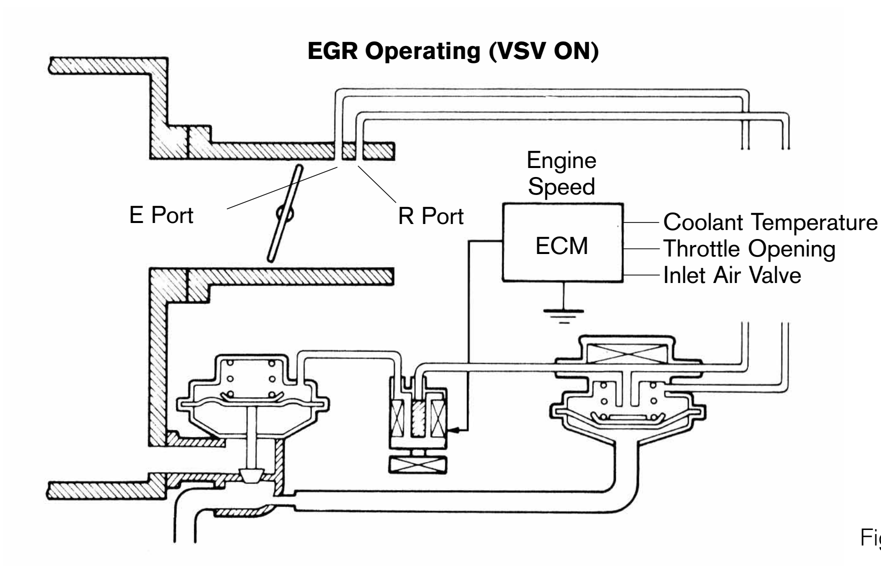


Fig. 5-12

T852f252

EGR Cut-Off Operation

To close the EGR valve, the VSV is turned on by a signal from the ECM. This opens the vacuum line to atmospheric pressure closing the EGR valve and shutting off the exhaust gas flow. This is done when EGR is not needed and to maintain driveability. This operation (EGR cut-off) is implemented when the following conditions exist:

- Coolant temperature below 57°C (134°F).
- During deceleration (throttle valve closed).
- Light engine load (amount of intake air very small).
- Engine speed approximately 4000 RPM or more.
- Engine racing (neutral start switch turned on).

EGR Gas Flow

Variations in exhaust pressure.

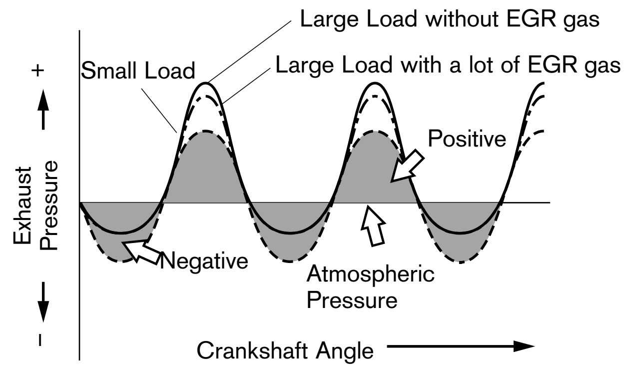


Fig. 5-13
T852f253

EGR Vacuum Modulator

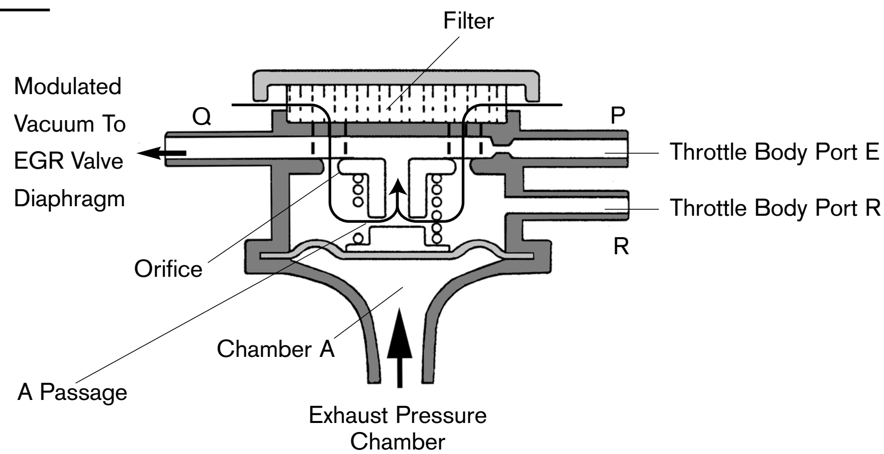


Fig. 5-14
T852f254

EGR Vacuum Modulator

The exhaust gas pressure increases in proportion to the amount of intake air. As the throttle valve opens and the amount of intake air volume increases, a higher exhaust gas pressure is applied to the constant pressure chamber of the EGR vacuum modulator. It pushes the diaphragm of the EGR vacuum modulator upward to narrow the "A" passage. Since vacuum acts then on the E and R ports of the throttle body, the vacuum is modulated by the size of the "A" passage. This modulated vacuum causes the EGR valve to open, which, in turn, allows exhaust gas into the intake manifold. This also causes the gas pressure inside the exhaust pressure chamber to go down, which in turn, lowers the EGR vacuum modulator diaphragm.

The EGR valve is now under less vacuum and the valve moves until the vacuum balances with the spring tension and the amount of EGR gas is regulated. Therefore, the amount of EGR is regulated according to the exhaust gas pressure and the vacuum signal strength.

Constant Vacuum System

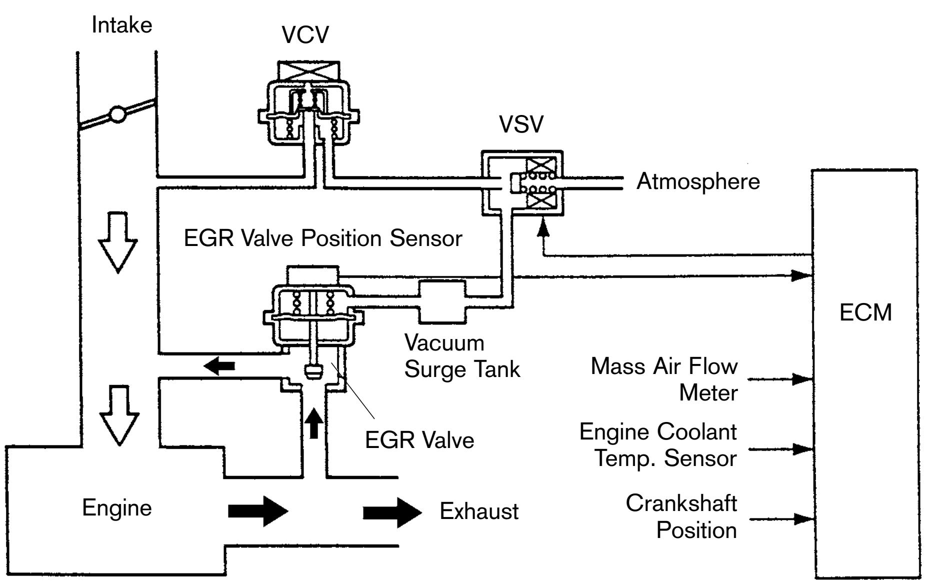


Fig. 5-15

T852f255

Constant Vacuum System Operation

This type of ECM EGR controlled system uses a Vacuum Control Valve (VCV), an EGR VSV, and an EGR valve position sensor to regulate exhaust gas flow.

Vacuum Control Valve (VCV)

When diagnosing the VCV, remember that the vacuum output is very low. An accurate vacuum gauge is needed.

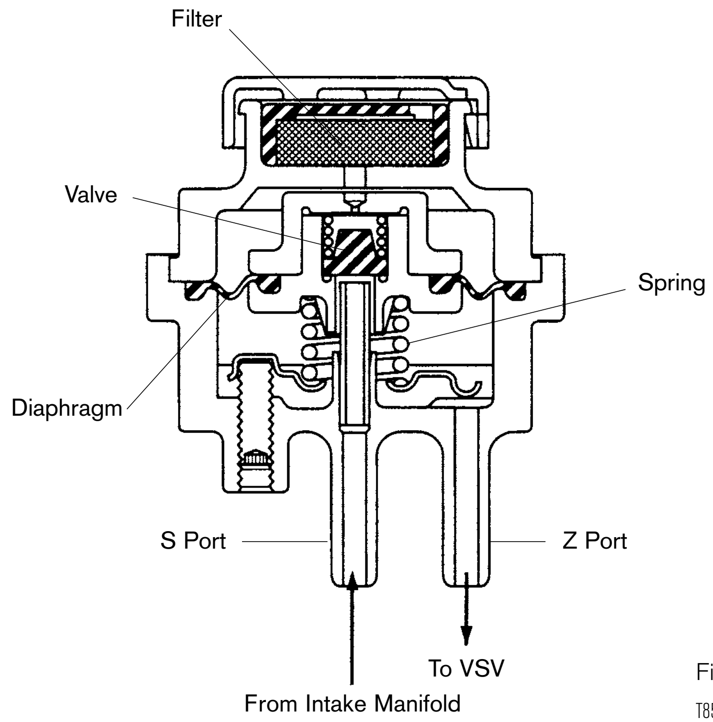


Fig. 5-16

T852f256

Vacuum Control Valve (VCV)

The VCV is a valve that regulates the intake manifold vacuum applied to the VSV to a constant level (-17 kPa, -l30 mmHg, -5 inHg).

The intake manifold vacuum that is supplied through the S port is applied to the diaphragm. If this force becomes greater than the spring force, the diaphragm moves downward allowing the valve to close the S port and the atmosphere supplied through the filter.

Conversely, if the vacuum that is applied to the diaphragm becomes weaker, the diaphragm moves upward causing the valve to open and to shut off the atmosphere and supply the intake manifold vacuum. This process is repeated to regulate the vacuum in the Z port to a constant level.

EGR Valve Position Sensor

This sensor measures EGR valve height.

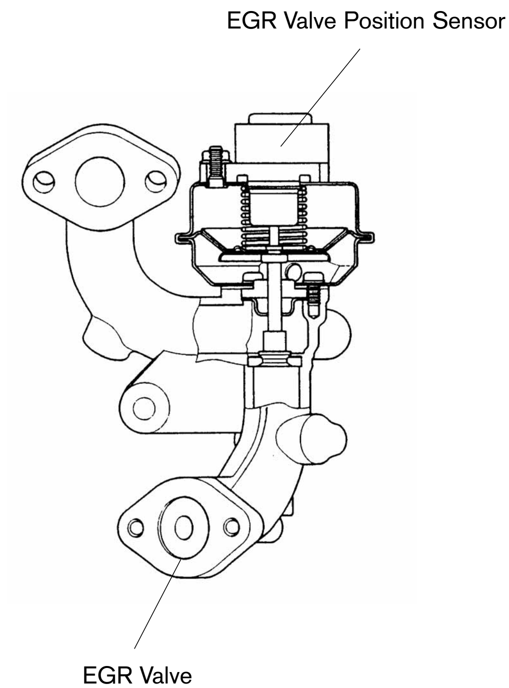


Fig. 5-17

T852f056

EGR Valve Position Sensor

The EGR valve position sensor is a potentiometer sensor mounted on the EGR valve. The EGR valve and signal arm in the position sensor move together. As the EGR valve opens, the voltage signal of the EGR valve position sensor increases.

EGR VSV

The EGR VSV is a three way VSV. When the VSV is off, atmospheric pressure is applied to the EGR valve keeping the valve closed. When the engine has reached the appropriate conditions, the ECM will turn on the EGR VSV applying vacuum to the EGR valve.

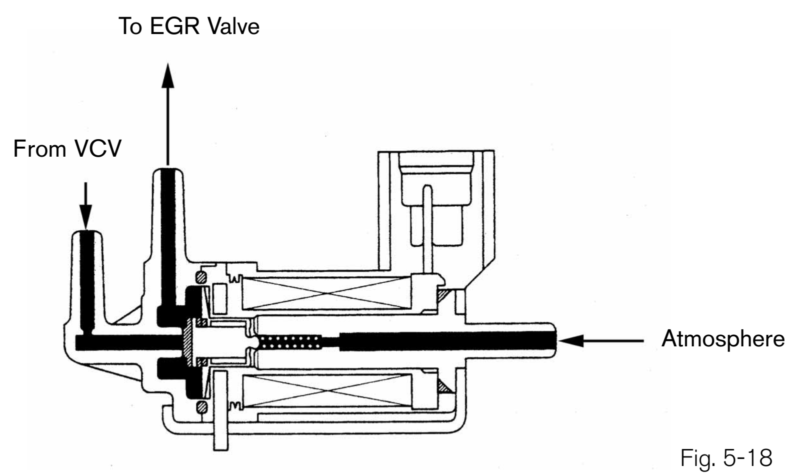


Fig. 5-18

T852f257

Operation

The ECM uses the EGR valve position sensor signal to control EGR valve position height and to detect excessive EGR flow. EGR valve height is controlled by the strength of the vacuum signal and the ECM controls vacuum signal strength by varying the pulsewidth signal sent to the EGR VSV. If greater EGR flow is needed, the ECM increases the pulsewidth signal to the EGR VSV. This applies more vacuum to the EGR valve.

Under the following conditions the ECM turns off the VSV and closes the EGR valve:

- Coolant temperature below 57°C (134°F).
- During deceleration (throttle valve closed).
- Light engine load (amount of intake air very small).
- Engine speed approximately ≈ 4000 rpm or more.
- Engine idling.

WORKSHEET 5–1
EVAP Systems

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test EVAP systems using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual & Vehicle EWD
- Diagnostic Tester
- Hand Tool Set
- Vacuum Gauge

Section 1

EVAP Identification

Use the Repair Manual and Technician Handbook to answer the following questions on the vehicle you are working on.

1. Is the EVAP system the Intrusive or Non-Intrusive type?

   ____

2. Is the EVAP system equipped with the ORVR system?

   ____

3. Identify on the canister the tank valve assembly.
4. Identify on the canister the air inlet valve assembly.
5. If equipped, identify the ORVR vent line.

Section 2

Purge VSV Operation

1. Select ACTIVE TEST.
2. Set to EVAP VSV and turn the VSV ON using the left and right arrow keys.
3. Disconnect the purge hose from the canister side of the purge VSV and listen for a duty cycle pulsing sound from the VSV.

4. If a pulsing sound is heard, will vacuum be present at the purge hose?

____

5. Turn the purge VSV OFF using the left and right arrow keys. Check for vacuum on the VSV with a vacuum gauge. If vacuum is present, the purge VSV is

____

Note: If a purge valve were stuck, open or closed, the following steps are recommended:

1. If the valve is stuck open or closed, this could be the result of active charcoal contamination or metal flakes from manufacturing inside the purge VSV.
2. If charcoal is found in the purge lines, all hoses must be cleaned of charcoal and the canister and purge VSV must be replaced.
3. If metal is found in the purge VSV, blow the metal lines out between canister and engine and replace the VSV.

Section 3

Vapor Pressure Sensor

1. Refer to SF section in the Repair Manual on vapor pressure sensor inspection.
2. Turn the ignition switch ON.
3. Disconnect the vacuum hose (the one connected to EVAP pressure).
4. Connect a voltmeter to terminals PTNK and E2. According to the RM, measure the voltage under specified conditions.

Condition	Applied Pressure	PTNK Voltage
Below Atmospheric Pressure		
Atmospheric Pressure		
Above Atmospheric Pressure		

As pressure increase, voltage increases. ___________

5. Predict the PTNK signal voltage if the PTNK wire were to become disconnected. Voltage will

____

6. Disconnect the vps electrical connector.
7. Record the voltage between PTNK and E2 terminals at the ECM: ___________
8. Why did this happen?

____

____

EVAP Systems

Name ______________________________________ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the EVAP system using the EWD and RM			
Find wire colors, pin numbers in the EVAP electrical circuits using the EWD and RM			
Visually inspect tank, fuel cap, lines, canister			
Activate purge VSV with Active Test			
Test purge VSV and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Locate in the RM three sections related to EVAP system concerns			
Test vapor pressure sensor			

Notes

WORKSHEET 5–2
EGR Cutoff Control System

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test the EGR cutoff control system using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set
- Vacuum pump with gauge

Section 1

Component Tests

VSV Component Check

1. Connect a DVOM to the EGR VSV terminal at the ECM.
2. According to the Repair Manual, perform the Inspect VSV operation test procedure. Test procedure and specifications are found in what section?

   ____

3. When the engine is cold, does the EGR valve have vacuum applied to it?

Circle the correct words in the following statements.

4. When cold, the EGR VSV is **ON/OFF** and **OPEN/CLOSED** to atmosphere.
5. When the EGR valve is open, the EGR VSV is **ON/OFF** and **OPEN/CLOSED** to atmosphere.

EGR Vacuum Modulator

1. Check the EGR Vacuum Modulator according to the Repair Manual.
2. With the engine OFF and Ports P and R blocked, should air pass freely from Port Q to atmosphere?

   Why? ____

3. With the engine ON and Ports P and R blocked, should air pass freely from Port Q to atmosphere?

   Why? ____

4. If the atmospheric port were blocked, what would be the engine symptoms?

____

EGR Valve

1. With the engine idling and warm, slowly apply vacuum to the EGR valve, so that the engine runs rough. What happened to EGR temperature?

____

2. On MAP sensor equipped engines, what happens to intake manifold pressure when the EGR valve is opened?

____

____

EGR Cutoff Control System

Name ____ Date ______________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the EGR system using the EWD and RM			
Find wire colors, pin numbers in the EGR electrical circuits using the EWD and RM			
Visually inspect EGR valve, modulator, hoses			
Activate EGR VSV with Active Test			
Test EGR VSV and compare to specifications to determine condition			
Test vacuum modulator and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Locate in the RM three sections related to EGR system concerns			

Notes

WORKSHEET 5–3
EGR Constant Vacuum System

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test the EGR constant vacuum system using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- Hand Tool Set
- Vacuum pump with gauge

Section 1

Component Tests:

VCV Component Check

1. According to the Repair Manual, perform the VCV test procedure for operation.

____

2. What port has vacuum applied to it? Did it match the Repair Manual?

____

3. A good VCV puts out:

____

EGR Valve Position Sensor

1. Using the vacuum pump, apply the vacuum specified and record EGR valve position sensor voltage.

0 inHG	2 inHG	4 inHG

2. From the voltage readings, is the EGR valve position sensor voltage signal normal?

EGR VSV

1. Connect the positive (+) lead of the DVOM to EGR VSV, terminal.
2. Connect the negative (-) lead to ground.

3. Start the engine and record voltage.

____

Is the EGR VSV open to atmosphere pressure with the EGR valve off?

____

Section 3

EGR Operation

1. With the DT, go to Active Test and select EGR. In User Data select EGR Temp, EGR valve position sensor.
2. Connect the positive (+) lead of the DVOM to EGR VSV connector/terminal.
3. Connect - lead to ground.
4. Record the following.

Engine RPM	EGR Temperature	EGR Valve Position	VSV Voltage	EGR Gas Flow (Y/N)

5. Activate the EGR system and record the following.

Engine RPM	EGR Temperature	EGR Valve Position	VSV Voltage

6. Increase engine RPM and record the following.

Engine RPM	EGR Temperature	EGR Valve Position	VSV Voltage

7. What happened to EGR temperature?

____

8. What happened to EGR valve position sensor voltage?

____

9. What happened to EGR VSV voltage as the EGR valve height increased?

____

10. If the EGR VSV were disconnected, what would be common engine symptoms, and what DTC would set?

____

EGR Constant Vacuum System

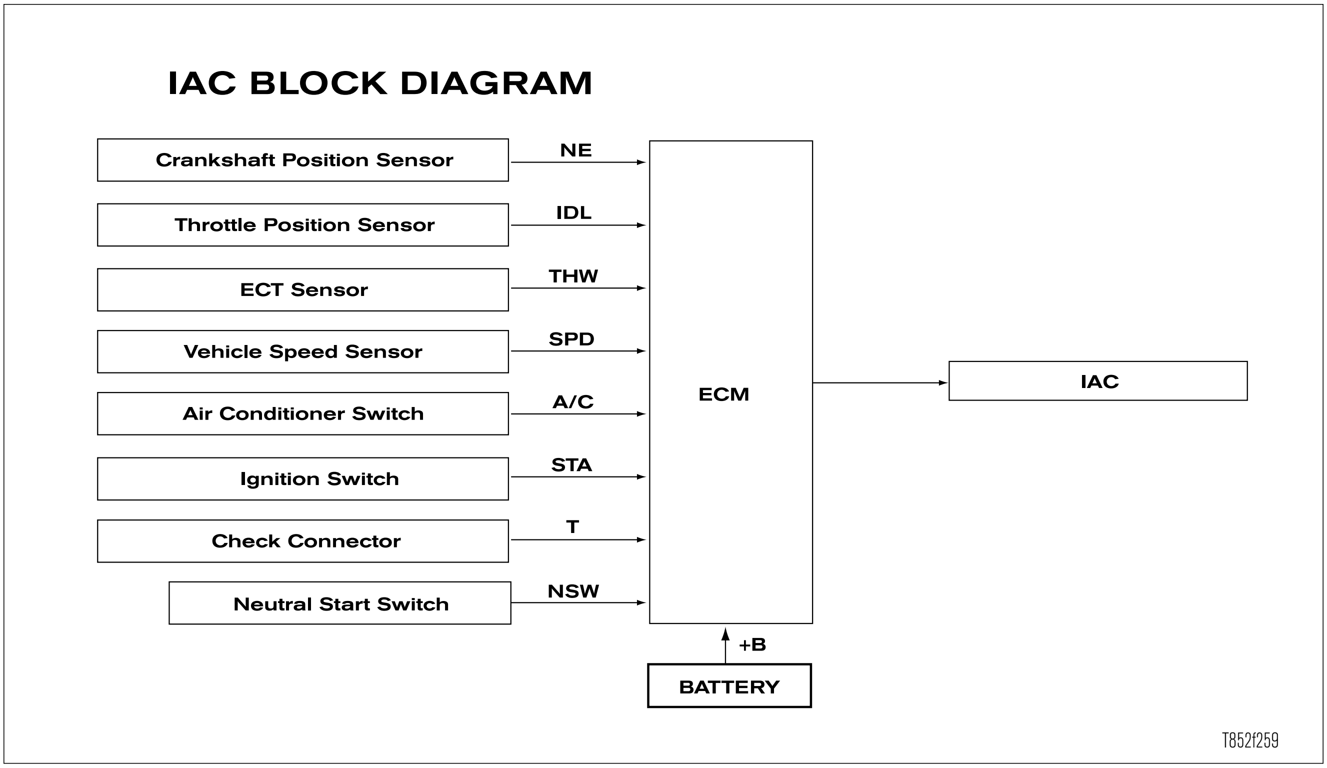
Name ______________________________ Date ____________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	*I have questions*	*I know I can*	Comment
Locate components in the EGR system using the EWD and RM			
Find wire colors, pin numbers in the EGR electrical circuits using the EWD and RM			
Visually inspect EGR valve, modulator, hoses			
Activate EGR VSV with Active Test			
Test EGR VSV and compare to specifications to determine condition			
Test VCV and compare to specifications to determine condition			
Test EGR valve position sensor and compare to specifications to determine condition			
Test EGR temperature sensor and compare to specifications to determine condition			
Check and retrieve relevant DTCs			
Locate in the RM three sections related to EGR system concerns			

Section 6

Idle Air Control Systems



Lesson Objectives

1. Determine the condition of the IACV system based on engine data
2. Determine the root cause of a failure(s) in the IACV system using appropriate diagnostic procedures

Section 6

Idle Air Control Systems

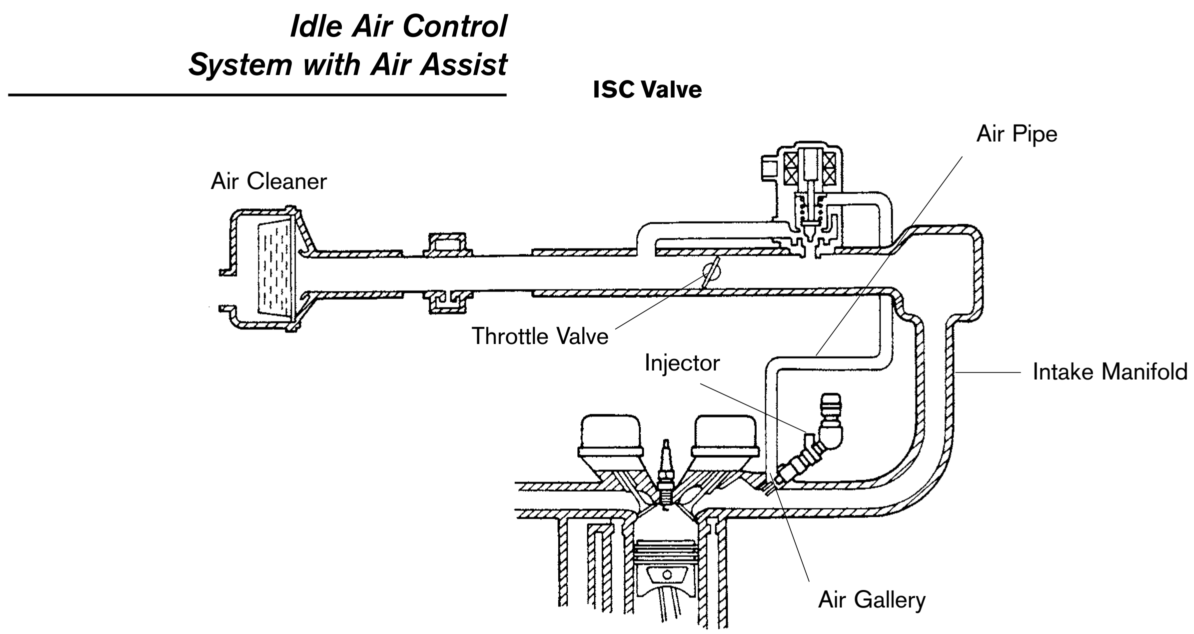


Fig. 6-01

T852f258

Idle Air Control Systems

The Idle Air Control (IAC) system regulates engine idle speed by adjusting the volume of air that is allowed to bypass the closed throttle valve. The ECM controls the Idle Air Control Valve (IACV) based on input signals received from various sensors. The system is necessary to provide stabilization of curb idle when loads are applied to the engine and to provide cold fast idle on some applications.

The idle air control system regulates idle speed under at least one or more of the following conditions, depending on application:

- Cold Fast Idle.
- Warm Curb Idle.
- Air Conditioner Load.
- Electrical Load.
- Automatic Transmission Load.
- Power Steering Idle Up.

The IAC system will also prevent engine stall on deceleration.

IAC System

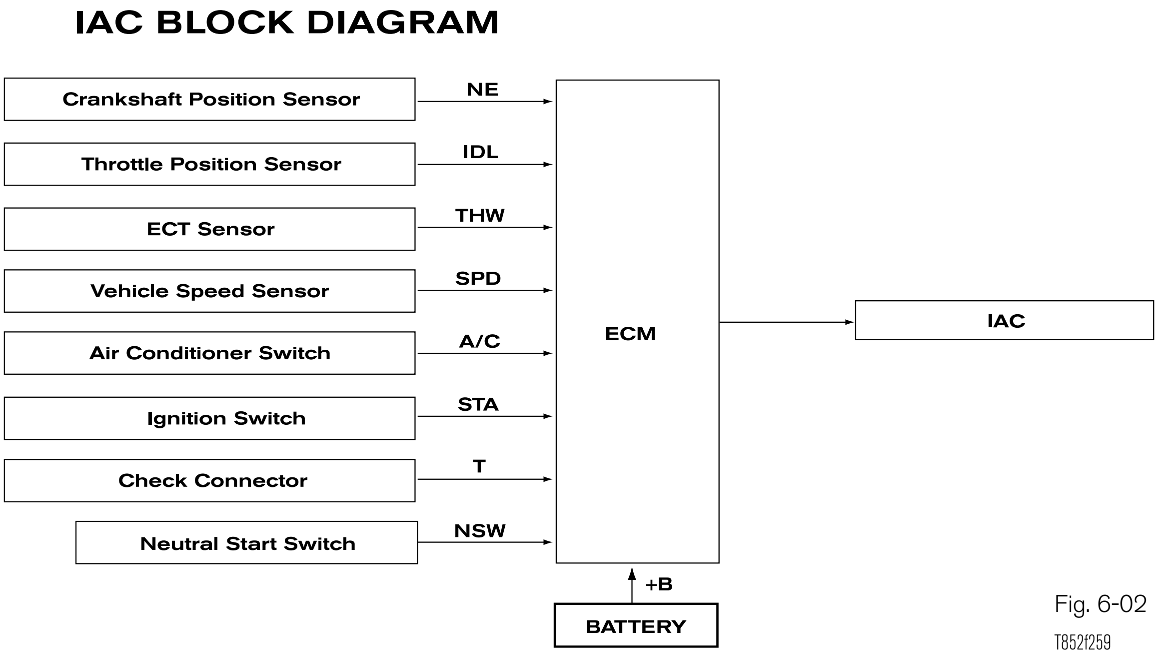


Fig. 6-02

T852f259

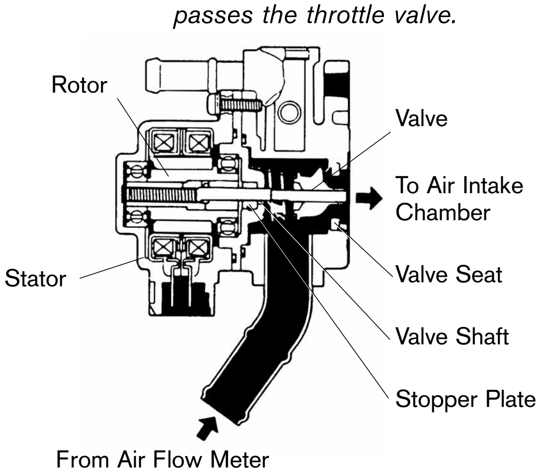
ECM Modulated Idle Air Control Systems (IAC)

There are four different types of ECM controlled IAC systems. These systems are referred to as:

- Stepper motor type.
- Rotary solenoid types.
- Duty control ACV type.
- On-off control VSV type.

Stepper Motor IACV

As the valve steps increase, more air by-passes the throttle valve.



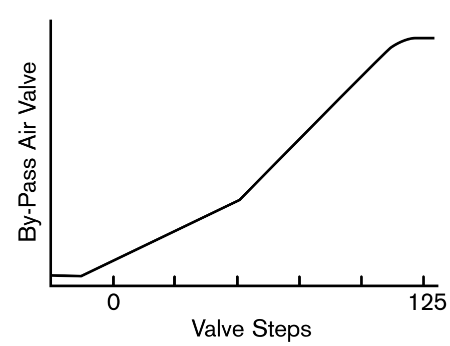


Fig. 6-03

T852f260/T852f261

Stepper Motor IAC Valve

The stepper motor IACV is located on the intake air chamber or throttle body. It regulates engine speed by means of a stepper motor and a pintle valve that controls the volume of air bypassing the closed throttle valve. The IACV throttle air bypass circuit routes intake air past the throttle valve directly to the intake manifold through an opening between the pintle valve and its seat. The size of this opening is determined by how far the pintle is from the seat.

The valve assembly consists of four electrical stator coils, a magnetic rotor, a valve and valve shaft. The valve shaft is screwed into the rotor so that as the rotor turns, the valve assembly will extend and retract.

Stepper Motor IAC Operation

The ECM commands a change in IAC position by sequentially turning on the stepper motor coils.

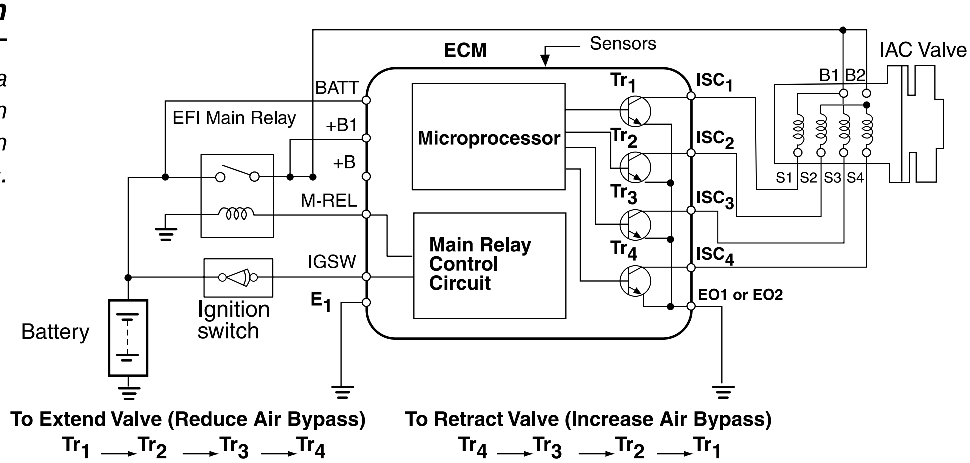


Fig. 6-04

T852f262

The ECM controls movement of the pintle valve by sequentially grounding the four electrical stator coils. Each time current is pulsed through one of the stator coils, the shaft moves one "step," either into or out of the air passage. The direction of valve movement depends on the sequence by which the ECM energizes the coils.

The ECM closes the air bypass by extending the valve through the following sequence:

ISC1 > ISC2 > ISC3 > ISC4

The ECM opens the air bypass by extending the valve through the following sequence:

ISC4 > ISC3 > ISC2 > ISC1

The pintle valve has 125 possible positions, from fully retracted (maximum air bypass) to fully extended (no air bypass). In the event that the IACV becomes disconnected or inoperative, its position will become fixed at the step count where it failed. Because the stepper idle air control motor is capable of controlling large volumes of air, it is used for cold fast idle control and is not used in combination with a mechanical air valve.

Initial Set-Up And After-Start Control

The IAC is opened to its 125th step immediately after the engine stops running. After engine start-up the ECM positions the IAC valve based on the current coolant temperature

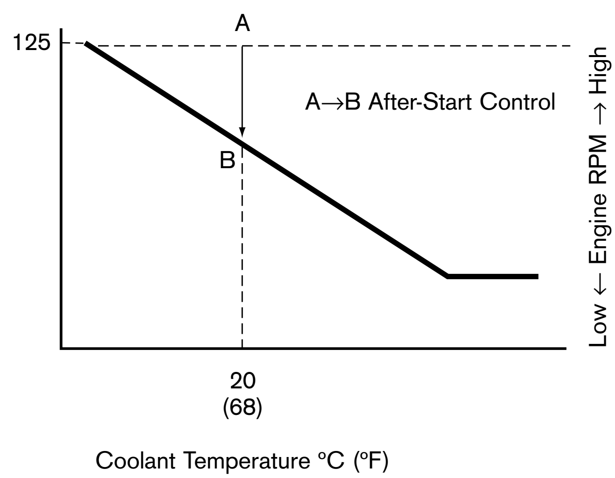


Fig. 6-05

T852f263

Primary Controlled Parameters

Initial Set-Up

Engines equipped with the stepper type IACV use an ECM controlled EFI main relay which delays system power down for about two seconds after the ignition is turned off. During these two seconds, the ECM fully opens the IACV to 125 steps from seat, improving engine stability when it is started. This reset also allows the ECM to keep track of the IACV position after each engine restart.

After-Start Control

Once the engine has started and reached approximately 500 RPM, the ECM drives the IACV to a precise number of steps from seat based on the coolant temperature at time of start-up. This information is stored in a look up table in the ECM memory and is represented by point B on the graph.

Warm-up Control

The IAC valve position adjusted to match the actual idle speed to calculated target speed.

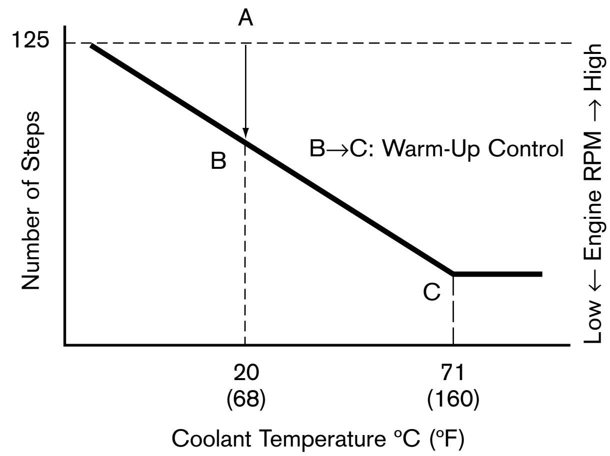


Fig. 6-06

T852f264

Engine Warm-up Control As the engine coolant approaches normal operating temperature, the need for cold fast idle is gradually eliminated. The ECM gradually steps the IACV toward its seat during warm-up. The warm curb idle position is represented by point C on the graph. When the coolant temperature is approximately 71°C (160°F), the cold fast idle program has ended.

Feedback Control

The IAC valve position adjusted to match the actual idle speed to calculated target speed.

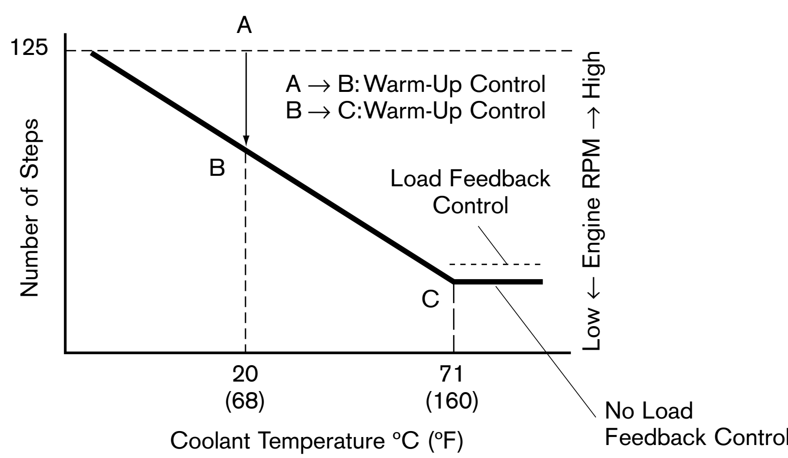


Fig. 6-07

T852f265

Feedback (Closed Loop) Idle Air Control The ECM has a preprogrammed target idle speed that is maintained by the IACV based on feedback from the NE signal. Feedback idle air control occurs any time the throttle is closed and the engine is at normal operating temperature. The target idle speed is programmed in an ECM look up table and varies depending on inputs from the A/C and NSW signals. Any time actual speed varies by greater than 20 RPM from target idle speed, the ECM will adjust the IAC valve position to bring idle speed back on target.

Target Idle Speed

Note the change in target speed as the A/C or NSW are on or off.

Air Conditioner Switch	Neutral Start Switch	Engine Speed
ON	ON	900 RPM
	OFF	750 RPM
OFF	ON	650 RPM
	OFF	580 RPM

Fig. 6-08

Engine Load/Speed Change Estimate Control

To prevent major loads from changing engine speed significantly, the ECM monitors signals from the Neutral Start Switch (NSW), the Air Conditioner switch (A/C), and models equipped with Power Steering Oil Pressure Switch (PS). By monitoring these inputs, the ECM reestablishes target idle speeds accordingly and adjusts IACV position.

Before a change in engine speed can occur, the ECM has moved the IACV to compensate for the change in engine load. This feature helps to maintain a stable idle speed under changing load conditions.

These speed specifications can be useful when troubleshooting suspected operational problems in the step type idle air control system or related input sensor circuits.

Other Controlled Parameters

Electrical Load Idle-up - Whenever a drop in voltage is sensed at the ECM +B or IG terminals, the ECM responds by increasing engine idle speed. This strategy ensures adequate alternator rpm to maintain system voltage at safe operational levels.

Deceleration Control - Some ECMs use a deceleration function to allow the engine to gradually return to idle. This strategy helps improve emissions control by allowing more air into the intake manifold on deceleration. This extra air is available to mix with any fuel that may have evaporated during the low manifold pressure conditions of deceleration.

Learned Idle Air Control - The idle air control program is based on an ECM stored look up table, which lists pintle step positions in relation to specific engine rpm values. Over time, engine wear and other variations tend to change these relationships. Because this system is capable of feedback control, it is also capable of memorizing changes in the relationship of step position and engine rpm. The ECM periodically updates its memory to provide more rapid and accurate response to changes in engine rpm.

NOTE If the battery is disconnected, the ECM must relearn target step positions.

Rotary Solenoid IAC System

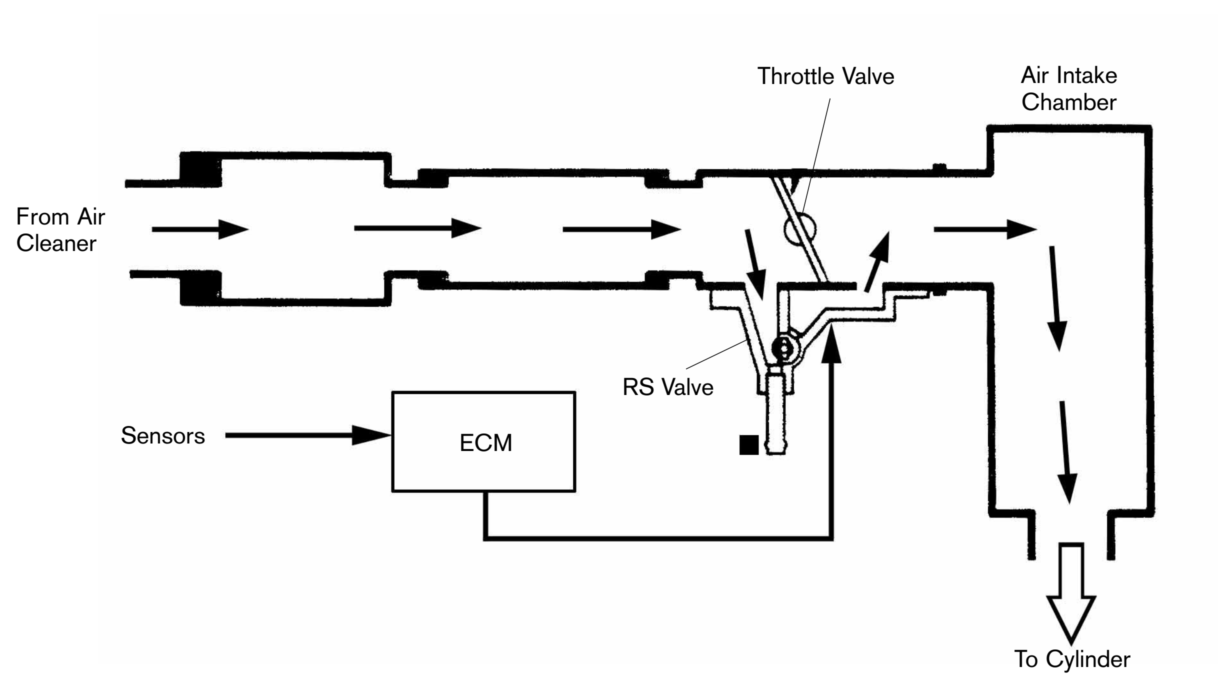


Fig. 6-09
T852f266

Rotary Solenoid The RS IACV is mounted on the throttle body and intake air bypassing the throttle valve passes through it. According to the signals sent from the ECM, the IACV controls the flow rate of air bypassing the throttle valve during idle. The air flow rate determines the idle speed. The IACV receives its power from the EFI relay and ground through the ECM.

Rotary Solenoid Circuit

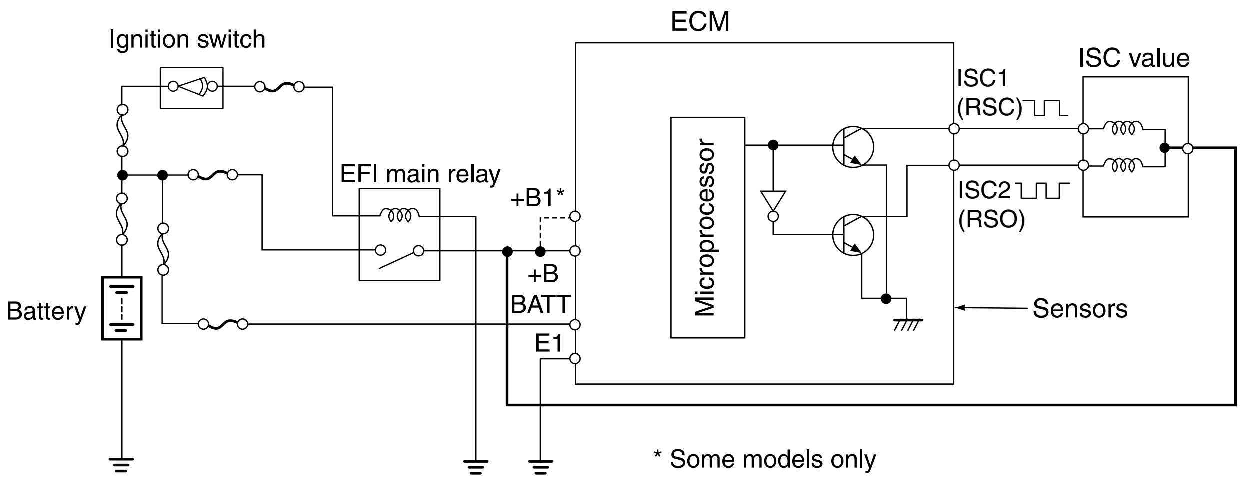
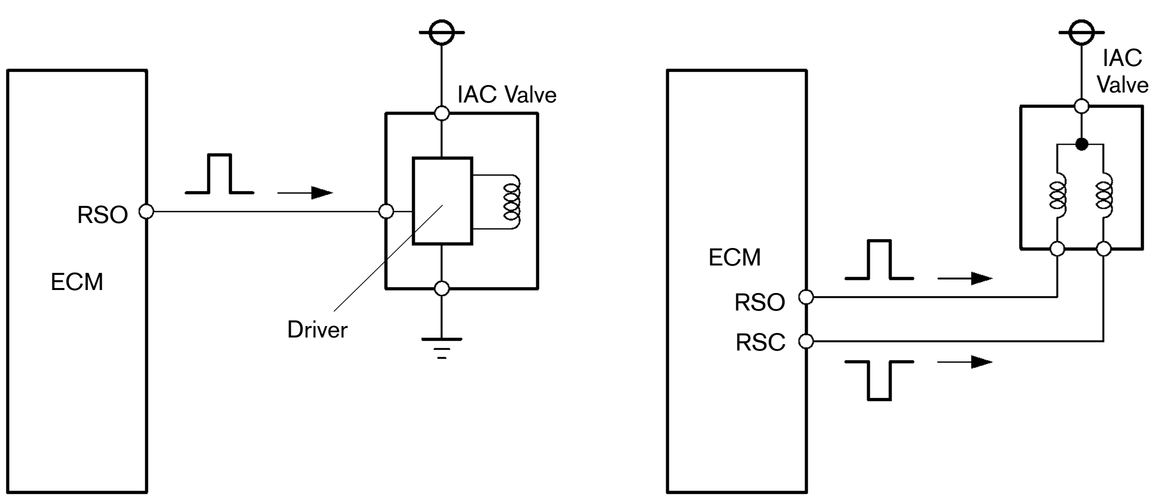


Fig. 6-10
T852f267

Types of Rotary Solenoid IACV



Single Driver Circuit

Dual Driver Circuits

Fig. 6-11
T852f268

There are two styles of rotary solenoid IACVs. The older style uses two driver circuits, one driver for each coil. The newer style uses a single driver circuit, one coil is controlled by the ECM while the other coil is always grounded. They are not interchangeable. An easy way to tell which type of rotary solenoid is to use the wiring schematic. The older style has two wires connected to the ECM while the newer type has one connected to the ECM and the other wire connected to ground.

Rotary Solenoid IAC

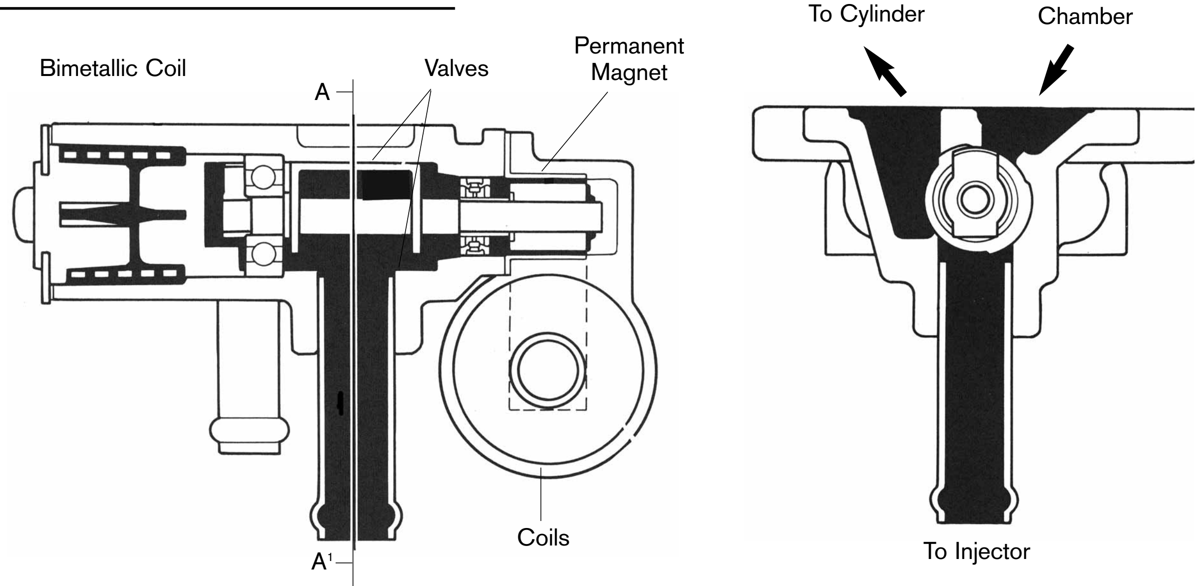


Fig. 6-12

T852f269/T852f270

Rotary IACV Operation

The valve assembly consists of two electrical coils, a permanent magnet mounted on the valve shaft, and a valve. A fail-safe bimetallic strip is fitted to the end of the shaft to operate the valve in the event of electrical failure in the IACV system.

Located at the end of the valve shaft, the cylindrical permanent magnet rotates when its two poles are repelled by the magnetism exerted by coils T1 and T2.

Anchored to the midsection of the valve shaft, the valve controls the amount of air passing through the bypass port. The valve, valve shaft, and permanent magnet all rotate together.

IACV Components

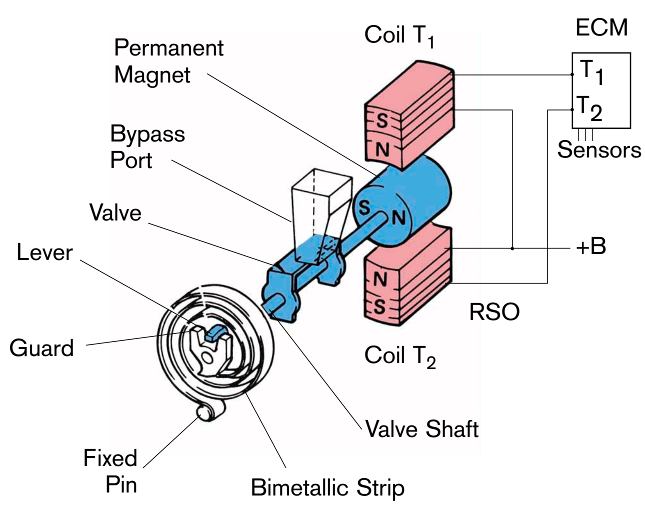


Fig. 6-13

T852f271

As shown, each coil is connected to a transistor, T1 and T2 located in the ECM. When transistor T1 turns on, current flows through that coil. The magnetic field of the coil and the magnetic field of the permanent magnet cause the valve to rotate clockwise. When T2 is turned on, the valve rotates counterclockwise.

The ECM varies the on time (duty ratio) for each coil. The difference in strength between the two magnetic fields determines the position of the valve. The frequency is very high, 250Hz. This high frequency helps the valve maintain the correct position for proper air flow.

Single Driver Rotary IACV Operation

The difference with this type of IACV is that the ECM sends a duty cycle signal to one coil inside the IACV; the other coil is always on. To change the IACV position, ECM changes the duty ratio in the controlled coil.

IACV Movement

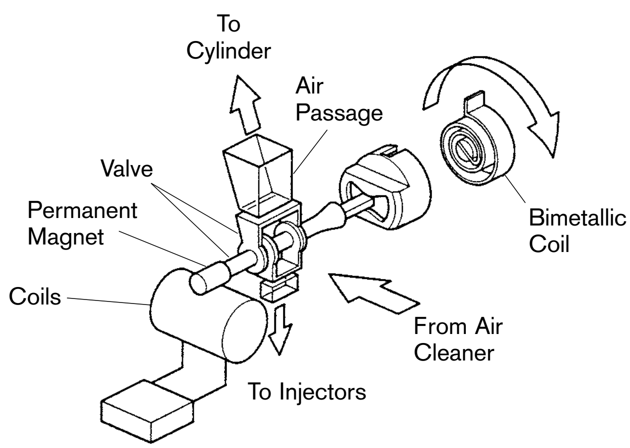


Fig. 6-14

T852f272

Bimetallic Spring Operation

If the electrical connector is disconnected or the valve fails electrically, the shaft will rotate to a position determined by the balancing of the permanent magnet with the iron core of the coils and the bi-metal strip.

The cold idle will not be as fast as normal and the warm idle will be higher than normal.

Using a bimetallic strip allows the IACV to change airflow rate with the change in temperature. The default rpm is approximately 1000 to 1200 RPM once the engine has reached normal operating temperature.

Rotary IACV Controlled Parameters

Engine Starting

As the engine is started, the ECM opens the IACV to a preprogrammed position based on coolant temperature and sensed rpm.

Warm-up

Once the engine has started, the ECM controls the fast idle based on coolant temperature. As the engine approaches normal operating temperature, engine speed is gradually reduced. At this time the ECM is comparing actual idle rpm to the target rpm.

Feedback Control

The ECM utilizes a feedback idle air control strategy (which functions very much like the stepper motor IAC system). That is, when the actual engine speed is lower than the target idling speed, the ECM signals the IACV to open. Conversely, when the actual idle speed is higher than the target idle speed, the ECM signal the IACV to close.

Engine Load/Speed Change Estimate Control

To prevent major loads from changing engine speed significantly, the ECM monitors signals from the neutral start switch (NSW), the air conditioner switch (A/C), headlights or rear window defogger (ELS), and in models equipped with power steering, an oil pressure switch (PS). By monitoring these inputs, the ECM reestablishes target idle speeds accordingly, and adjusts IACV position.

Before a change in engine speed can occur, the ECM has moved the IACV to compensate for the change in engine load. This feature helps to maintain a stable idle speed under changing load conditions.

These speed specifications can be useful when troubleshooting suspected operational problems in the IAC system or related input sensor circuits.

The Rotary Solenoid IAC system utilizes a learned idle air control strategy. The ECM memorizes the relationship between engine rpm and duty cycle ratio and periodically updates its memory. Over time, engine wear and other variations tend to change these relationships. Because this system is capable of feedback control, it is also capable of memorizing changes in the relationship of duty ratio and engine rpm. The ECM periodically updates its memory to provide more rapid and accurate response to changes in engine rpm.

NOTE

If the battery is disconnected, the ECM must relearn target step positions.

A/C Idle-Up

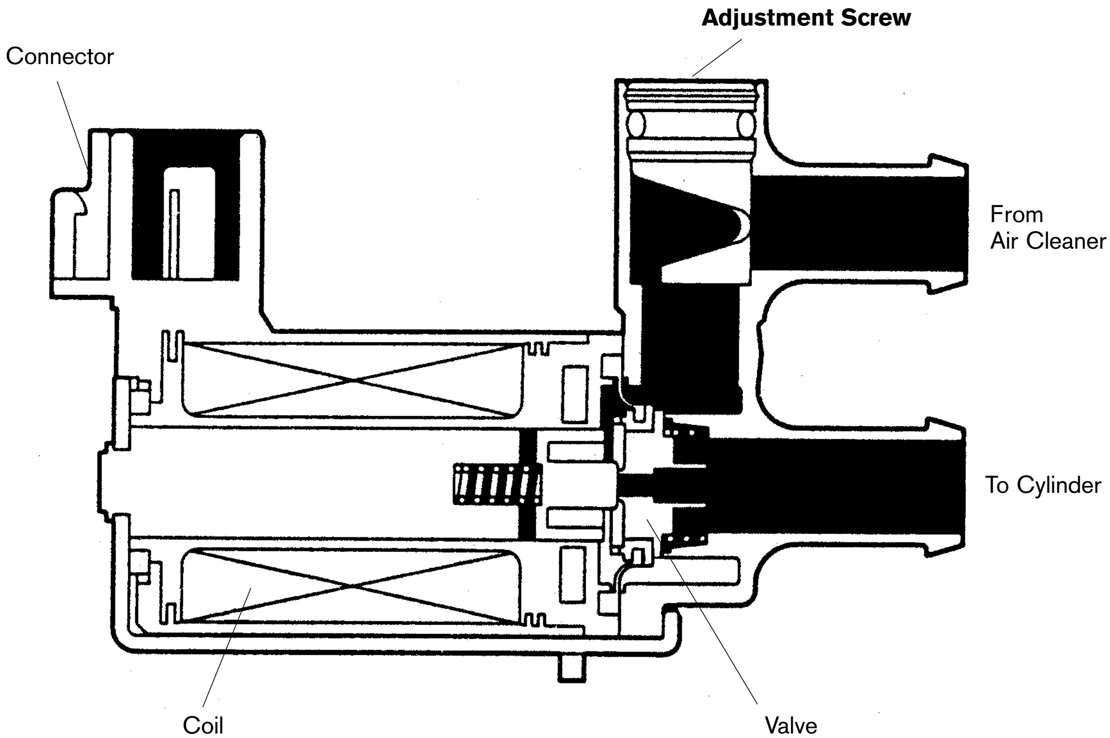


Fig. 6-15
T852f273

Air Conditioning Idle-Up

The air conditioning idle-up system is used in some models equipped with the rotary solenoid to increase engine idle rpm any time the air conditioning compressor is in operation. This system maintains engine idle stability during periods of A/C compressor operation. Additionally, it keeps compressor speed sufficiently high to ensure adequate cooling capacity at idle speed. The air control VSV is turned on or off by the air conditioning ECU.

Power Steering Idle-Up

Non-ECM Controlled System.

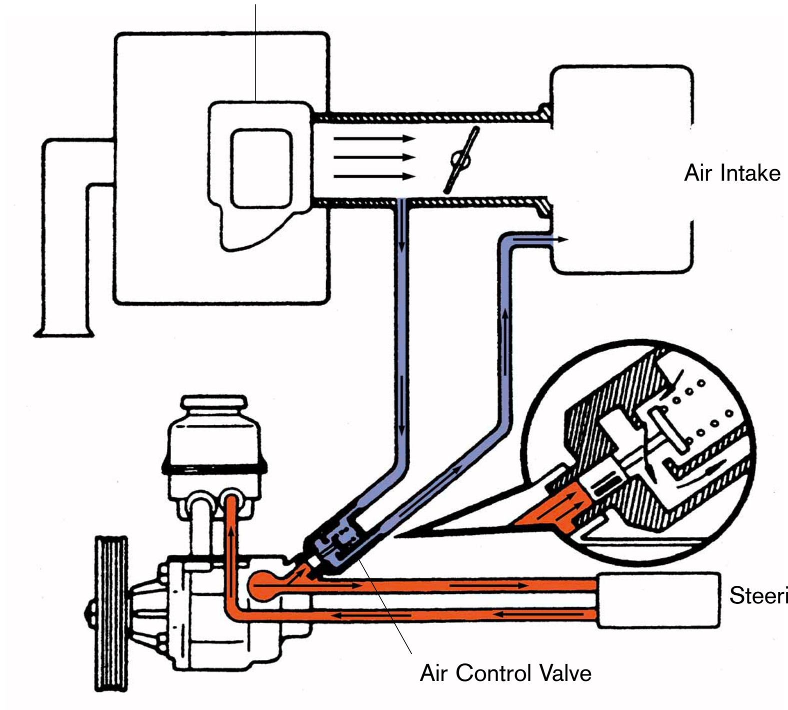


Fig. 6-16

T852f274

Power Steering Idle-Up

The power steering system draws a significant amount of horsepower from the engine when the steering wheel is turned to either stop. This can have an adverse effect on idle quality. To address this potential problem, many engines equipped with power steering use a power steering idle-up system that activates whenever the steering wheel is turned to a stop. There are two types:

- Non-ECM controlled.
- ECM controlled.

Non-ECM Controlled

The Non-ECM controlled power steering idle-up system consists of a hydraulically operated air control valve and a vacuum circuit which bypasses the throttle valve. Whenever power steering pressure exceeds the calibration point of the control valve, the valve opens, allowing a calibrated volume of air to bypass the closed throttle valve.

The system is only functional during very low speed maneuvering and at idle. The system can be tested by turning the steering wheel and listening for an RPM increase.

ECM Controlled

The ECM controlled power steering idle-up uses a pressure switch or sensor in place of the air control valve. Receiving a change in voltage signal from the sensor, the ECM will command the IACV to open, increasing engine RPMs.

Notes

WORKSHEET 6–1
Rotary Solenoid IACV System

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test rotary solenoid IACV circuits using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester
- DVOM
- Hand Tool Set

Section 1

1. Setup the Diagnostic Tester, go to Data List. Connect the DVOM to either IACV terminal.
2. Start the engine and note IACV percentage and voltage.
3. With the engine warmed up, increase engine RPM to 2500. What happened to IACV percentage and voltage?

   ____

4. With engine at idle, create an intake manifold leak that will cause the engine to run rough but not stall.
5. What happened to IACV percentage?

   ____

Section 2

1. Using the RM, inspect IACV operation by connecting TE1 and E1 terminals in DLC1 (if applicable). What happened to the idle?

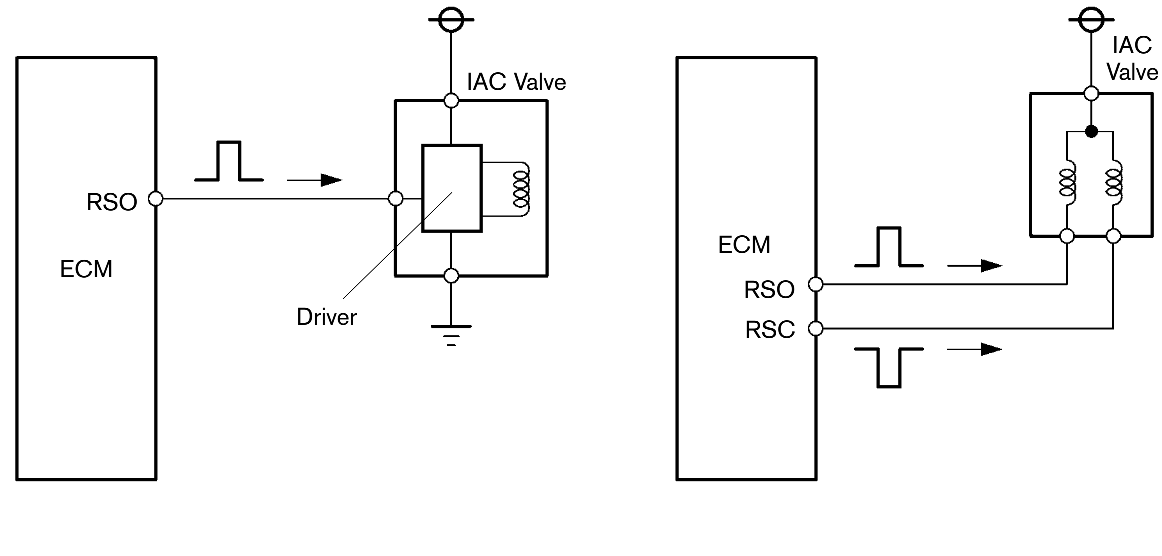
   ____

2. Go to Active Test for the IACV system. Increase the IACV percentage. What happened to engine RPM?

   ____

3. Decrease IACV percentage. What happened to engine RPM?

   ____



Types of Rotary Solenoid IACV

T852f268

Section 3

Using the Repair Manual, complete the following statements.

1. For the rotary solenoid with two driver circuits:

   Applying battery voltage to terminal +B and grounding the RSC terminal will cause the valve to

   ____

   Applying battery voltage to terminal +B and grounding the RSO terminal will cause the valve to

   ____

2. For the rotary solenoid with a single driver circuit:

   ____

   Applying battery voltage to terminal +B and grounding the RSO terminal will cause the valve to

   ____

Rotary Solenoid IACV System

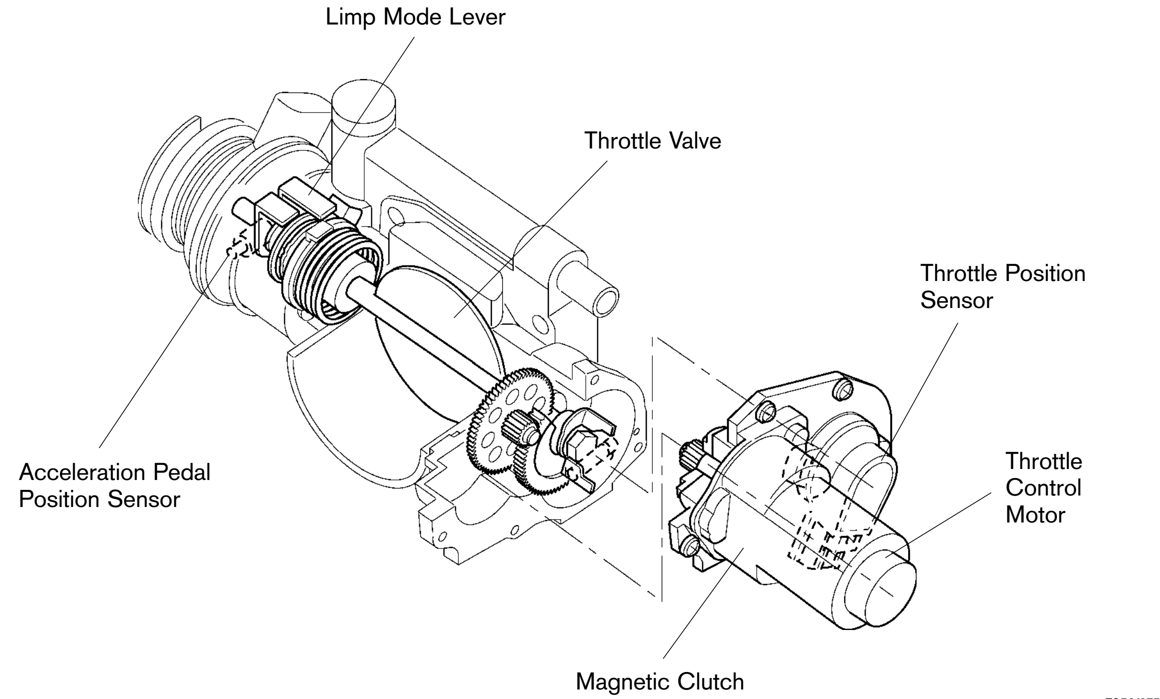
Name ______________________________ Date ______________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	*I have questions*	*I know I can*	Comment
Locate components in the IACV system using the EWD and RM			
Find wire colors, pin numbers in the fuel delivery electrical circuits using the EWD and RM			
Locate the IACV status in the Data List and compare to specifications to determine condition			
Activate RS IACV with Active Test			
Determine effect on IACV operation when there are engine problems			
Test RS IACV operation			
Check and retrieve relevant DTCs			
Locate in the RM two sections related to IACV system concerns			

Section 7

Electronic Throttle Control Systems



Lesson Objectives

1. Determine the condition of the ETCS-i system based on engine data
2. Determine the root cause of a failure(s) in the ETCS-i system using the appropriate diagnostic procedures

Notes

Electronic Throttle Control Systems

Electronic Throttle Control System – intelligence (ETCS–i)

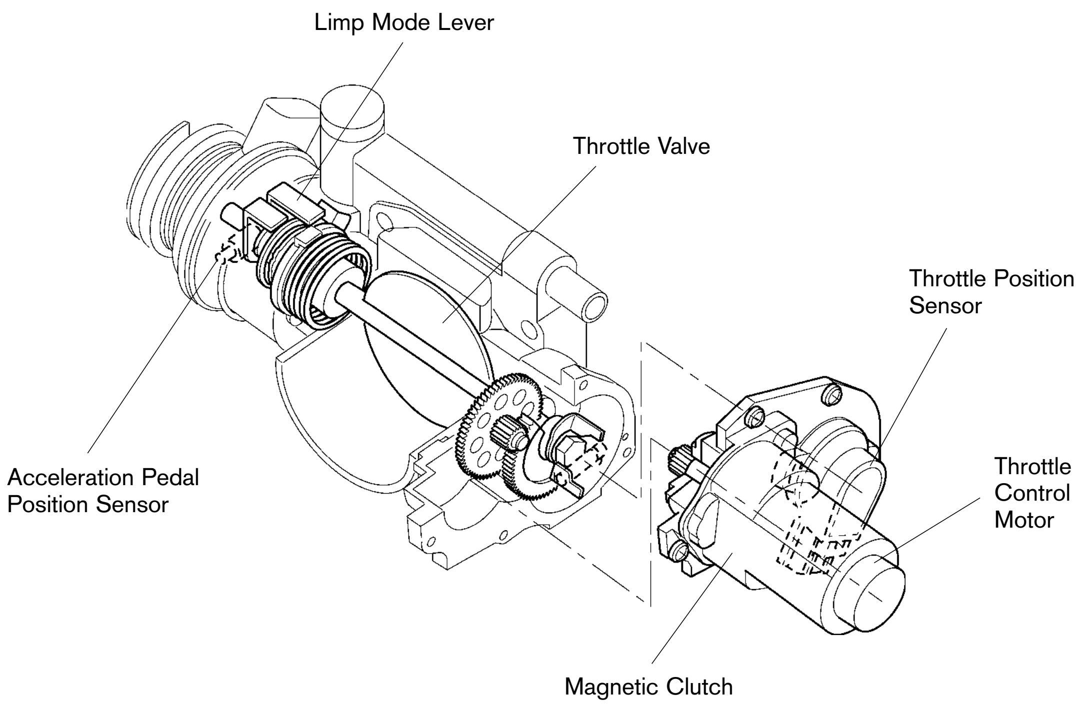


Fig. 7-01

T852f275

Electronic Throttle Control System

Electronic Throttle Control System - intelligence (ETCS-i) has several advantages because the ECM will position the throttle valve for optimum performance. In a mechanical system, the opening rate of the throttle valve is controlled directly by the driver. ETCS-i can control the rate for better engine performance. On vehicles equipped with Vehicle Skid Control (VSC), ETCS-i will adjust the throttle valve to maintain traction on acceleration. The ISC system and cruise control functions are part of the ECTS-i system. There is also a limp home feature if the system is shut off.

The throttle motor operates the throttle valve. An electromagnetic clutch connects the throttle motor to the throttle valve. The throttle position sensor detects throttle valve angle. The accelerator pedal position sensor detects accelerator pedal position. The ECM adjusts the throttle valve angle in response to engine and vehicle conditions. Some versions used a thermostat to keep the throttle body at the proper temperature.

ETCS-i Overview

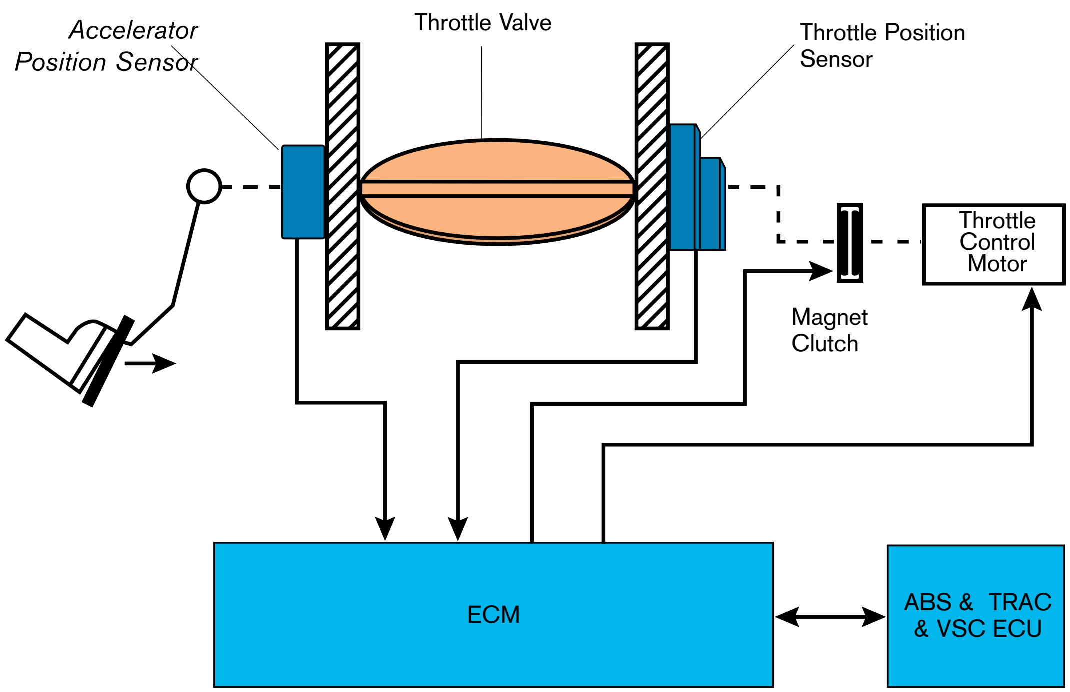


Fig. 7-02

T852f276

Thermostat

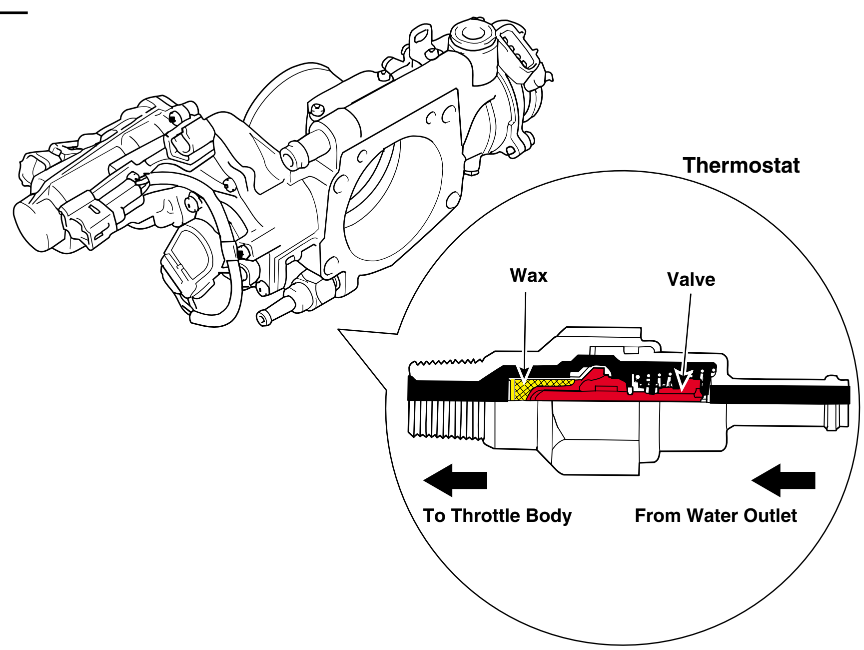


Fig. 7-03

T852f277

Operation

The following describe the functions of the major components of ETCS-i.

- **Acceleration Pedal Position Sensor (APPS)** - The APPS, which is mounted on the throttle body, is integrated with the throttle lever. The throttle lever is connected by cable to the accelerator pedal. As the driver moves the accelerator pedal the APPS signal voltage changes indicating pedal position. There are two voltage output signals from the APPS. The ECM uses these two signals to calculate the desired throttle valve angle. Also, by using two signals the ECM is able to compare and detect if there is anything wrong with the APPS's performance.

- **Throttle Position Sensor** - The TPS is used to detect the actual angle of the throttle valve. This signal indicates to the ECM throttle valve position and that the throttle valve moved to the desired angle. Throttle valve position detection is necessary for the ECM to make adjustments to the throttle valve position and to detect if there is a failure in the system.

- **Throttle Control Motor** - The throttle control motor is a DC motor controlled by the ECM. The ECM controls the direction and the amperage of the current through the motor. The circuit is pulsewidth modulated (duty ratio cycle regulated). If there is a malfunction in the system, the ECM shuts the circuit (and clutch circuit) off and the return springs close the throttle valve. The ECM will turn the motor off if there is excessive amperage or not enough amperage in the motor circuit.

- **Magnetic Clutch** - Under normal operation, the magnetic clutch connects the throttle control motor to the throttle valve. The circuit is pulsewidth modulated reducing power consumption. If there is a malfunction in ETCS-i, the ECM turns off the clutch circuit (and motor) if there is too much or not enough amperage in the circuit.

- **Thermostat** - A thermostat is installed in the throttle body to shut off the flow of coolant when coolant temperature is high. This prevents the throttle body from heating up the intake air reducing performance. The thermostat uses a wax expansion valve to open and close the coolant passage.

- **Fail-Safe** - If an abnormal condition occurs with the ETCS-i, the MIL will illuminate to alert the driver. At the same time, current to the throttle control motor and magnetic clutch are cut off. With no power to the motor or magnetic clutch, the return spring closes the throttle valve to the default position. In this situation, called limp mode, the accelerator pedal operates the limp mode lever. When in limp mode, the throttle can only be partially opened reducing engine power. Furthermore, ISC and cruise control systems will not operate.

ETCS-i Throttle Opening Rate

With the SNOW switch on, or in slippery conditions engine output is reduced in relation to accelerator pedal effort. In other words, the driver will have to push further on the accelerator than normal to achieve a similar power output.

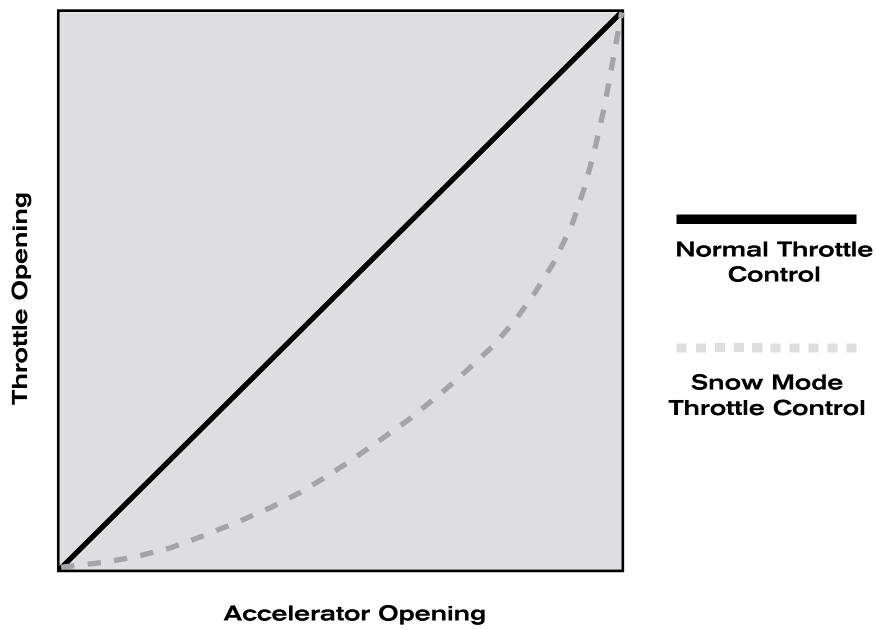


Fig. 7-04

T852f278

ETCS-i Control Modes

The ECM drives the throttle control motor to a target throttle angle as determined by operating conditions. The following describes the different modes:

- **Non-linear Control** - Non-linear control means the ECM can control the throttle valve opening rate and position based on such factors as accelerator pedal effort and engine rpm to achieve better performance and comfort. In slippery conditions, the throttle valve can be controlled to aid in vehicle stability.

- **Shift Shock Reduction Control** - The throttle control is synchronized to the Electronically Controlled Transmission control during the shifting of the transmission to reduce the shift shock.

- **Idle Speed Control** - The ECM adjusts the throttle opening to maintain the target idle speed.

- **TRAC Throttle Control** - As part of the TRAC system, the throttle valve is closed by a demand signal from the ABS, TRAC, and VSC ECU if an excessive amount of slippage is occurring at the driven wheel.

- **VSC Coordination Control** - VSC performance is enhanced when the throttle valve opening angle is modified by the ABS, TRAC, and VSC ECUs.

- **Cruise Control** - ETCS-i eliminates the need for a separate cruise control system. Cruise control strategies and functions are incorporated into the ECM.

ETCS-i Throttle Motor Circuit Operation

The ECM controls the direction and amount of current needed to activate the throttle control motor to adjust throttle valve position. The throttle motor can be in any one of the following five modes:

- Default position.

- Throttle closing.

- Throttle opening.

- Throttle hold.

- Idle speed control.

The motor circuit consists of four control transistors on the MO and MC circuits. One transistor supplies power and the other transistor completes the path to ground. This configuration allows the ECM to control the direction of current through the motor.

This circuit is also pulsewidth modulated to control the rate of throttle movement and to hold the throttle in a given position. For rapid throttle opening, the pulse width duty ratio will be high (current flow high) for rapid movement.

To hold the throttle in the desired position, the ECM applies enough current to oppose spring pressure.

If the traction control mode is engaged, the pulsewidth will be less, limiting the rate of opening from idle. If the throttle valve is opened too far, the ECM will decrease the pulsewidth closing the throttle.

Default Position

When there is no current applied to the motor, the springs hold the throttle valve in the default position. This condition occurs when the engine ignition key is off or when the ECM has detected a failure in the ETCS-i system. When a failure is detected, current to the motor and clutch is turned off. These actions disengage the motor from the throttle shaft and prevent the motor moving the throttle valve. In this state, the idle is higher than normal when the engine is at operating temperature. The throttle valve will move if the driver presses down further on the accelerator pedal.

Throttle Closing

Current flows from the MC to the MO terminal. The MC supply transistor and the MO ground transistor are turned on. The rate the throttle valve closes is a combination of spring tension, pulsewidth duration, and direction of current flow. To further close the throttle valve after the default position, current must flow as shown in the drawing.

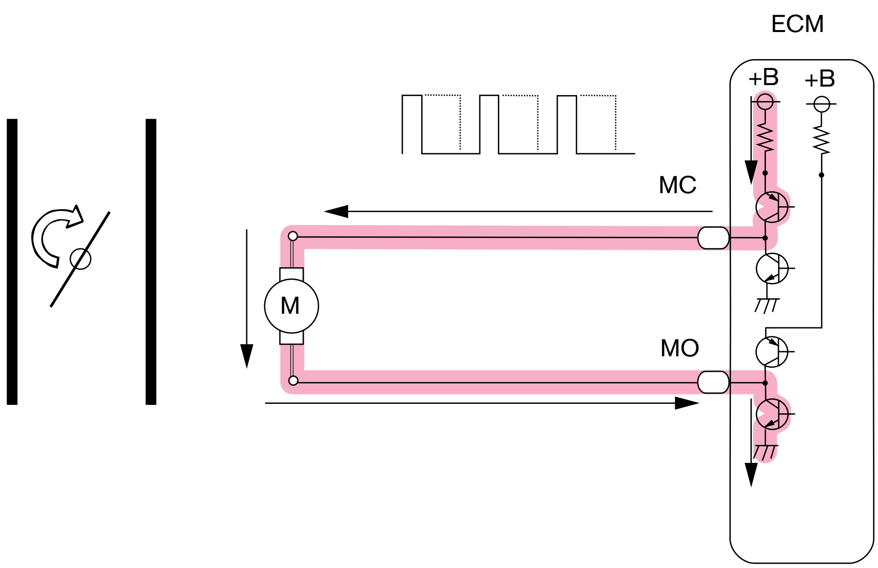


Fig. 7-05

T852f279

Throttle Opening

Above the default position, the MO supply transistor and MC ground transistor are turned on allowing current to flow from MO to MC terminals.

Below the default position, the current flow direction is the same as in the throttle close operation, but the pulsewidth is decreased and in combination with spring tension, the throttle valve opens.

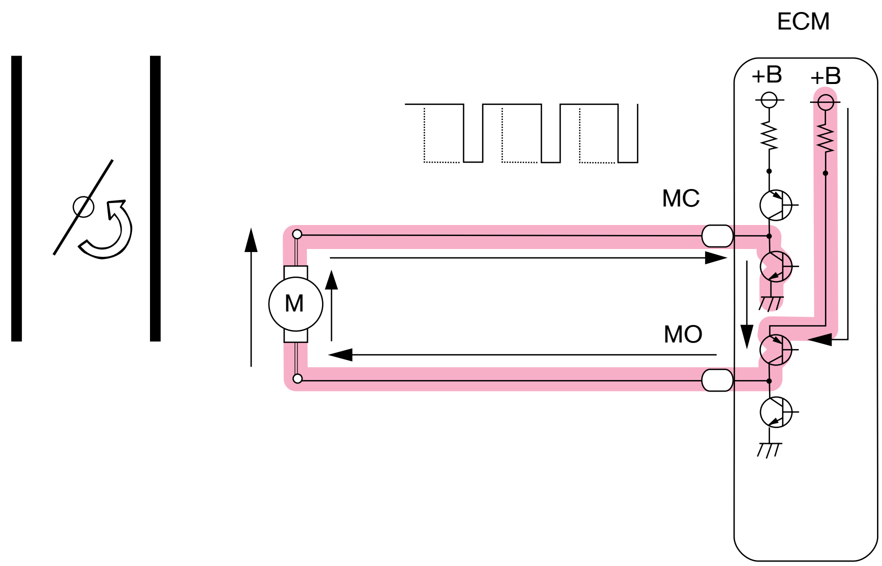


Fig. 7-06

T852f280

Throttle Hold To maintain the desired throttle valve angle, the applied duty ratio creates enough force in the motor to oppose spring pressure.

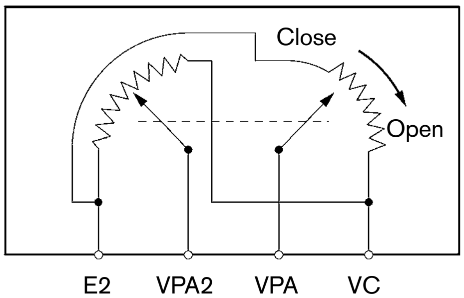
Idle Speed Control The throttle valve is adjusted to maintain the desired idle speed. If the desired idle speed needs the throttle valve below the default position, the throttle close circuit is activated. Any decrease in duty ratio will open the throttle valve and raise engine RPM. If the desired idle speed needs the throttle valve above the default position, the throttle open circuit is activated.

Diagnostics

When ETCS-i is in Fail Safe mode, the driver will notice the pedal travel is longer in relation to engine response and that the MIL is on. Retrieve the DTCs and follow repair manual procedures.

APPS & TPS

The APPS and TPS are checked like a conventional TPS. The difference is that there is an extra voltage signal to check.



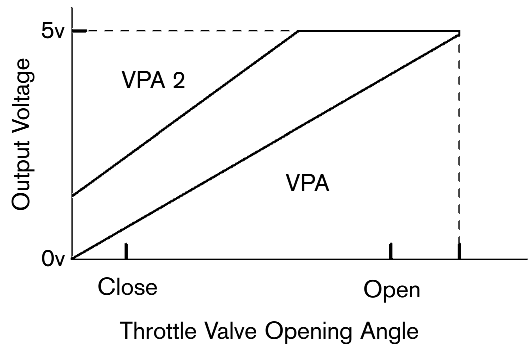


Fig. 7-07
T852f281

Throttle Motor

The throttle motor control circuit operational check is performed with an oscilloscope. The RM provides the waveform when connected to the M+ or M- terminal. The waveform will vary with a change in throttle angle. An ohmmeter is used to check the resistance of the motor coils.

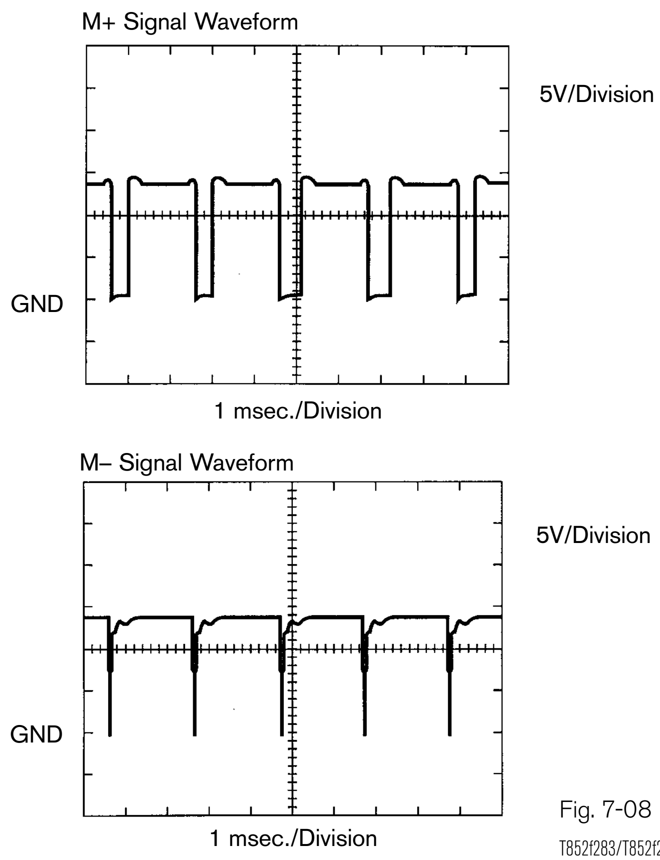


Fig. 7-08
T852f283/T852f282

Electromagnetic Clutch Circuit

Like the throttle control circuit, the clutch circuit is checked with an oscilloscope. A normally operating circuit will be a square wave. An ohmmeter is used to check the resistance of the clutch coil.

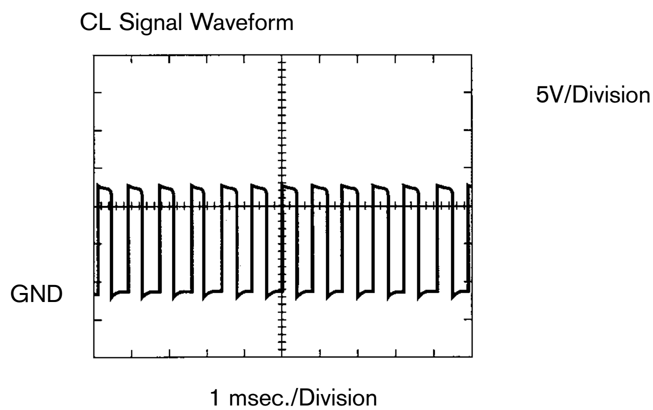


Fig. 7-09

T852f284

Notes

WORKSHEET 7–1
ETCS-i System

Vehicle	Year/Prod. Date	Engine	Transmission

Technician Objectives

With this worksheet, you will learn to test ETCS-i systems using the required tools and equipment, retrieve and apply the needed service information, retrieve and interpret service data information.

Tools and Equipment

- Vehicle Repair Manual
- Vehicle EWD
- Diagnostic Tester & DVOM
- Hand Tool Set

Section 1

Throttle Control Motor

1. Connect the Diagnostic Tester Auto probe to the throttle motor circuit according to the Repair Manual. Start the engine and raise engine to approximately 1000 RPM. Draw or print the waveform.

2. Does the waveform match the Repair Manual waveform?

3. Raise engine RPM to 2000. What happened to the waveform and frequency? Draw the pattern.

Throttle Clutch

1. Connect the Diagnostic Tester Autoprobe to the ETCS-i clutch circuit. Set the Diagnostic Tester to the Oscilloscope function, according to the RM. Connect DVOM to DC volts, Hz.
2. Start the engine and at idle RPM note the waveform.
3. Does the waveform match the Repair Manual waveform?
4. Draw or print the waveform.
5. What is the frequency?
6. Raise engine RPM to 2000. What happened to the waveform and frequency?

Go to ETCS-i DATA LIST. Record the following at:

	Idle	1700 RPM	What parameters changed and why?
Parameter Name	DATA	DATA	
ACCEL POS #1			
ACCEL POS #2			
THROTTLE POS #2			
THROTTLE TARGET			
THROTL OPN DUTY			
THROTL CLS DUTY			
THROTTLE MOT			
ETCS MAG CLUTCH			
+BM			
ACCEL IDL POS			
THROTTLE IDL POS			
FAIL #1			
FAIL #2			
THROTTL INITIAL			
ACCEL LEARN VAL			
THROTTLE MOT			
ETCS MAG CLUTCH			

ETCS–i System

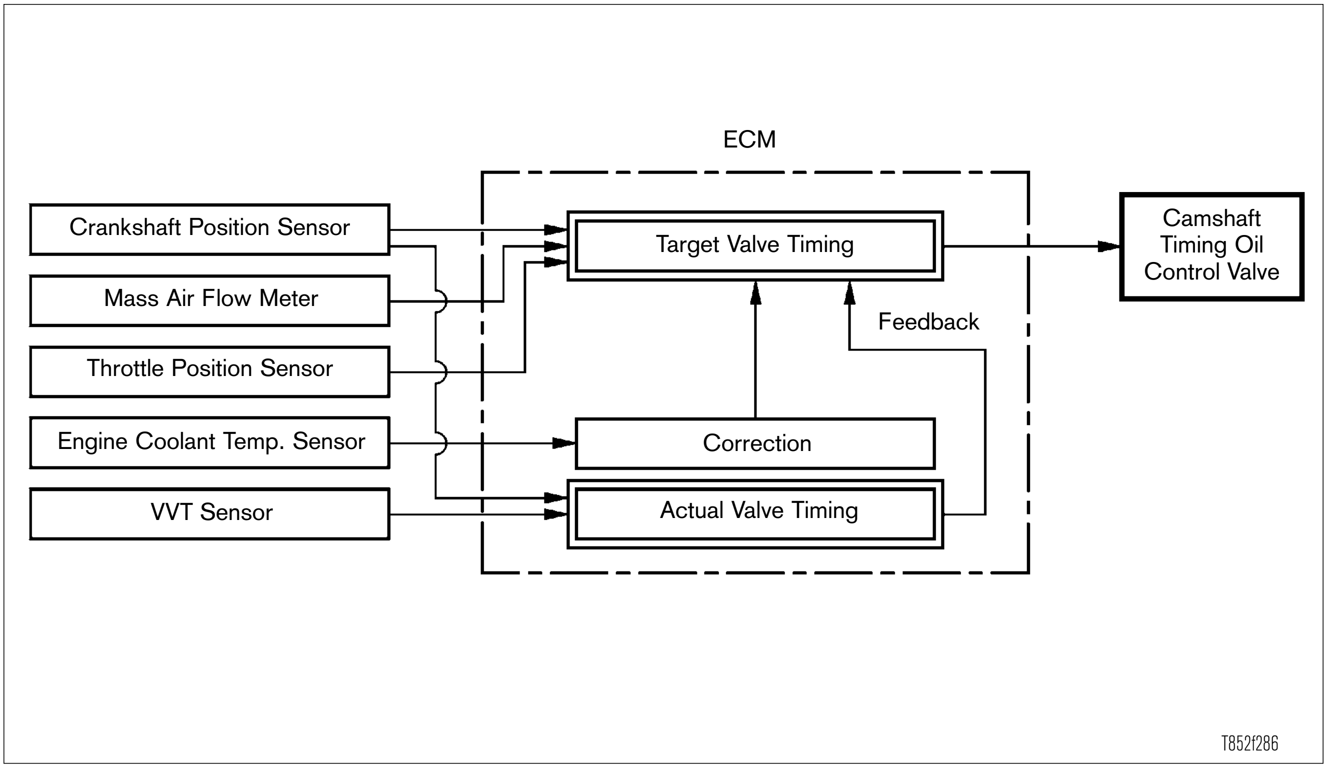
Name ______________________________ Date ________________

Review this sheet as you are doing the worksheet. Check each category after completing the worksheet and instructor presentation. Ask the instructor if you have questions. The comments section is for you to write where to find the information, questions, etc.

Topic	I have questions	I know I can	Comment
Locate components in the ETCS-i system using the EWD and RM			
Find wire colors, pin numbers in the fuel delivery electrical circuits using the EWD and RM			
Locate the ETCS-i Data List and compare to specs. to determine condition			
Test throttle control motor and clutch with oscilloscope			
Interpret ETCS-i Data List signals			
Check and retrieve relevant DTCs			
Locate in the RM two sections related to ETCS-i system concerns			

Section 8

Variable Valve Timing & Acoustic Control Induction Systems



Lesson Objectives 1. Familiarity with the VVT-i systems and ACIS systems operation

Variable Valve Timing & Acoustic Control Induction Systems

VVT-i System

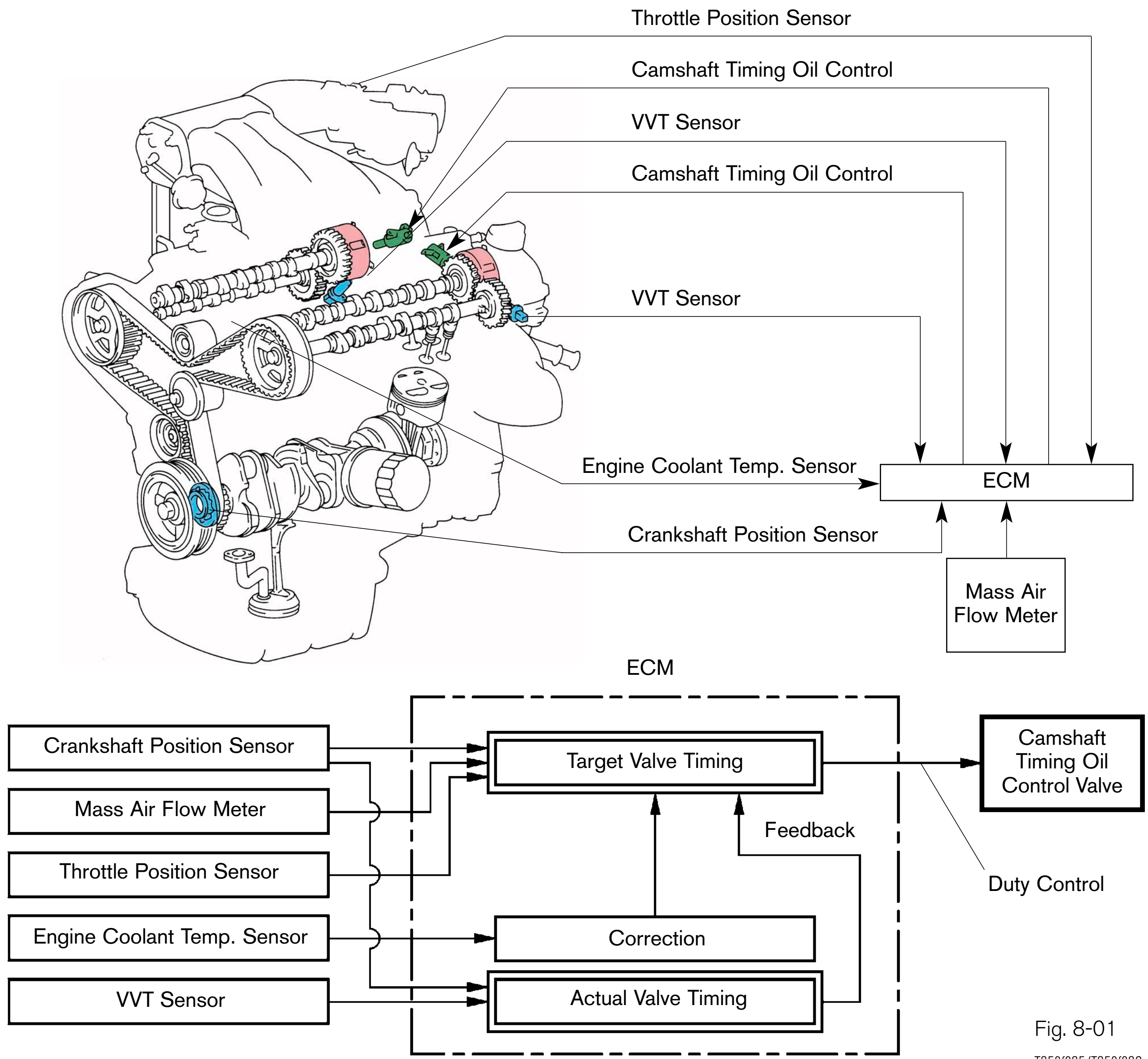


Fig. 8-01

T852f285/T852f286

Variable Valve Timing Systems

Without variable valve timing, engine valve timing is a compromise between the needs to produce maximum torque (horsepower) at low to medium speeds, idle stability, fuel economy, low emissions, and maximum horsepower output. Continuously adjusting when the valves open and close, called variable valve timing, yields significant improvements in all these areas. The ECM, according to driving conditions such as the engine speed and load, will advance or retard the camshaft, changing when the valves open and close. This system is called the Variable Valve Timing-intelligent (VVT-i) system.

VVT-i Range

The G signal represents the movement of the camshaft in degrees in relation to the crankshaft.

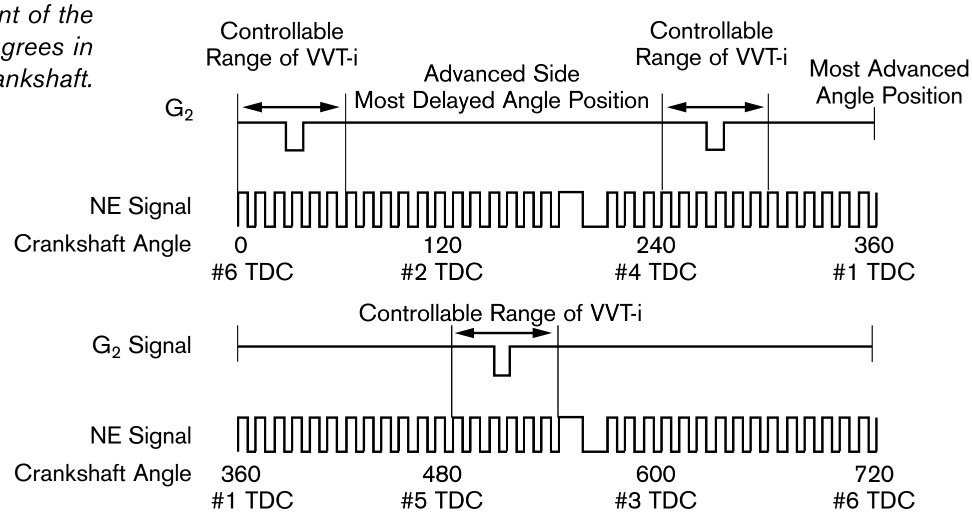


Fig. 8-02

Phase Relationship Between G_2 and NE Signal

T852f287

Components of VVT-i

VVT-i uses the crankshaft position sensor and Variable Valve Timing (VVT) sensors (camshaft position sensor) to measure the amount of camshaft movement. This feedback is necessary for the ECM to know how much and which direction to move the camshaft, and for diagnosis.

A continuously variable valve timing mechanism, called a controller or actuator, is used to adjust the camshaft from the starting stage to the high speed traveling state.

A camshaft timing Oil Control Valve (OCV), controlled by the ECM, directs engine oil pressure to the advance or retard side of the VVT-i controller.

Effect of Continuous Valve Timing Changes

Smooth Idle - At idle rpm, valve overlap is eliminated by retarding the camshaft. With the intake valve opening after the exhaust valve has closed, there is no blow back of exhaust gases to the intake side. Now, combustion is more stable because of the clean air/fuel mixture. This allows the engine idle smoothly at a lower rpm and fuel consumption is reduced.

Torque Improvement in Low to Medium Speed Range - In the low to medium speed range with a heavy load, the camshaft is advanced increasing the valve overlap. This has two effects. First, the exhaust gases help pull in the intake mixture. Second, by closing the intake valve early, the air/fuel mixture taken into the cylinder is not discharged.

This improves volumetric efficiency and increases torque (and therefore horsepower) in the low and midrange rpm range. The driver notices a more powerful acceleration.

EGR Effect - VVT-i eliminates the need for an EGR valve. As a result of increasing the valve overlap in which the exhaust and intake valves are both open, the exhaust gas is able to flow to the intake side. Diluting the air/fuel mixture with exhaust gases reduces the combustion temperature and the production of NO_x. Also, some of the unburned air/fuel mixture present in the exhaust gas will be burned.

Better Fuel Economy - A VVT-i equipped engine is more efficient and provides better fuel economy from a variety of factors. Without VVT-i, the engine would have to be larger and heavier to produce the same horsepower. Smaller pistons, connecting rods, and crankshaft reduce friction and mechanical losses. A lighter engine improves vehicle fuel economy.

Improved fuel consumption is also realized because of the further reduction in the intake stroke resistance. In the medium-load operation range, when the valve overlap is increased, the vacuum (negative pressure) in the intake manifold is reduced. Now, it takes less energy to move the piston downward on the intake stroke. With the pumping loss reduced during the intake stroke, more energy is available to propel the vehicle.

At idle, with no valve overlap, the idle speed is lower improving fuel economy.

Improved Emission Control Performance - In the light-medium load operation range, VVT-i increases the valve overlap creating an internal EGR effect. By opening the intake valve earlier in the exhaust stroke at a lower RPM allows the exhaust gases to push into the intake manifold mixing with the fresh air. The return of exhaust gas into the cylinder lowers the combustion temperature, resulting in NO_x reduction. Essentially, VVT-i will increase the valve overlap to obtain the same EGR effect as an engine equipped with an EGR valve. In other words, when an EGR valve on an EGR equipped engine opens is when VVT-i will increase the valve overlap.

Another benefit is that HCs are also reduced. Some of the unburned air/fuel mixture from the previous cycle returns to the cylinder for combustion. Finally, $C0_2$ is reduced because of the decrease in fuel consumption.

Oil Control Valve (OCV)

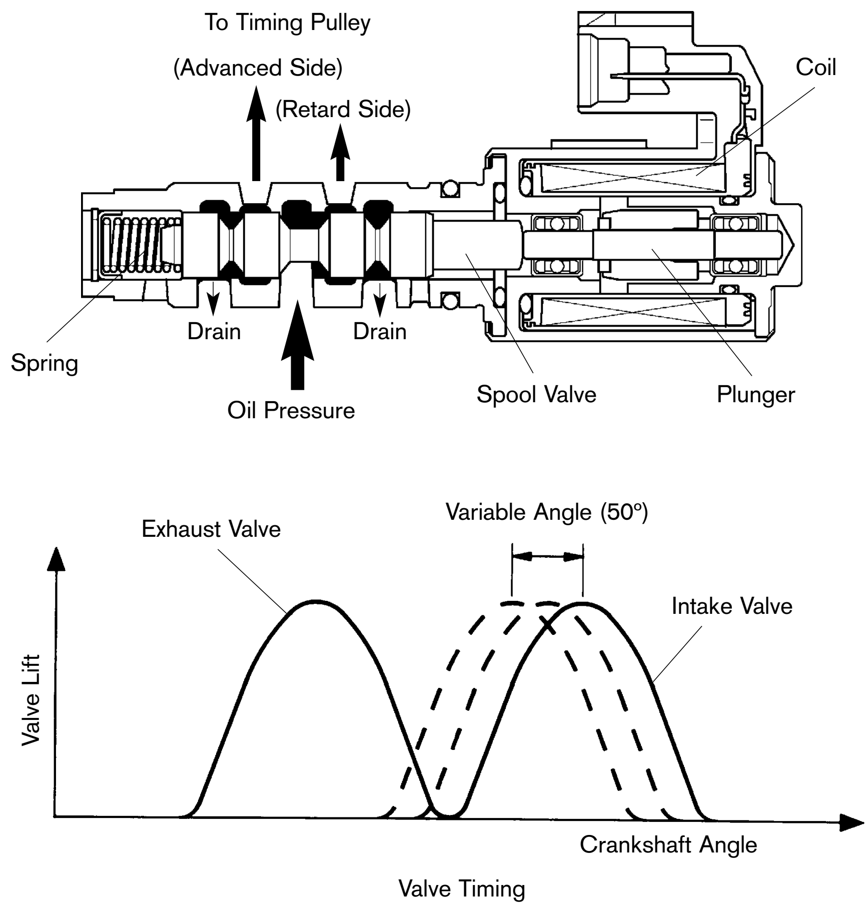


Fig. 8-03

T852f288/T852f289

Operation Camshaft Timing Oil Control Valve

The Camshaft Timing Oil Control Valve (OCV), controlled by the ECM, directs engine oil pressure to the advance or retard side of the VVT-i controller. The spool valve position is determined by the magnetic field strength opposing the spring. As the ECM increases the pulsewidth (duty ratio), the magnetic field moves the spool valve overcoming spring pressure and directing more oil to the advance side. To retard the timing, the ECM decreases the pulsewidth, and spring pressure moves the spool valve towards the retard position. When the desired camshaft angle is achieved, the ECM will generate a pulsewidth signal to move the spool valve to hold position. In the hold position, the oil is trapped in the controller maintaining the desired angle. When the engine is stopped, the spring pushes the spool valve to the most retarded state.

VVT-i Controller Assembly

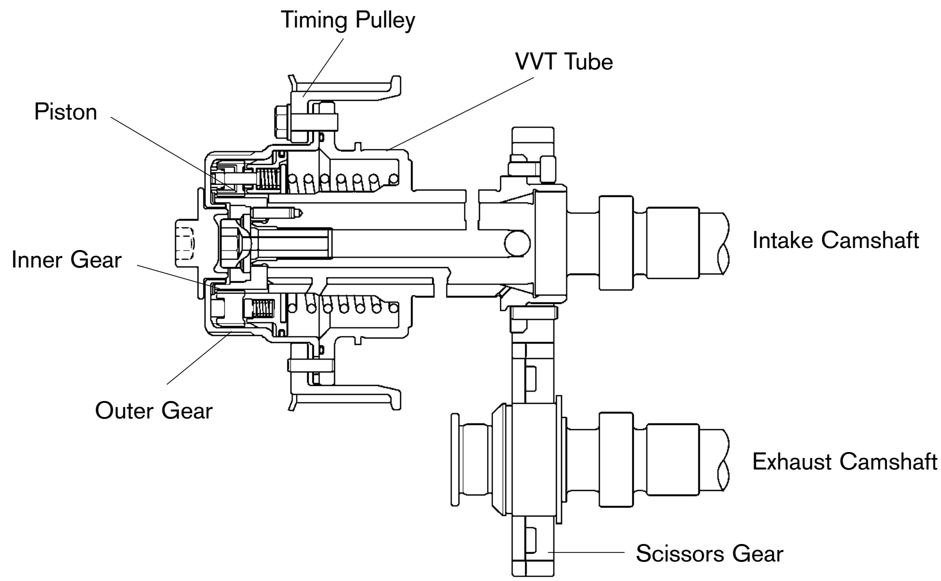


Fig. 8-04

T852f290

VVT-i Controller

The helical splines force the camshaft to advance or retard in relation to the timing pulley.

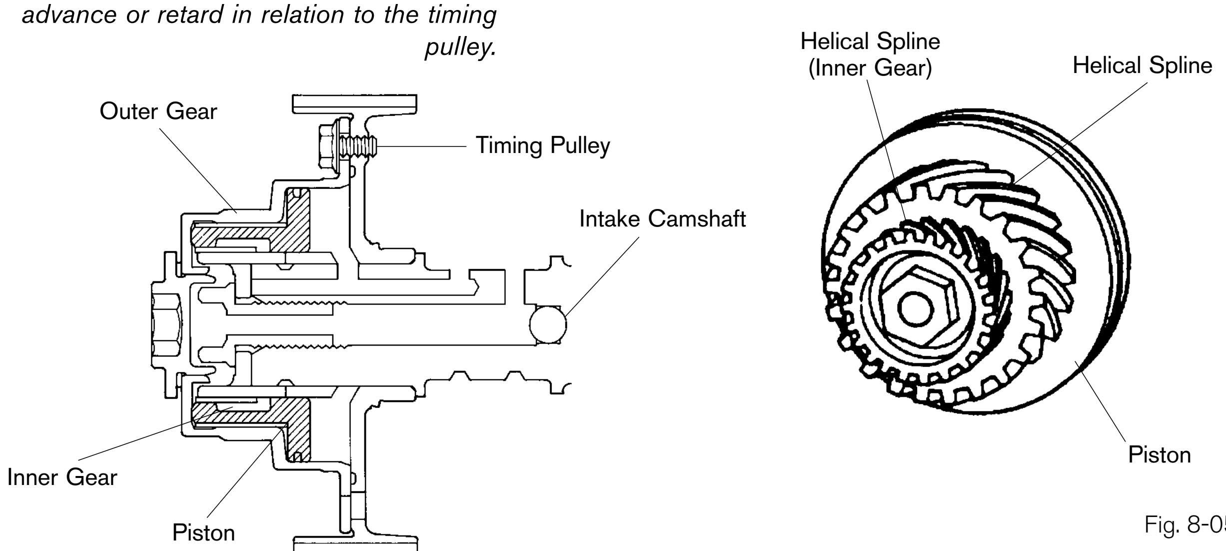


Fig. 8-05

T852f291/T852f292

VVT-i Controller (Helical Type) Operation

This VVT-i controller comprises of an outer gear driven by the timing belt, an inner gear affixed to the camshaft, and a movable piston that is placed between the outer gear and inner gear. As the piston moves laterally (axially), the helical splines on the piston and inner gear force the camshaft to move in relation to the timing gear.

Advance

By the command of the ECM, when the OCV is in the position shown, hydraulic pressure is applied from the left side of the piston, which causes the piston to move to the right. Because of the twist in the helical splines on the inside diameter of the piston, the intake camshaft rotates in the advance direction in relation to the camshaft timing pulley.

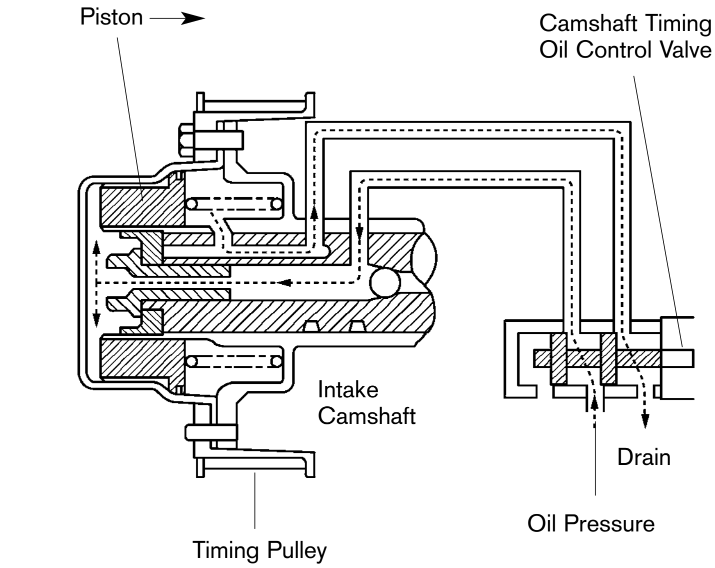


Fig. 8-06

T852f293

Retard

When the OCV is in the position shown, the piston moves to the left and rotates the camshaft in the retard direction.

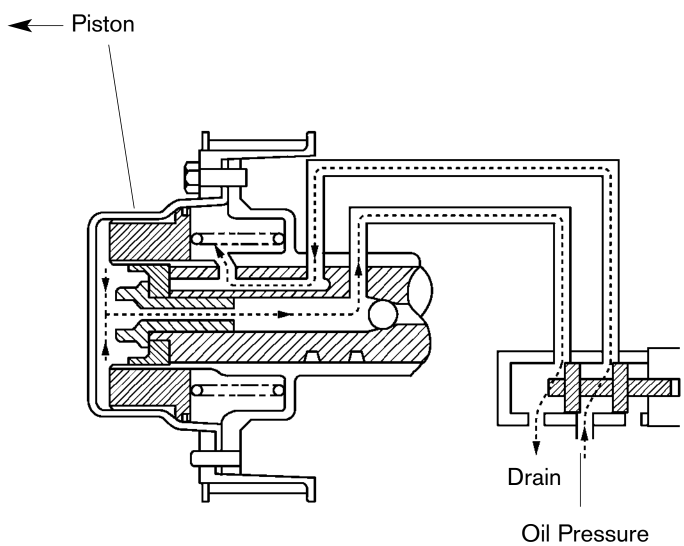


Fig. 8-07

T852f294

Hold

To hold to the desired position, the OCV shuts off the oil passages to maintain the hydraulic pressure at both sides of the piston, thus maintaining that position.

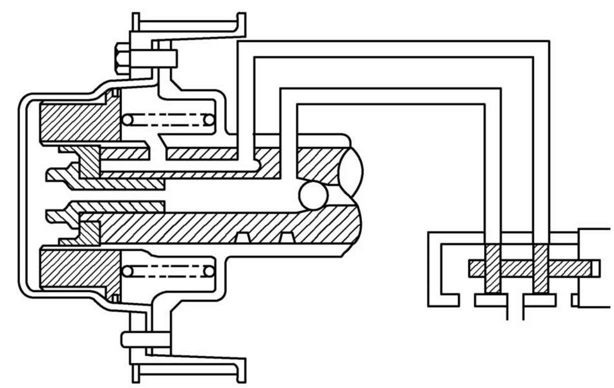


Fig. 8-08

T852f295

VVT-i Actuator (Vane Type)

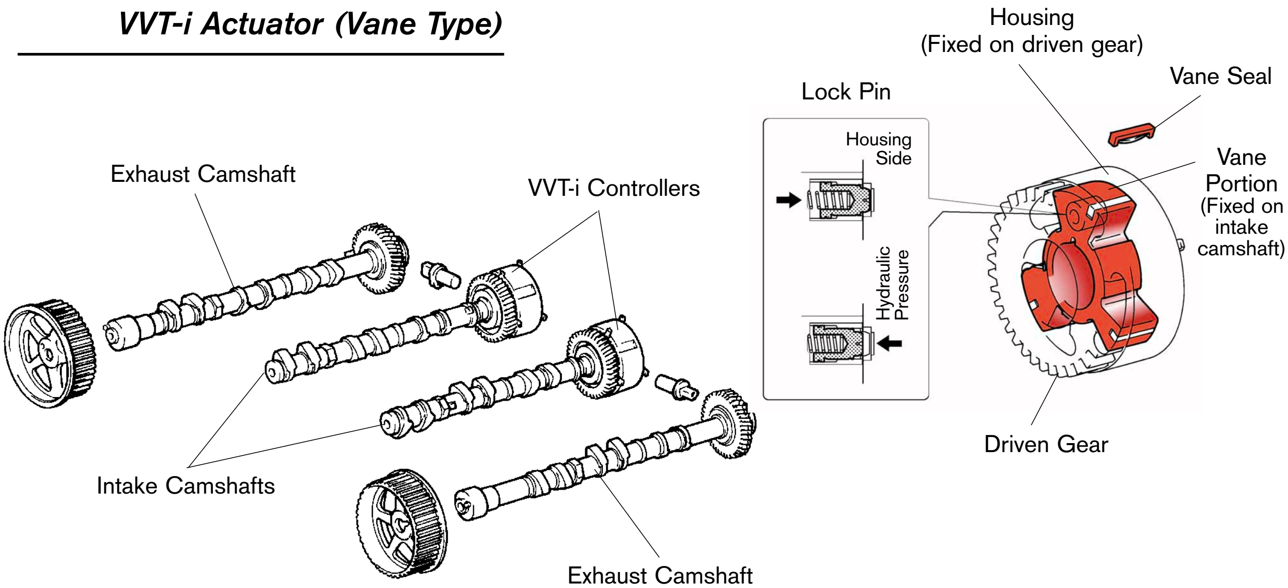


Fig. 8-09

T852f296/T852f297

VVT-i Actuator (Vane Type) Operation

This controller consists of a housing driven by the exhaust camshaft and a vane fixed to the intake camshaft. Oil pressure is directed to either side of the vane causing the camshaft to rotate in relation to the driven gear.

VVT-i Operation

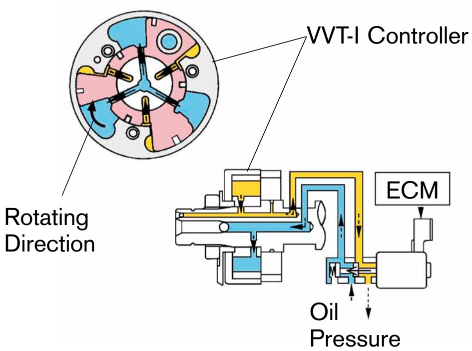
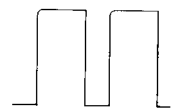
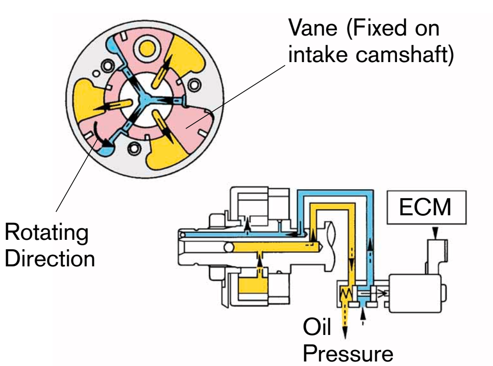
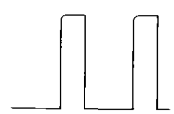
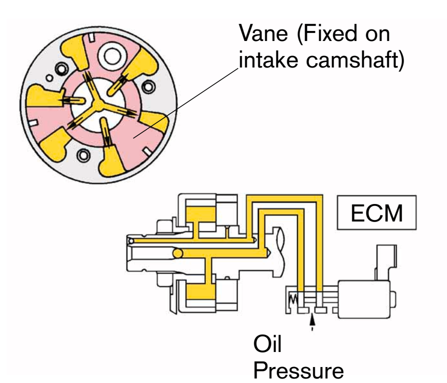
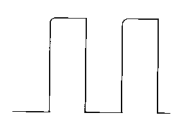
	Operation	Camshaft Timing Oil Control Valve Drive Signal	Description
Advance			When the camshaft timing oil control valve is positioned as illustrated at left by the advance signal from the ECM, the resultant oil pressure is applied to the timing advance side vane chamber to rotate the camshaft in the timing advance direction.
Retard			When the camshaft timing oil control valve is positioned as illustrated at left by the retard signal from the ECM, the resultant oil pressure is applied to the timing retard side vane chamber to rotate the camshaft in the timing retard direction.
Hold			The ECM calculates the target timing angle according to the traveling state to perform control as described above. After setting at the target timing, the camshaft timing oil control valve is in the neutral position unless the traveling state changes. This adjusts the valve timing at the desired target position and prevents the engine oil from running out when it is unnecessary.

Fig. 8-10

T852f298/T852f299
T852f300/T852f301
T852f302/T852f303

Variable Valve Timing with Lift - intelligent (VVTL-i)

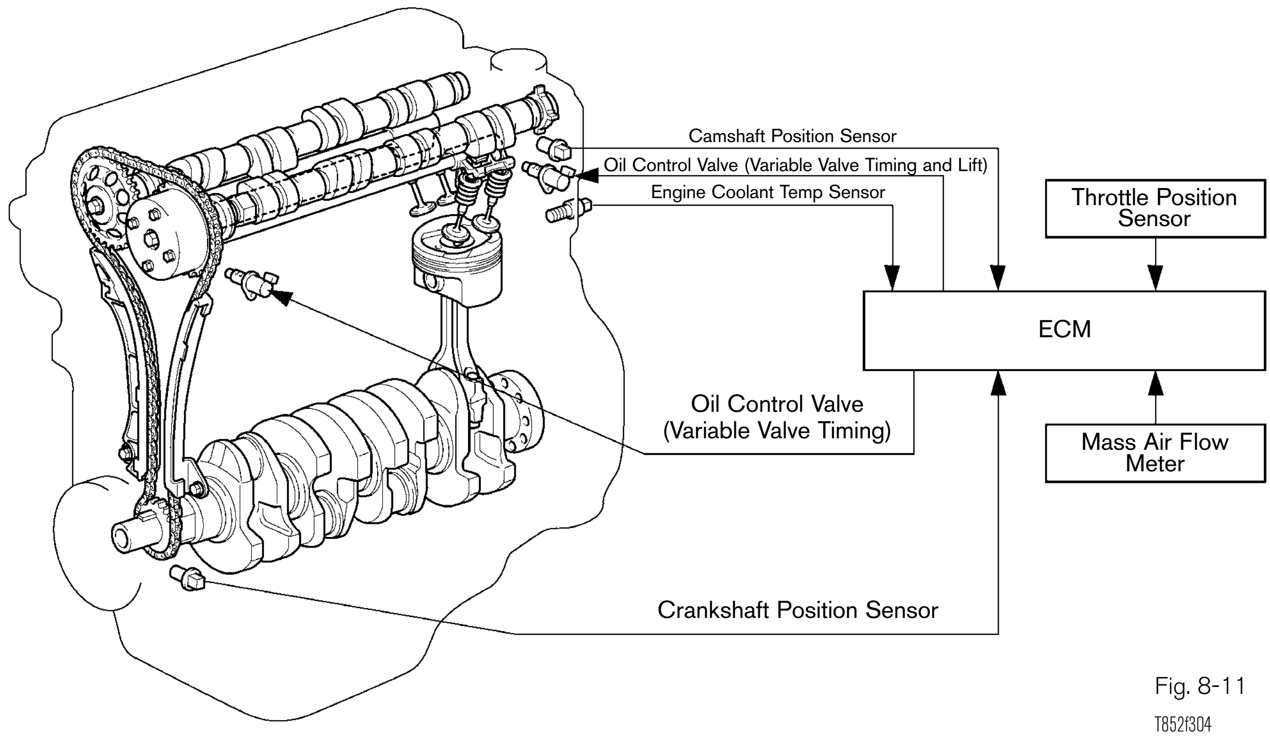


Fig. 8-11

T852f304

VVTL-i

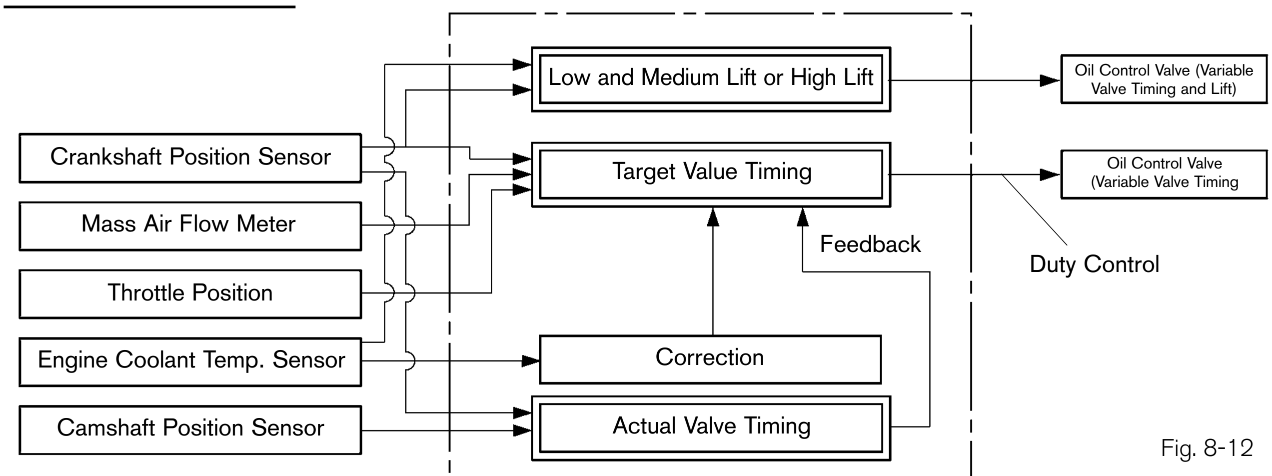


Fig. 8-12

T852f305

Variable Valve Timing Lift-intelligence System

Based on the VVT-i system, the Variable Valve Timing with Lift - intelligent (VVTL-i) system has adopted a cam changeover mechanism that changes the amount of lift and duration of the intake and exhaust valves while the engine is operating at high speeds. In addition to achieving higher engine speeds and higher outputs, this system enables the valve timing to be optimally set, resulting in improved fuel economy.

When the engine is operating in the low-to-mid-speed range, the low/medium-speed cam lobes of the camshafts operate to move the two valves via the rocker arms. Then, when the engine is operating in the high-speed range, the signals from the sensors cause the ECM to change the hydraulic passage of the oil control valve, thus changing to the high-speed cam lobes. Now, the lift and the duration of the intake and exhaust valves increases, allowing a greater volume of the air/fuel mixture to enter the cylinder, and a greater volume of the exhaust gases to leave the cylinder. As a result, the engine produces more power over a wider RPM range.

The construction and the operation of the valve timing control are basically the same as in the VVT-i system.

Camshaft Lobes

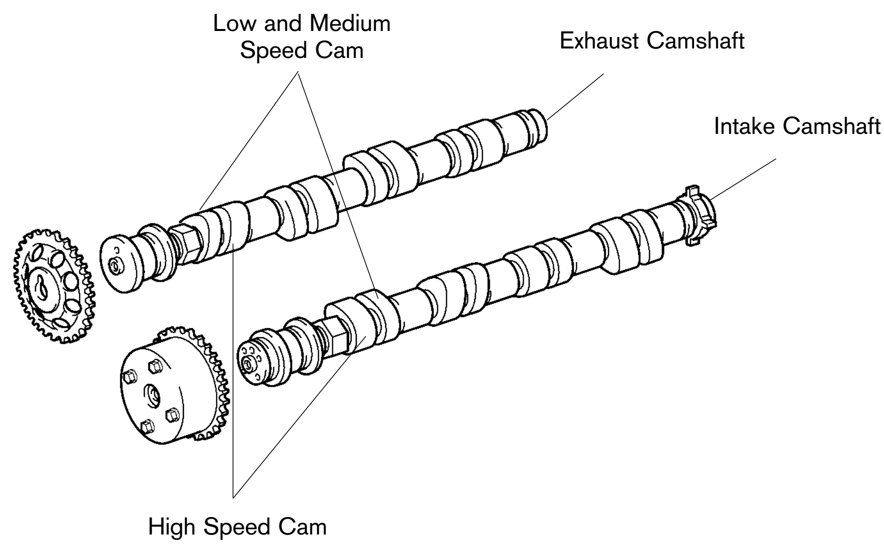


Fig. 8-13

T852f306

Rocker Arm Assembly

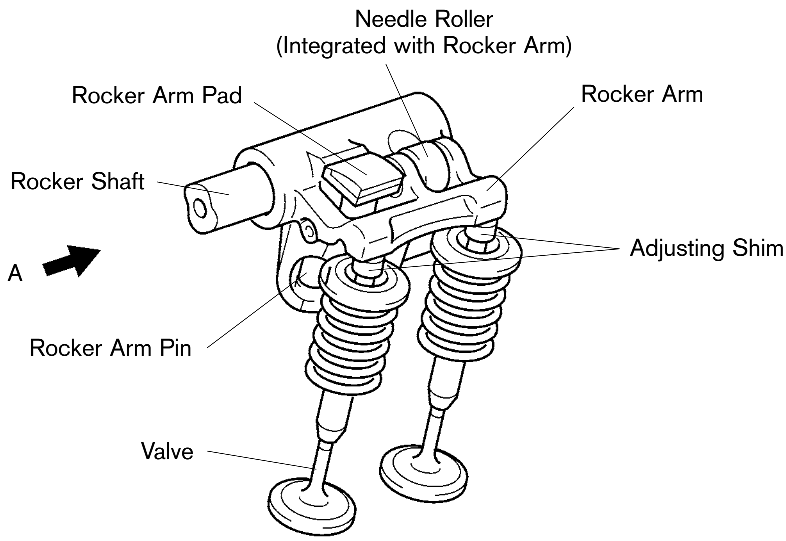
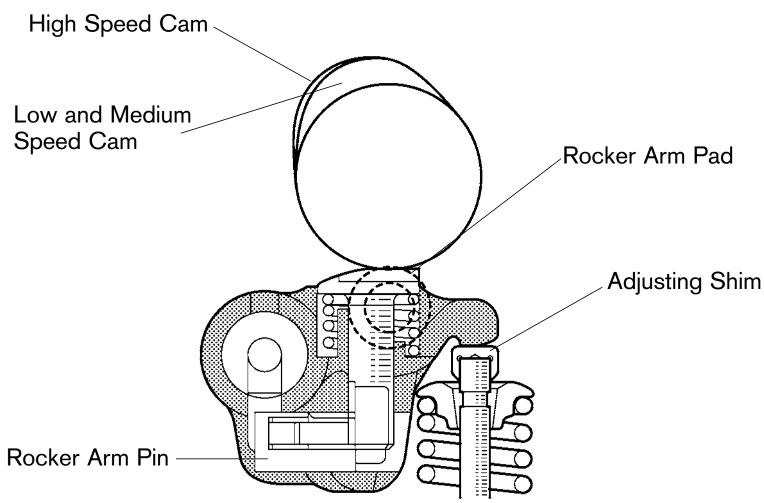


Fig. 8-14
T852f307

Construction

The main components of the rocker arm assembly are the rocker arm, rocker arm pad, rocker arm pin, and the rocker shaft. This assembly is used for both the intake and exhaust camshafts, with each connected to its respective rocker arm shaft. Both the intake and exhaust camshafts contain low and medium-speed cams and high-speed cams.

Rocker Arm Assembly (Cams)



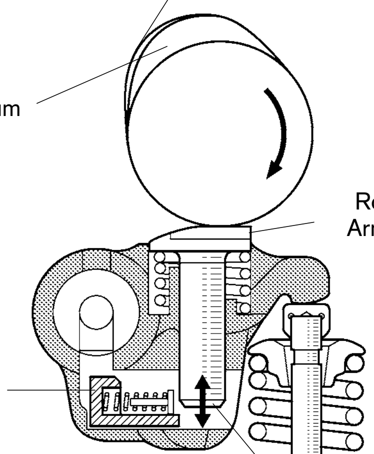
A of View

Fig. 8-15
T852f308

Operation When the engine coolant temperature is higher than 60°C (140°F) and the engine speed is higher than 6000 RPM, this system switches from the low/medium speed cams to the high-speed cams.

Low/Medium Speed Operation

When the engine is operating in the low-to mid-speed range (below 6000 RPM), the low and medium-speed cam pushes the needle roller of the rocker arm down to operate the two valves. At this time, the high-speed cam is also pushing down on the rocker arm pad, but because the rocker arm pad moves freely, this movement does not cause the rocker arm and the valves to move.



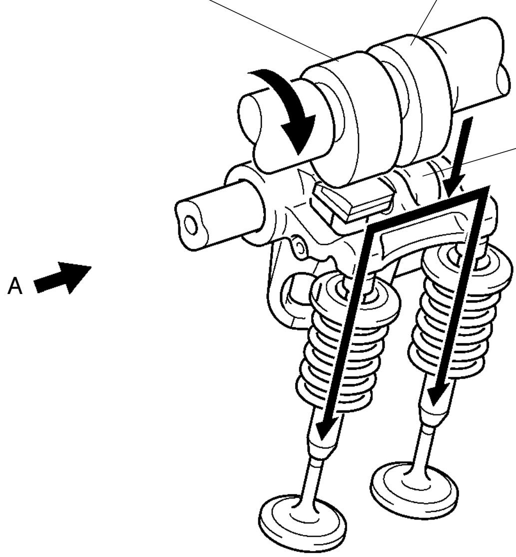


Fig. 8-16

T852f309/T852f310

High Speed

When the engine reaches a high speed (over 6000 RPM), oil pressure from the OCV pushes the rocker arm pin out to lock the bottom of the rocker arm pad. Now, the high-speed cam operates the two valves via the rocker arm pad and the rocker arm. Because the high-speed cam has a greater cam lift and duration than the low/medium-speed cam, the intake and exhaust valves are open a longer period of time.

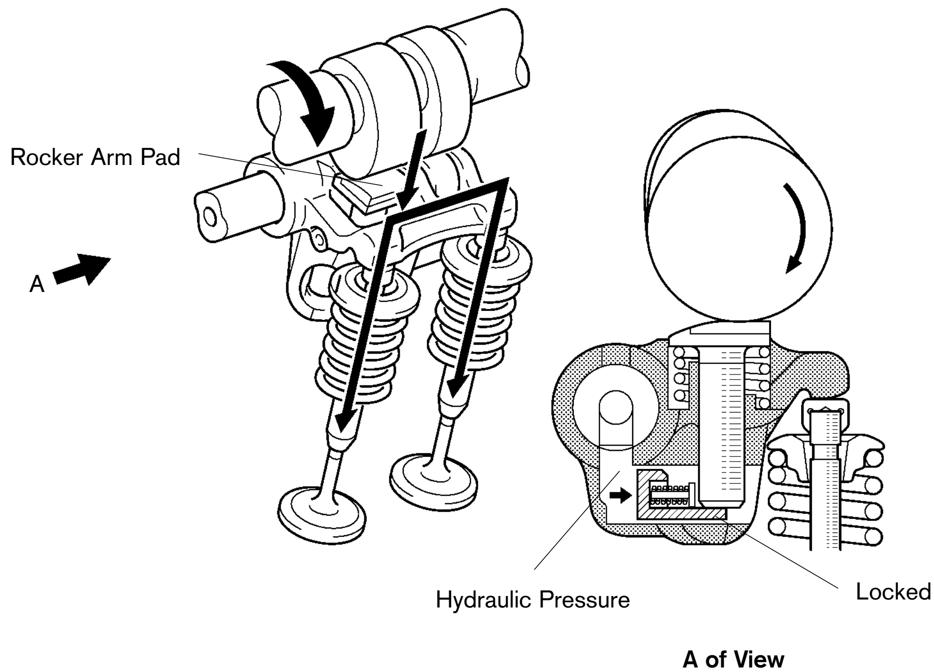


Fig. 8-17

T852f311/T852f312

Oil Control Valve

Spool valve position is controlled by the duty ratio signal from the ECM. When high speed operation is needed, oil pressure is directed to the high-speed cam side of the cam changeover mechanism.

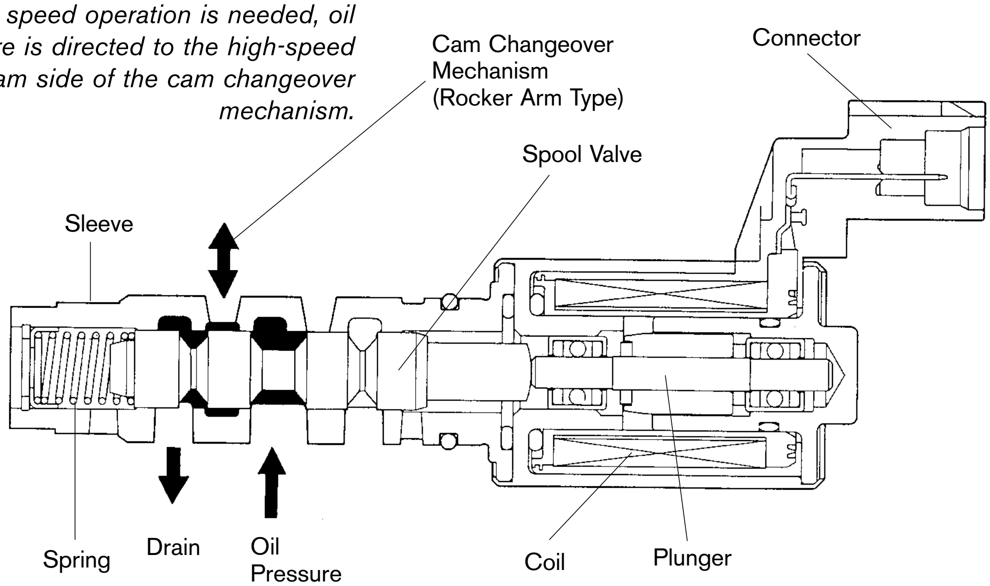


Fig. 8-18

T852f313

Low and Medium Speed Oil Flow

The oil control valve is open on the drain side so that the oil pressure will not be applied to the cam changeover mechanism.

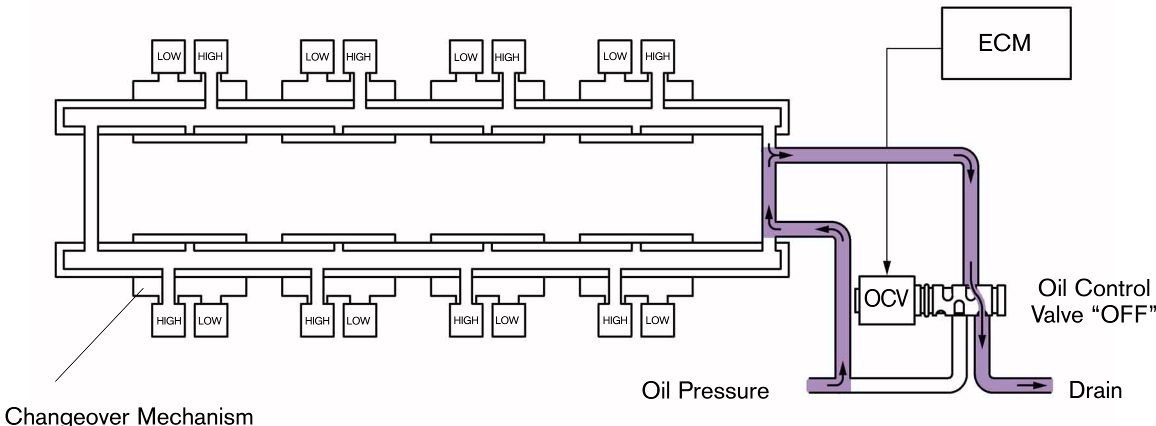


Fig. 8-19

T852f314

High Speed

The oil control valve closes on the drain side in order to apply the oil pressure to the high-speed cam of the cam changeover mechanism.

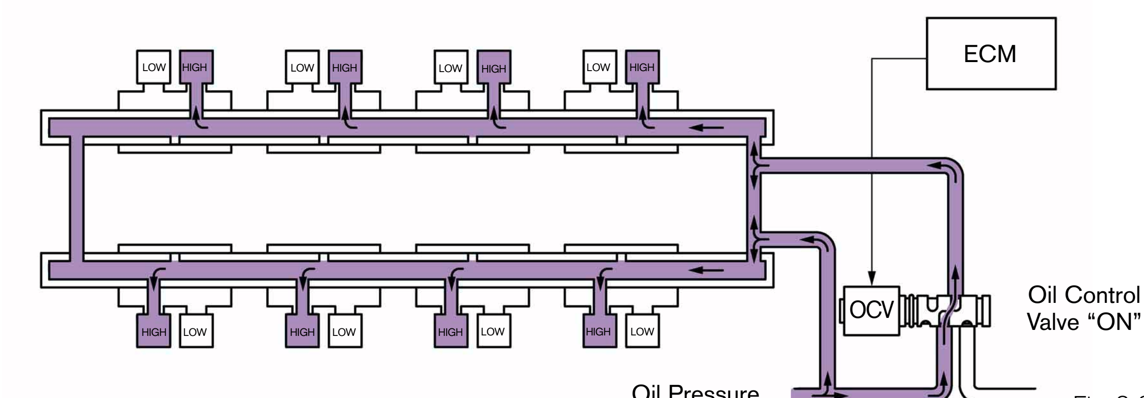


Fig. 8-20

T852f315

Oil Pressure Control

When the engine is operating in the low-to-mid-speed range, the oil control valve is open on the drain side so that the oil pressure will not be applied to the cam changeover mechanism. Then, when the engine reaches a high speed, the oil control valve closes on the drain side in order to apply the oil pressure to the high-speed cam of the cam changeover mechanism.

Acoustic Control Induction System (ACIS)

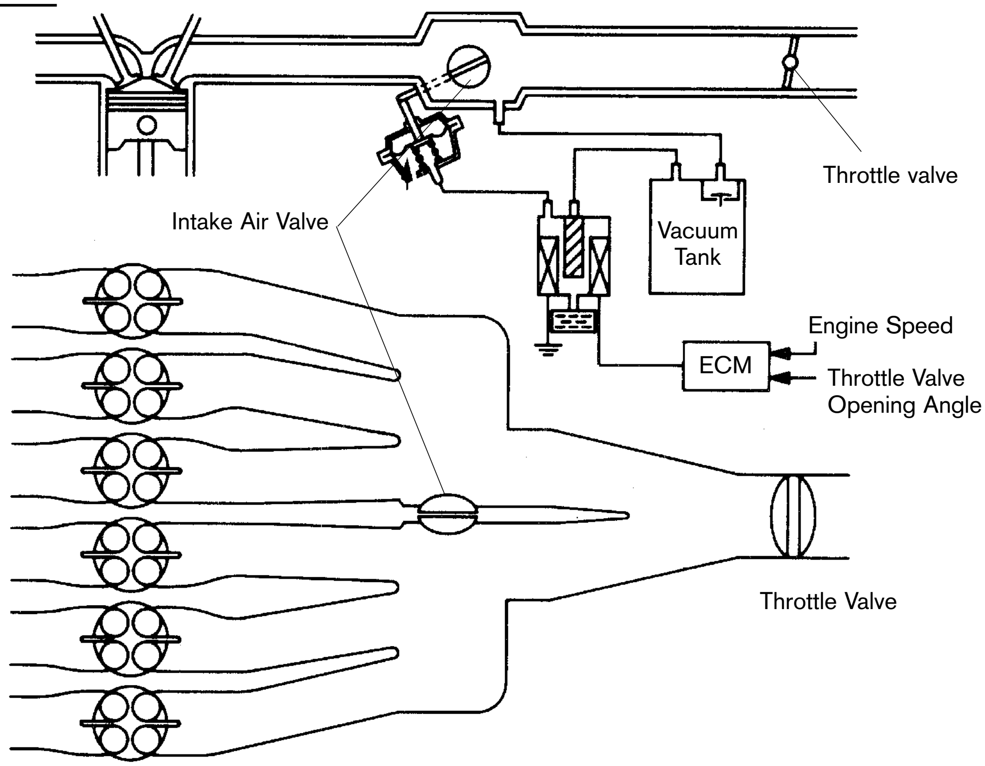


Fig. 8-21

T852f316

Acoustic Control Induction System (ACIS)

The Acoustic Control Induction System (ACIS) improves the torque in the whole RPM range, especially that in the low-speed range, by changing the intake manifold length in stages. The intake manifold length is varied in stages by optimum control of the intake air control valve(s). The air flow in the intake pipe pulsates due to opening and closing of the engine intake valves. When an intake valve is closed, the air near the valve is compressed by the inertia force. This compressed air pushes off the intake valve at high speed toward the intake chamber. If the intake manifold length and intake chamber shape are set to cause the compressed air pressure to return to an engine intake valve during the intake stroke, the intake air volume is increased improving volumetric efficiency. This is called the intake inertia effect. This improves torque and horsepower.

The ACIS changes the intake manifold length in stages according to the pulsating flow cycle that varies with the engine speed and throttle valve opening.

The ACIS is tuned for each type of engine. Vacuum stored in the vacuum chamber is applied to the intake control valve through the VSV. The VSV is switched on and off by the ECM. The intake control valve is switched according to engine speed and load.

There are two-stage and three-stage ACIS systems. The three-stage uses two VSVs.

2-Stage V-6 ACIS

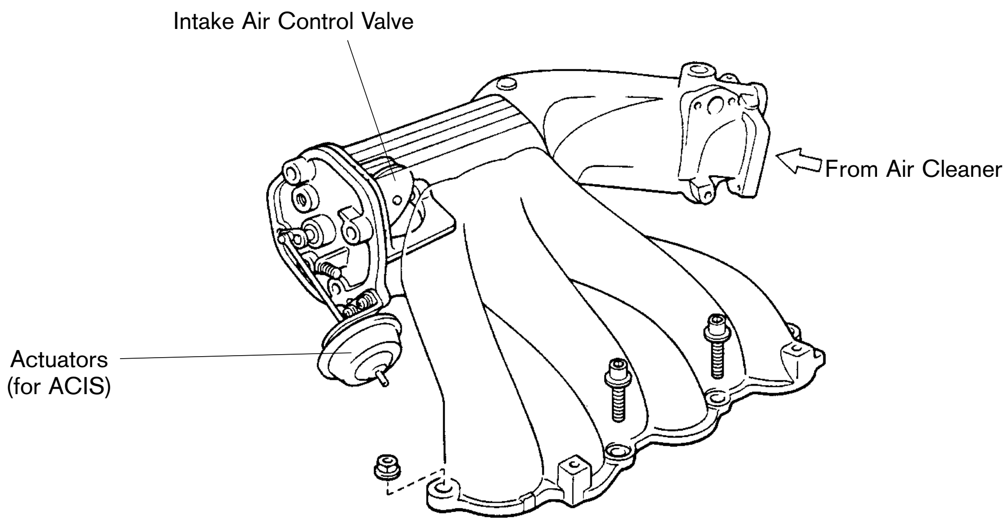


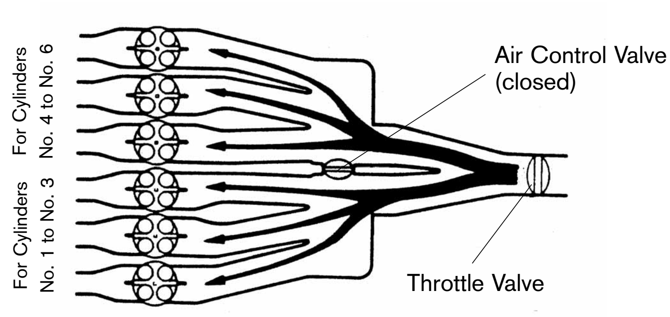
Fig. 8-22

T852f317

2JZ-FE ACIS

① VSV turned ON

Closing air control valve has the same effect as lengthening the intake manifold.



② VSV turned OFF

Opening air control valve has the same effect as shortening the intake manifold.

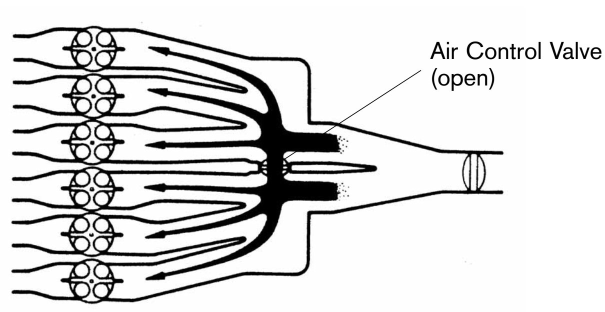
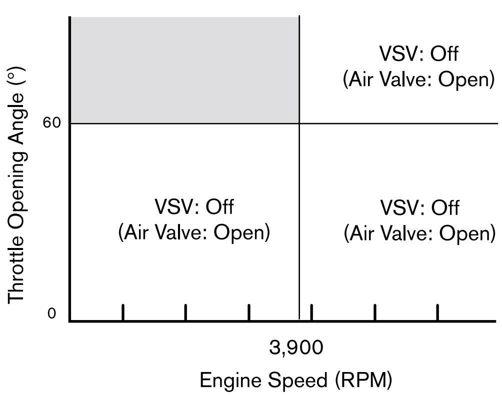


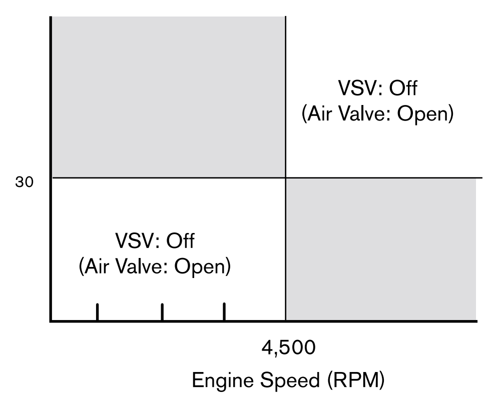
Fig. 8-23

T852f318/T852f319

1MZ-FE 2-Stage ACIS VSV Chart



1MZ-FE 2 Stage ACIS VSV chart.



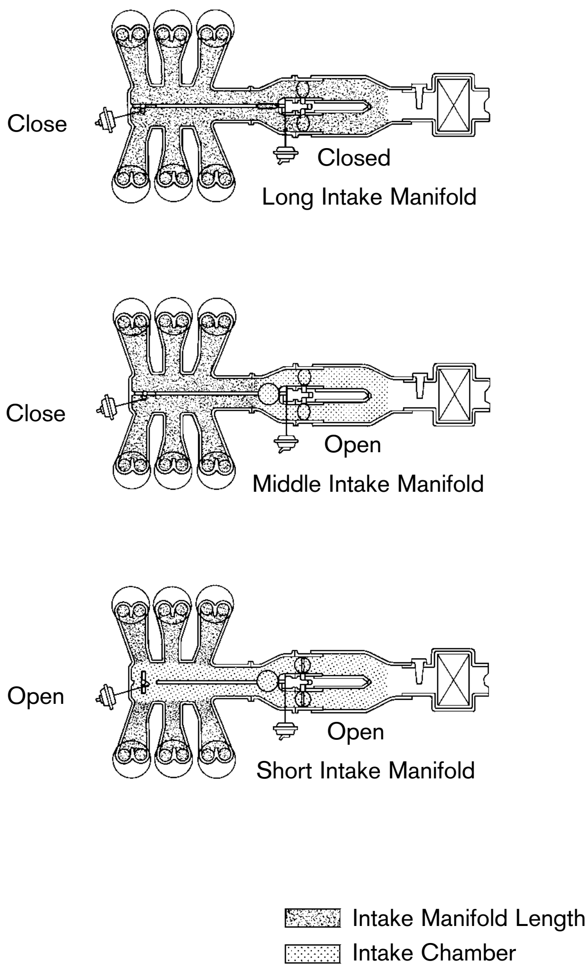
2JZ-FE 2 Stage ACIS VSV chart.

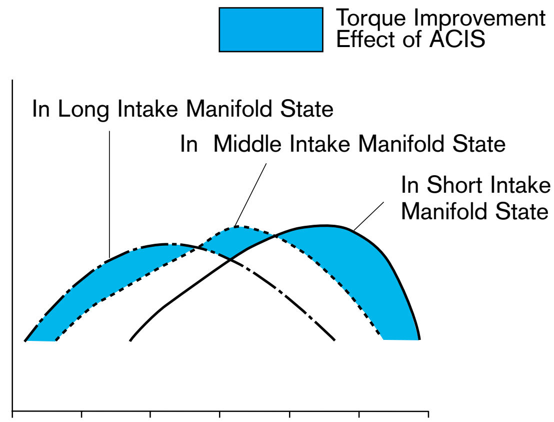
Fig. 8-24

T852f320

1MZ-FE 3-Stage ACIS

3-Stage ACIS System for greater control





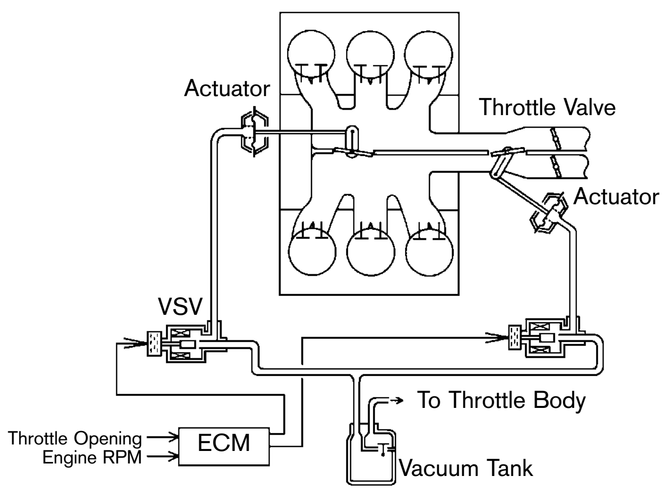


Fig. 8-25

T852f321/T852f324
T852f322/T852f325
T852f323/T852f326

ACIS VSV

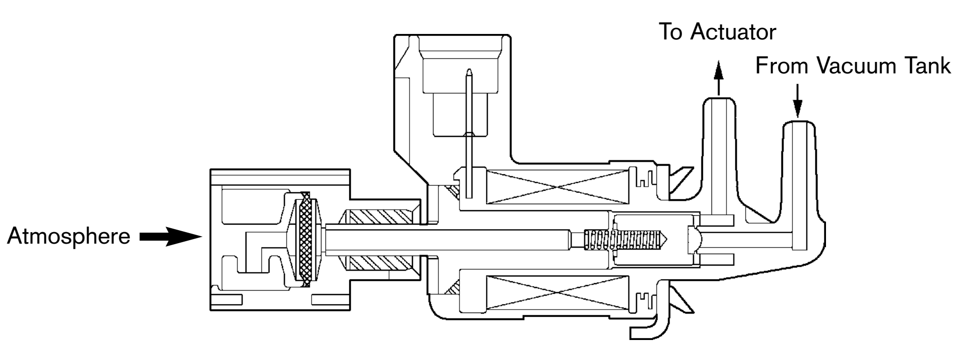
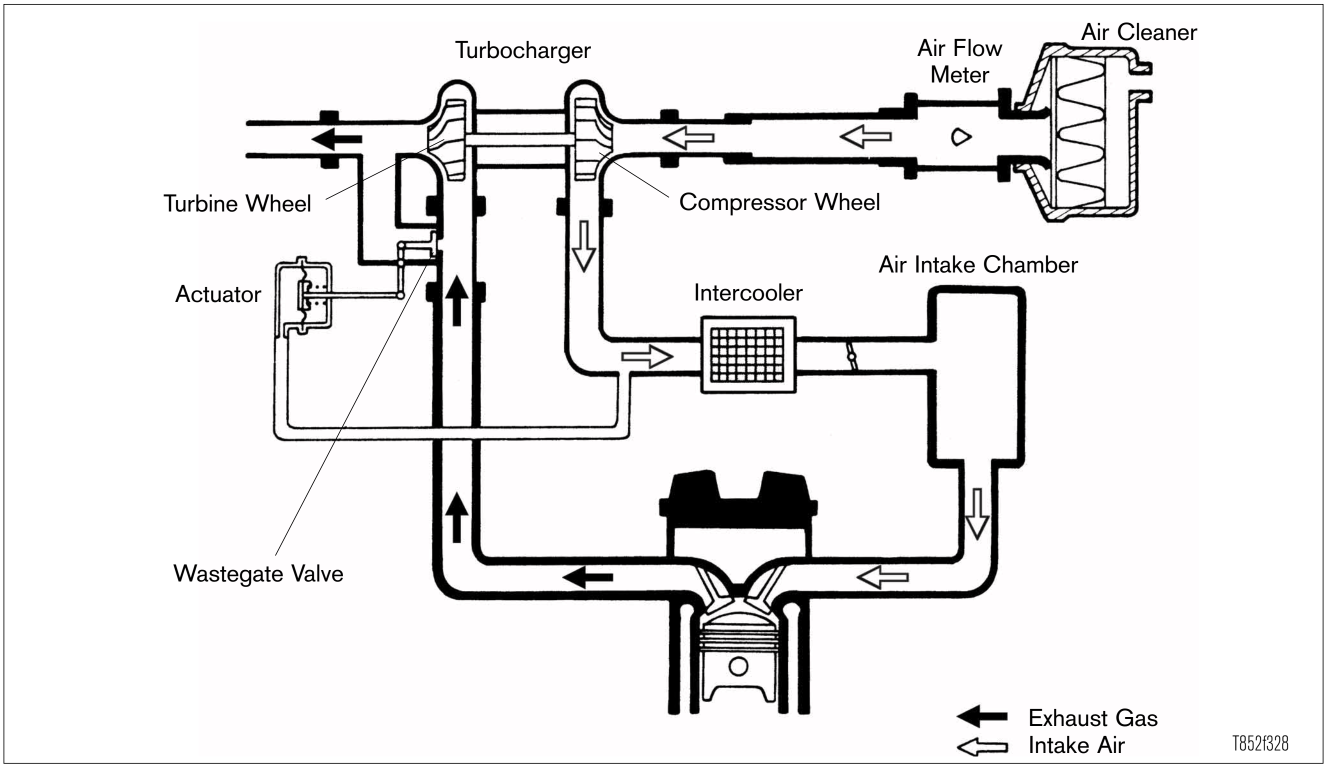


Fig. 8-26

T852f327

Section 9

Turbocharging & Supercharging Systems



Lesson Objectives 1. Familiarity with turbocharging systems and supercharging systems operations

Turbocharging & Supercharging Systems

Turbocharging System with Intercooler

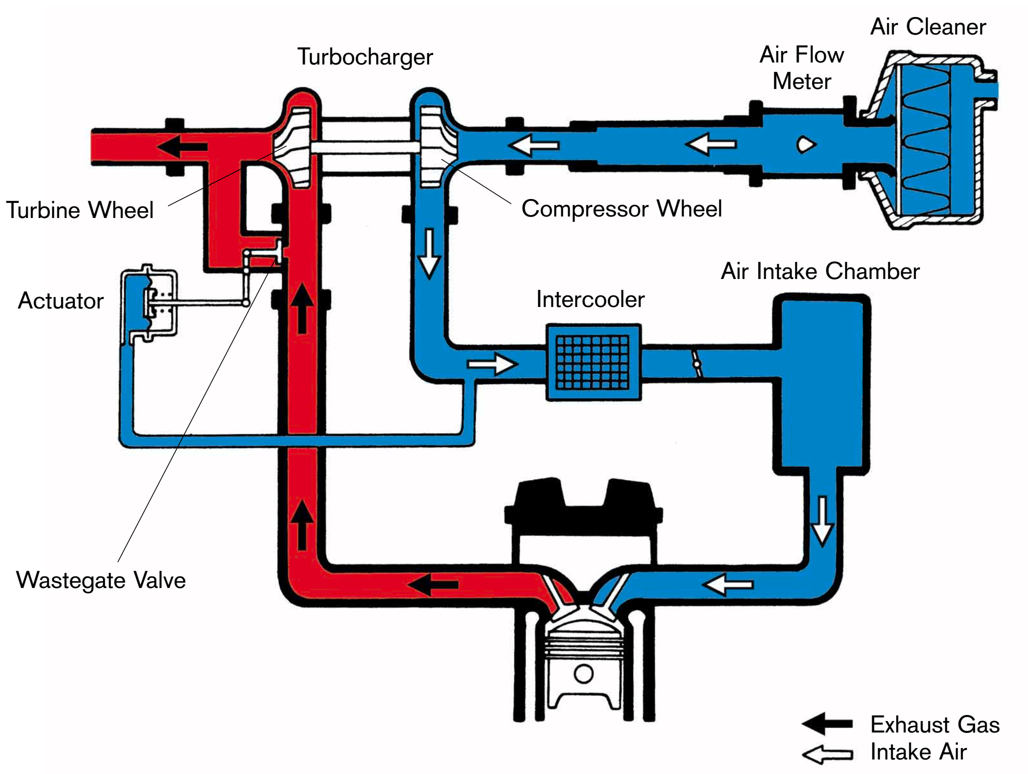


Fig. 9-01

T852f328

Turbocharging Systems

The turbocharger is basically an air pump that is designed to utilize some of the fuel's energy that would otherwise be wasted in the form of heat carried away by the exhaust gases. The exhaust gases drive the turbine wheel, that is coupled to the compressor wheel by means of a shaft. This compressor wheel is driven at high speeds, forcing more air into the cylinders. Since turbochargers use the wasted energy in the exhaust gases, the power output of the engine can be increased with less power loss. The turbocharger is provided with a waste gate valve to control the boost pressure on the intake air. Most turbocharged gasoline engines are also equipped with an intercooler to increase engine horsepower. The intercooler lowers the intake air temperature increasing air intake density.

Turbocharger Components

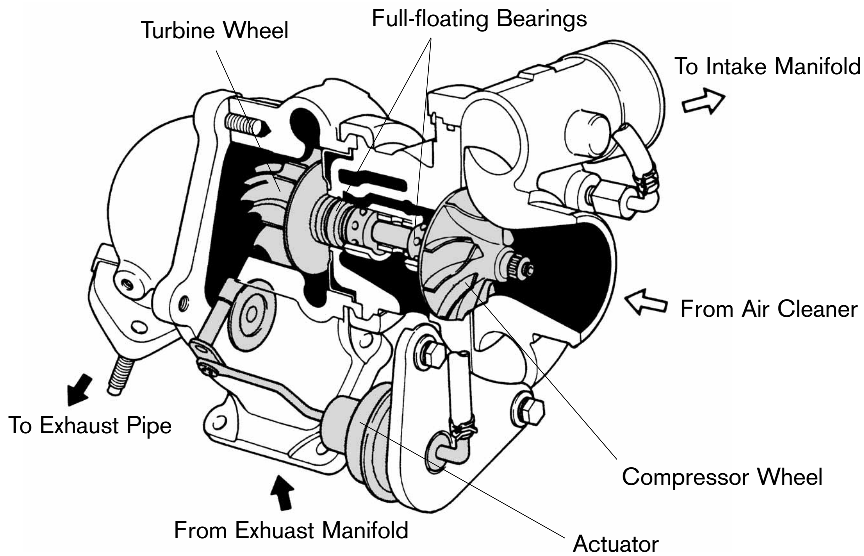


Fig. 9-02

T852f329

Components Turbine and Compressor

The turbine wheel and the compressor wheel are mounted on the same shaft. Exhaust gas flows from the exhaust manifold to the turbine wheel, and the pressure of the exhaust gas turns the turbine wheel. When the turbine wheel turns, the compressor wheel also turns, forcing the intake air into the cylinders. Since the turbine wheel is exposed directly to the exhaust gases, it becomes extremely hot; and, since it rotates at high speeds, and must be heat resistant and durable, it is made of an ultra-heat resistant alloy.

Center Housing Assembly Center Housing Assembly

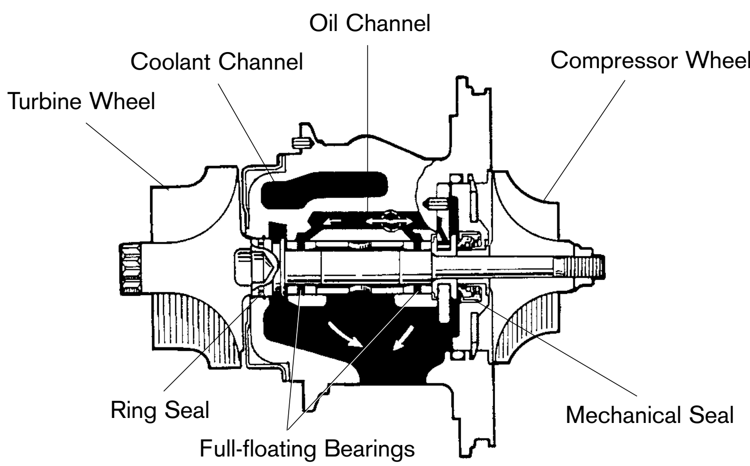


Fig. 9-03

T852f330

Center Housing

The center housing supports the turbine and compressor wheels via the shaft. Inside the housing, engine oil is circulated through channels that are provided for this purpose. Also, engine coolant is circulated through coolant channels that are built into the housing.

Full Floating Bearings

Since the turbine and compressor wheels turn at speeds of up to 100,000 rpm, full-floating bearings are used to ensure the absorption of vibrations from the shaft and to lubricate the shaft and bearings. These bearings are lubricated by the engine oil and rotate freely between the shaft and the housing to prevent seizing during high-speed operation. Engine oil is prevented from leaking by two ring seals or by a mechanical seal and a ring seal fitted to the shaft.

Wastegate Valve and Actuator

The waste gate valve is built into the turbine housing. Its purpose is to reduce the boost pressure when this begins to rise too high. When this valves opens, part of the exhaust gas bypasses the turbine wheel and flows to the exhaust pipe. The opening and closing of the waste gate valve is controlled by the actuator.

Lubrication

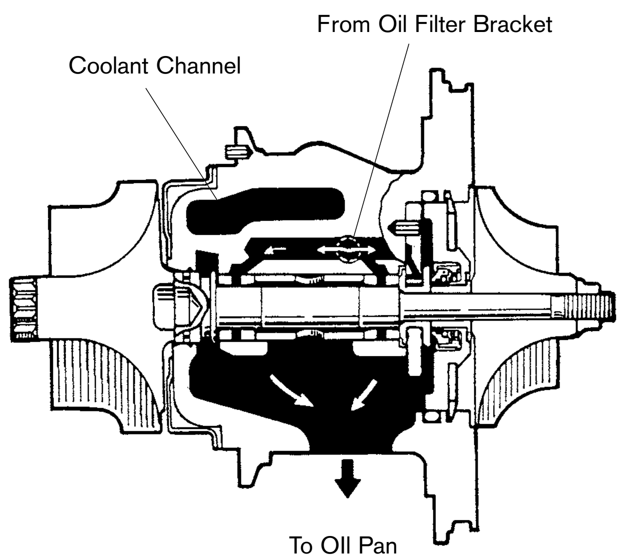


Fig. 9-04

T852f331

Lubrication

In order to lubricate the full-floating bearings inside the center housing, engine oil is supplied from the oil inlet pipe and circulated among the bearings.

After lubricating the bearings, this oil passes through the oil outlet pipe and returns to the oil pan.

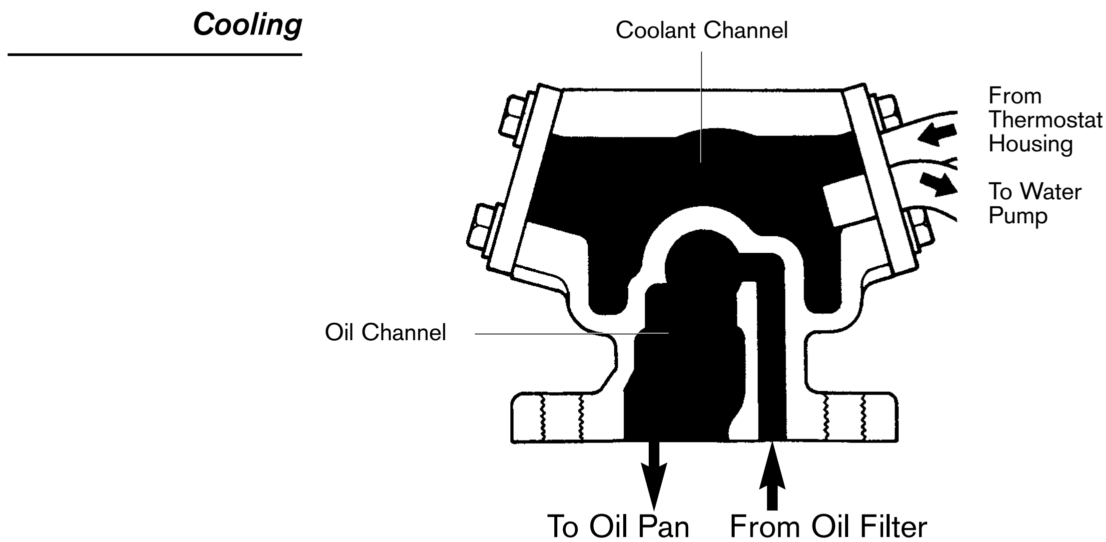


Fig. 9-05
T852f332

Cooling The turbocharger is cooled by engine coolant. Engine coolant is sent from the thermostat housing and introduced into the coolant channel (provided in the center housing) via the coolant inlet pipe. After cooling the turbocharger, the coolant passes through the coolant outlet pipe and returns to the water pump.

Boost Pressure Control

A turbocharger attains a high output by boosting the pressure of the air fed into the cylinders, but if the boost pressure rises too high, the explosive force created by combustion of the air/fuel mixture will become too great and the engine will be unable to withstand the pressure. Therefore, boost pressure is controlled by the actuator and waste gate valve. With some gasoline engines, the boost pressure is also controlled in accordance with the octane rating of the fuel used (premium or regular gasoline).

Wastegate Closed As long as the boost pressure inside the intake manifold cannot overcome the spring in the actuator, the actuator will not operate and the waste gate valve remains closed. All exhaust gas is therefore routed into the turbine housing.

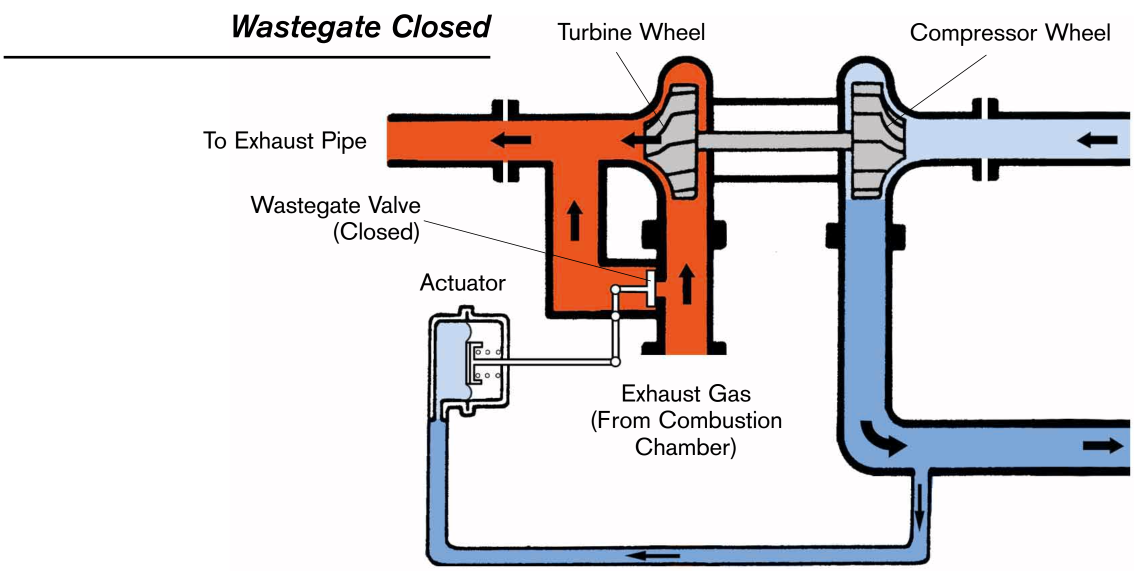


Fig. 9-06

T852f333A

Wastegate Opened As the accelerator pedal is depressed, fuel injection volume and exhaust gas pressure increase, thus increasing the boost pressure. When the boost pressure overcomes actuator spring pressure, that is, the intercept point, the waste gate valve is opened by the actuator (because of the combined forces of the exhaust gas pressure on the waste gate valve and the boost pressure on the actuator diaphragm) and part of the exhaust gas is diverted around the turbine wheel. As a result, the turbine speed is kept within the optimal range to prevent the boost pressure from rising excessively.

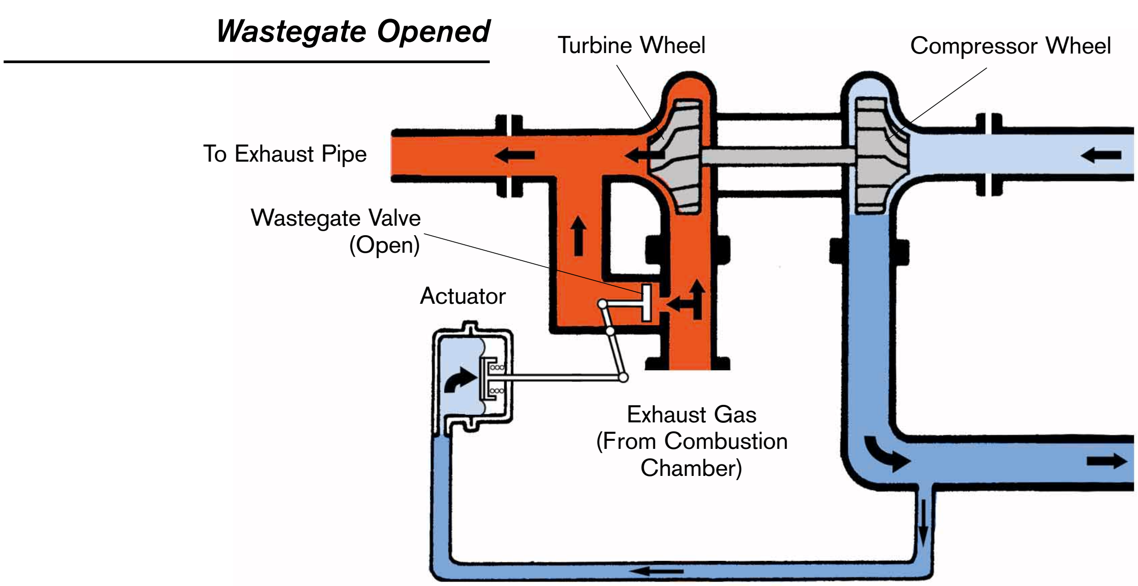


Fig. 9-07

T852f333B

ECM Boost Control

The boost pressure is basically controlled by the actuator and waste gate valve as mentioned previously. In some gasoline engines, the boost pressure also is controlled in two patterns in accordance with the type of fuel used (premium or regular gasoline). This maximizes engine performance and maintains engine durability, as well as suppressing knocking under all engine running conditions, including during warm-up, irrespective of the gasoline octane rating.

Pressure at the inlet side of the compressor housing is introduced into the actuator via the VSV (Vacuum Switching Valve) which is controlled by the ECM. The ECM turns the VSV ON or OFF depending on whether premium or regular gasoline is being used (as determined by the knock sensor signal) and engine conditions. The VSV stays OFF when regular gasoline is used.

Boost Pressure vs. Engine Speed

The relationship between the engine speed and boost pressure when the accelerator pedal is fully depressed is shown in the graph at the right. These characteristics will vary depending upon the load that is placed upon the engine.

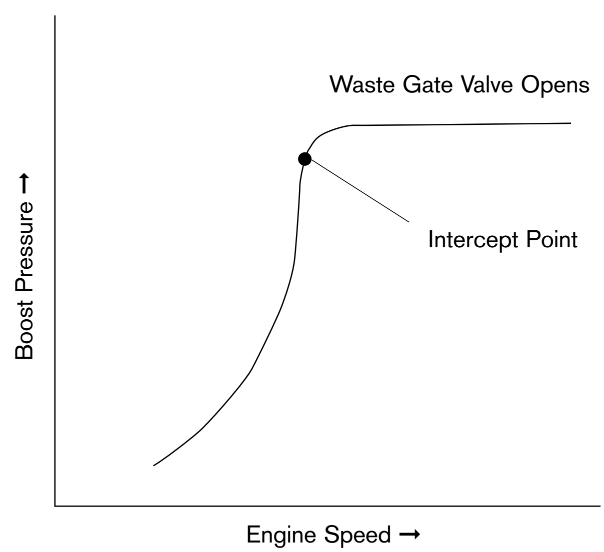


Fig. 9-08
T852f335

ECM Boost Control

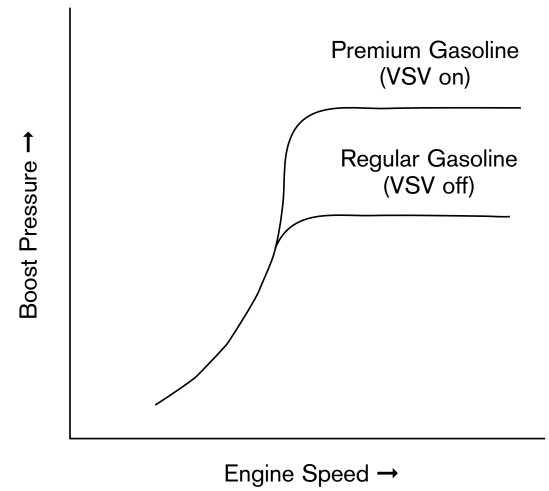


Fig. 9-09

T852f336

VSV ON

When the VSV goes ON, the pressure applied to the actuator escapes to the inlet side of the compressor housing. As a result, this pressure (Pa) becomes lower than the boost pressure (PB). The result is a higher boost needed to overcome spring pressure in the actuator and open the wastegate.

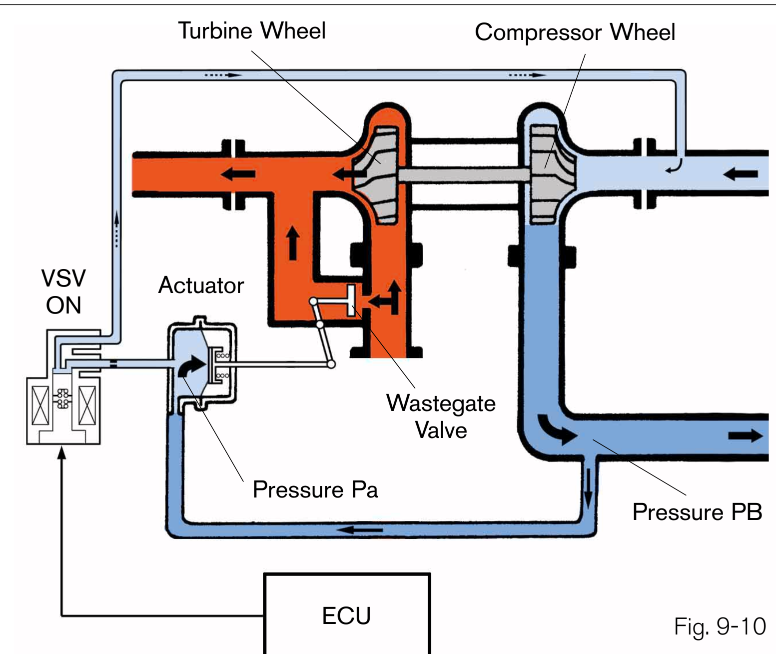


Fig. 9-10

T852f333C

VSV OFF

As long as the VSV is OFF, the boost pressure (PB) is applied directly to the actuator

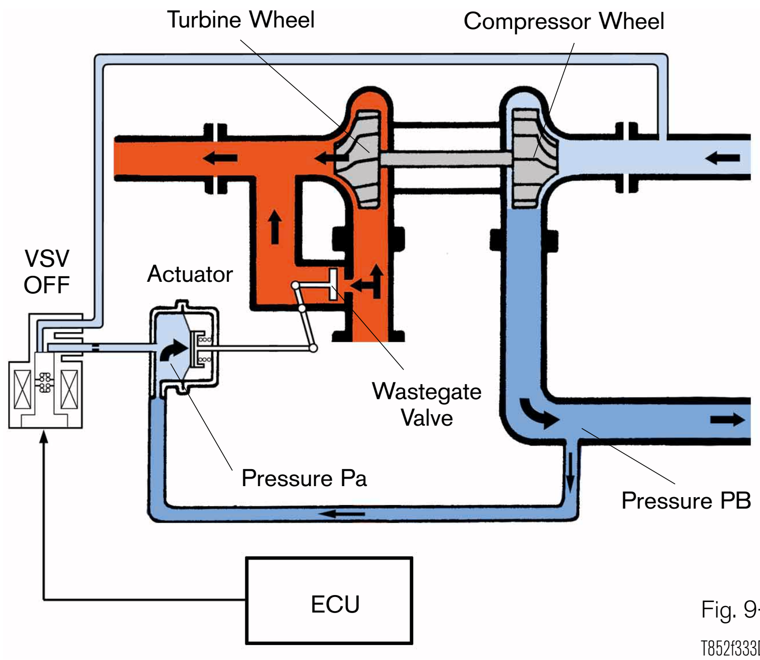


Fig. 9-11

T852f333D

Two-Way Twin-Turbocharger System

In place of the single turbocharger system used in the 7M-GTE engine, the 2JZ-GTE engine adopts the Two-Way Twin-Turbocharger System. Under this system, the two compact turbochargers provide separate functions according to the engine running condition. While one turbocharger gives boost at low rpm and low engine load conditions, the two turbochargers together give boost at high rpm and high engine load conditions for increased output.

Two-Way Twin-Turbocharger System

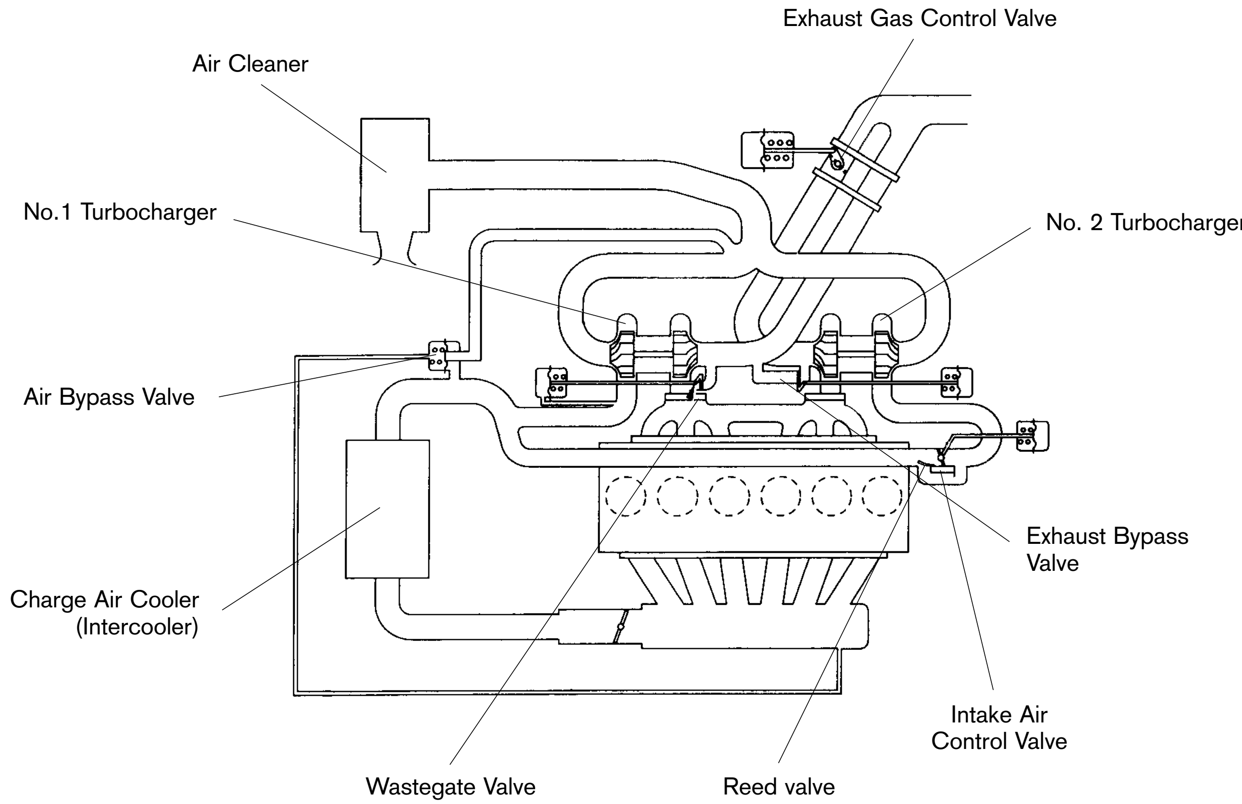


Fig. 9-12

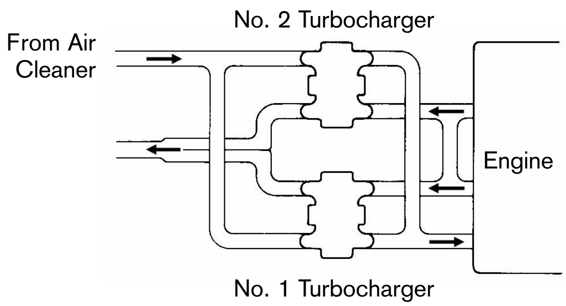
T852f339A

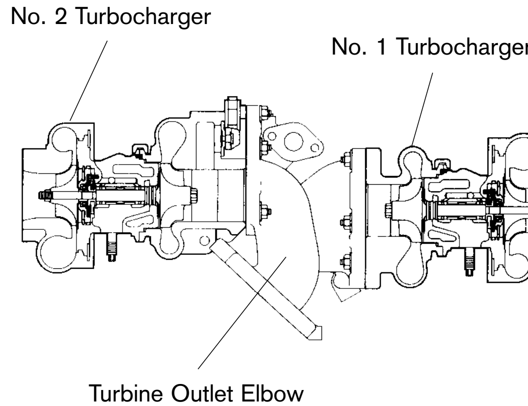
Components of Two-Way Twin-Turbocharger System

Twin-Turbochargers - By directly mounting the twin-turbocharger assembly onto the exhaust manifolds, the exhaust gas travel is made extremely short and direct. This results in an efficient transmission of power to the turbochargers with a minimal exhaust gas pressure loss.

Twin-Turbocharger Assembly

The twin-turbocharger assembly consists of the No. 1 turbocharger, No. 2 turbocharger, and turbine outlet elbow.





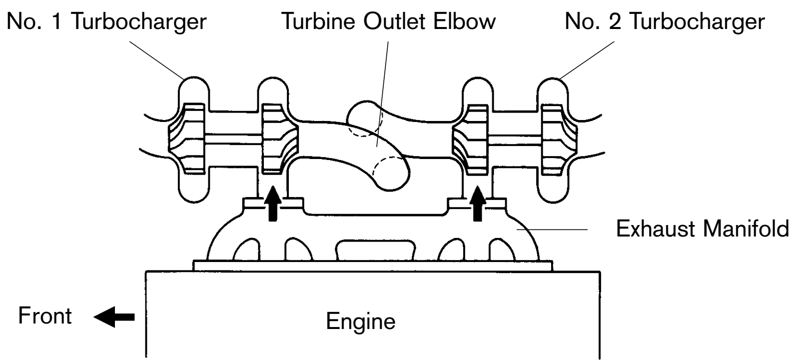
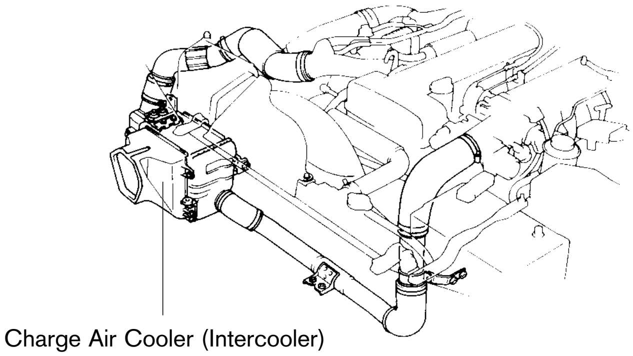


Fig. 9-13

T852f340/T852f341
T852f342

Charge Air Cooler (Intercooler) - The intercooler, located between the turbocharger and intake manifold, cools the intake air increasing air density and therefore engine power.

Charge Air Cooler



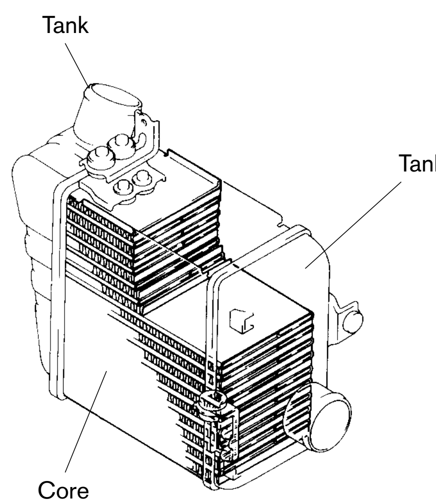


Fig. 9-14

T852f343/T852f344

Control Valves

There are six control valves used in the Two-Way Twin-Turbo System.

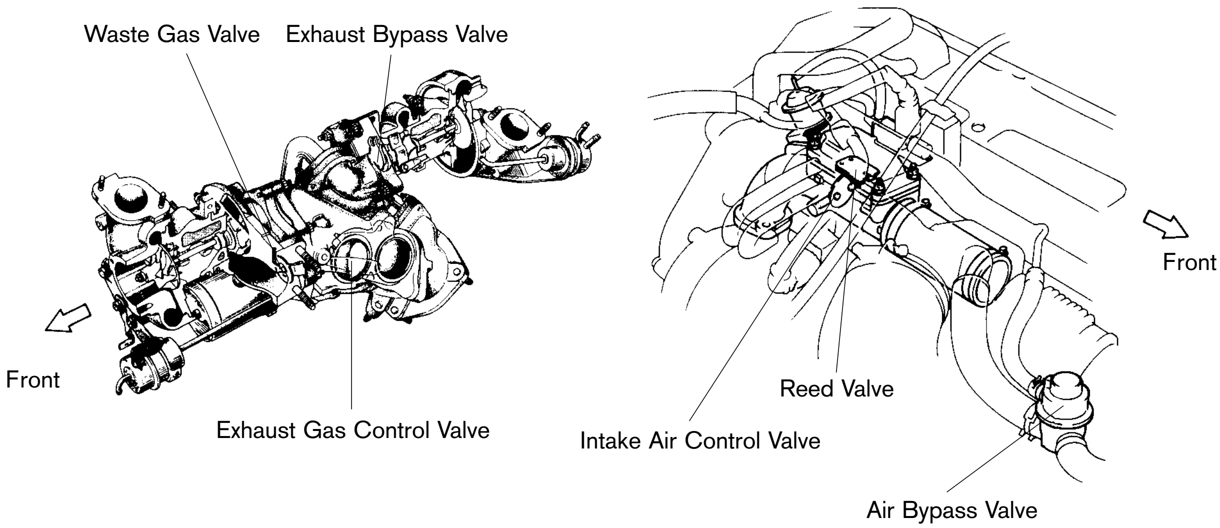


Fig. 9-15

T852f345/T852f346

Intake Air Control Valve - Located downstream of the No. 2 turbocharger intake airflow, during No. 2 turbocharger start/stop operation it permits or stops the flow of intake air through the No. 2 turbocharger.

Exhaust Gas Control Valve - Made of ceramic, and located downstream of the No. 2 turbocharger exhaust gas flow, during No. 2 turbocharger start/stop operation it permits or stops the flow of exhaust gas through the No. 2 turbocharger.

Waste Gate Valve - Integrated into the No. 1 turbocharger, this valve controls the boost pressure of the entire system by bypassing a portion of the exhaust gas flowing through the No. 1 turbocharger during a two-turbocharger boost operation.

Exhaust Bypass Valve - Integrated into the No. 2 turbocharger, this valve controls the boost pressure of the entire system by bypassing the exhaust gas from the No. 2 turbocharger during a single-turbocharger boost operation (when only the No. 1 turbocharger is boosting). At the same time, this bypass allows the turbine wheel of the No. 2 turbocharger to start spinning ahead of the starting of the No. 2 turbocharger operation.

Reed Valve - Immediately following the start of the No. 2 turbocharger operation, the intake air control valve is closed. This causes a quick rise in the intake air pressure between the No. 2 turbocharger and the intake air control valve. The reed valve controls the intake air pressure by bypassing a portion of this high-pressure intake air downstream of the reed valve.

Air Bypass Valve - When the throttle valve is quickly released during boosting, the intake air pressure between the turbocharger and the throttle valve increases rapidly. The air bypass valve diverts a portion of this high-pressure intake air upstream of the turbocharger, thereby controlling the boost pressure, and reducing the pulsing noise.

Twin-Turbocharger System

In this system, the separate functions of the two turbochargers are achieved by controlling the operation of the No. 2 turbocharger. This is accomplished by using control valves to allow or stop the intake air and exhaust gas flow. Although the No. 2 turbocharger's basic start/stop operation timing is determined by the engine speed, the timing is varied according to the engine load.

Twin Turbo Operation

Region A: low rpm, low engine load.

Region B: high rpm, high engine load.

TC1: Only the No. 1 turbocharger operating.

TC1 + TC2: Both the No. 1 and No. 2 turbochargers operating.

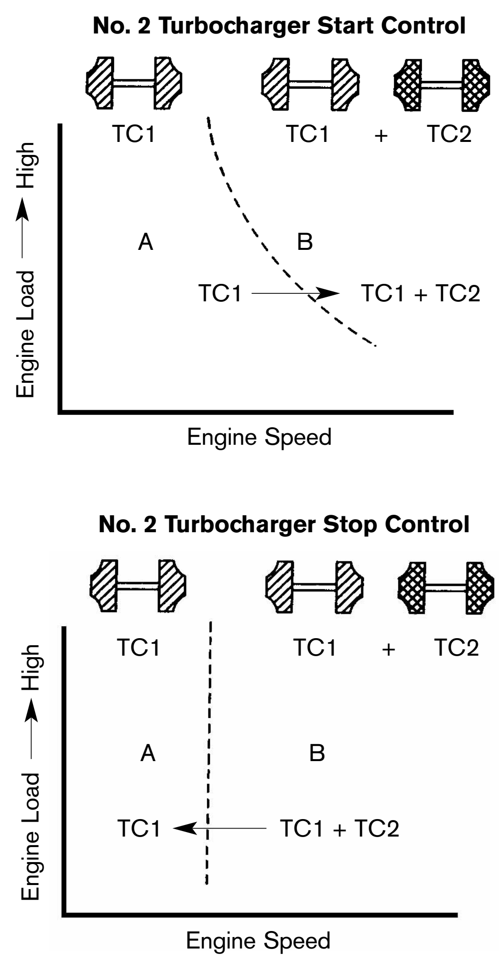


Fig. 9-16

T852f347/T852f348

Single-Turbocharging Phase

Since the actuators for the intake air control valve and exhaust gas control valve are inactive during low engine rpm operation, these valves remain closed. The waste gate valve is also closed, and only the No. 1 turbocharger will provide the boost pressure. When the intake air turbocharging pressure downstream from the No. 1 turbocharger reaches a predetermined level, the exhaust bypass valve executes a boost pressure control. At the same time, the exhaust bypass valve opens to supply the exhaust gas to the turbine side of the No. 2 turbocharger, causing the No. 2 turbocharger turbine wheel to start rotating. Accordingly, when the No. 2 turbocharger starts boosting, this process can smooth out the joining of the boost pressures.

Single-Turbocharging Phase

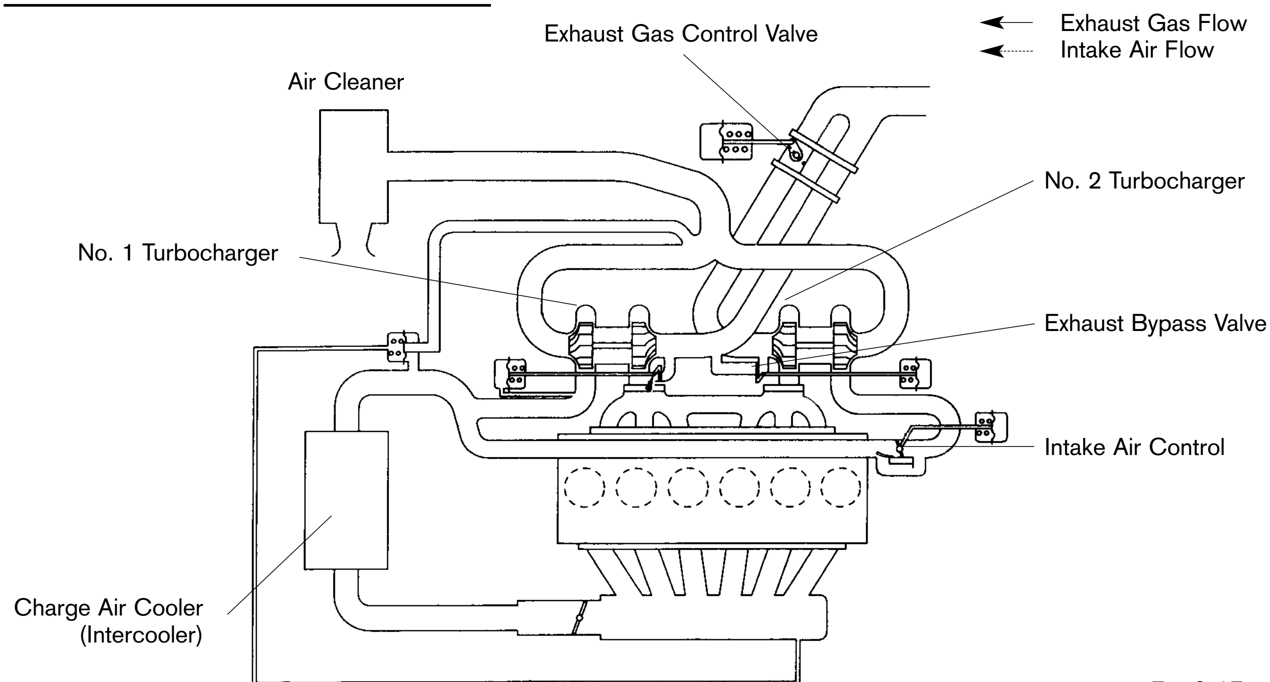


Fig. 9-17

T852f339B

Valve Condition (*Single-Turbocharging*)

Intake Air Control Valve	Exhaust Gas Control Valve	Exhaust Bypass Valve	Waste Gate Valve
Close	Close	Activated	Close

Single-Turbocharging/Twin-Turbocharging Transition Operation

When the engine operation passes from the low-rpm to the high-rpm region, first the exhaust gas control valve opens; this is followed by the opening of the intake air control valve. When the exhaust gas control valve opens, it causes the No. 2 turbocharger turbine wheel, which had already begun its rotation, to quickly raise its rpm. Thus, the pressure of the intake air flowing through the No. 2 turbocharger becomes higher than that of the intake air of the No. 1 turbocharger.

Since this high pressure intake air pushes open the reed valve described below and flows to the No. 1 turbocharger side, further rise in pressure is averted. Then, when the intake air control valve opens, the highly pressurized intake air smoothly joins the intake air coming from the No. 1 turbocharger.

Conversely, when the engine operation passes from the high-rpm to low-rpm region, in order to stop the No. 2 turbocharger, the valves close in an order opposite to the one described above. The intake air control valve closes first, followed by the closing of the exhaust gas control valve.

Twin-Turbocharging Operation

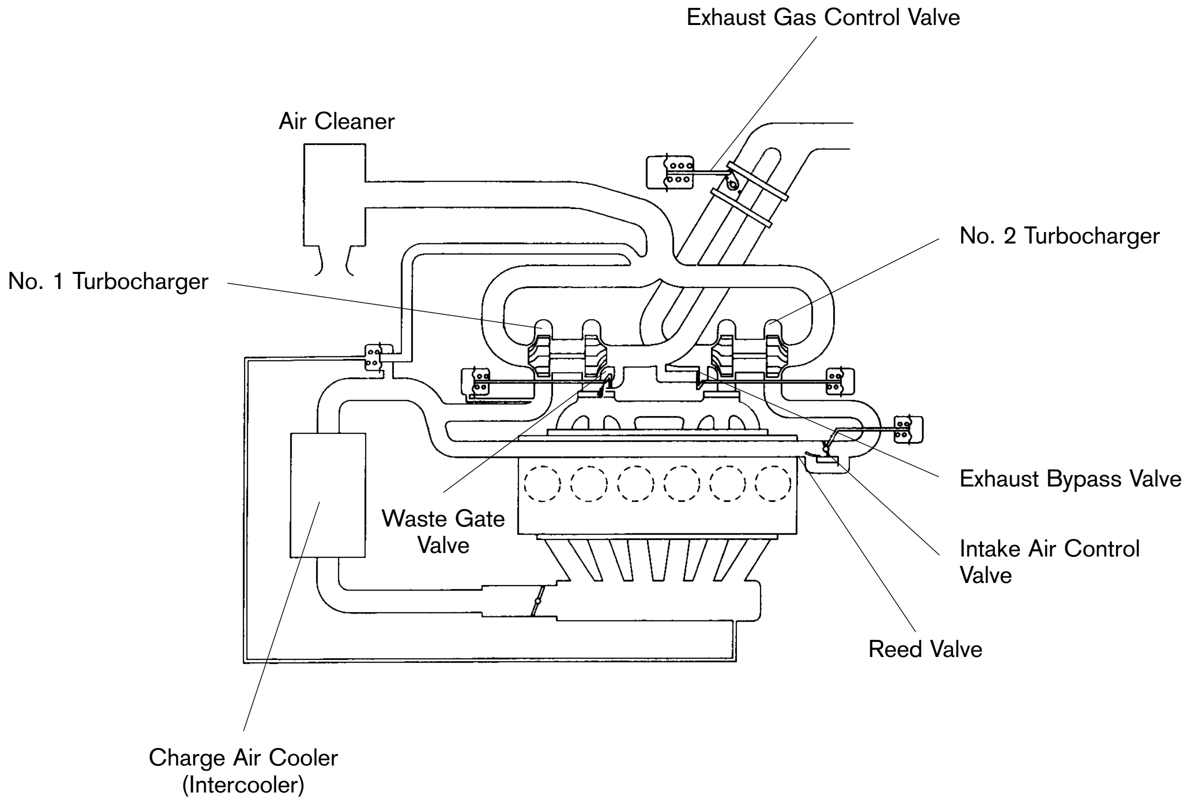


Fig. 9-18

T852f339C

Valve Condition (*Single-Turbocharging* ⟶ *Twin-Turbocharging Transition*)

Intake Air Control Valve	**Exhaust Gas Control Valve**	**Exhaust Bypass Valve**	**Waste Gate Valve**
Close ⟶ Open	Close ⟶ Open	Activated ⟶ Open	Close

Valve Condition (*Twin-Turbocharging* ⟶ *Single-Turbocharging Transition*)

Intake Air Control Valve	**Exhaust Gas Control Valve**	**Exhaust Bypass Valve**	**Waste Gate Valve**
Open ⟶ Close	Open ⟶ Close	Open	Activated ⟶ Close

Valve Condition (*Twin Turbocharging*)

Intake Air Control Valve	Exhaust Gas Control Valve	Exhaust Bypass Valve	Waste Gate Valve
Open	Open	Open	Activated

Operation of Twin-Turbocharging

The exhaust gas control valve and intake air control valve are open, allowing the No. 1 and No. 2 turbochargers to boost. At this time, even if the exhaust bypass valve operates, it cannot effect any boost pressure control, since it is located downstream of the No. 2 turbocharger. During a high rpm operation, it is the waste gate valve that executes the boost pressure control of the entire system, in place of the exhaust bypass valve.

Turbocharger Handling Precautions

The turbocharger is a precision-built part, but since its design is very simple, it is also very durable if a few simple precautions concerning its use and care are observed. The turbocharger operates under extremely severe conditions: the turbine wheel is exposed to exhaust gases whose temperatures reach as high as 900°C (1,652°F) when the engine is running at maximum load, and the rotating assembly rotates at speeds of up to 100,000. Therefore, that which has the greatest effect upon the performance and durability of the turbocharger is the lubrication of the bearings that support the turbine and compressor wheels. Consequently, to provide lasting, trouble-free operation, the following precautions must be observed: the engine oil becomes hot very quickly due to its use in both cooling and lubricating the turbocharger, so it deteriorates rapidly. For this reason, engine oil and oil filter maintenance should be carried out faithfully. The replacement intervals of the engine oil and oil filter are determined by the conditions under which the vehicle is used and/or the countries/regions in which the vehicle is to be sold. Therefore please refer to the appropriate Maintenance Procedures manuals for the correct replacement intervals. Be sure to use the appropriate types of engine oil for turbocharged engines.

Since the bearings are not sufficiently lubricated immediately after the engine is started, racing or sudden acceleration of the engine should be avoided. The following conditions are especially likely to lead to premature wearing of or damage to the bearings unless the engine is allowed to idle for at least 30 seconds after starting:

- Operating the engine immediately after the engine oil and/or oil filter are changed.
- Running the engine after it has not been used for more than about half a day.
- Starting the engine in cold weather.

Do not stop the engine immediately when pulling a trailer or after high-speed or uphill driving. Idle the engine for 20-120 seconds, depending on the severity of the driving conditions.

During high-speed driving, the turbine wheel is exposed to very hot exhaust gases, and its temperature rises extremely high. Since the temperature of the shaft linking the turbine wheel to the compressor wheel is cooled by oil and coolant, however, its temperature does not rise as high. Nevertheless, if the engine is stopped immediately after high-speed driving, circulation of oil and coolant will stop, and the temperature of the shaft will suddenly rise due to the high temperature of the turbine wheel. Therefore, letting the engine idle before shutting it off will allow the shaft to cool off gradually. (This is because the temperature of the exhaust gas is lower (300°~400°C (573°~752°F) during idling.)

Turbocharger Service Precautions

If the engine is run with the air cleaner, air cleaner case cover or hose removed, foreign particles entering will damage the turbine and compressor wheels because they rotate at extremely high speeds.

If the turbocharger malfunctions and must be replaced, first check the following items for the cause of the problem and remedy as necessary:

- Engine oil level and quality.
- Conditions under which the turbocharger was used.
- Oil lines leading to the turbocharger.

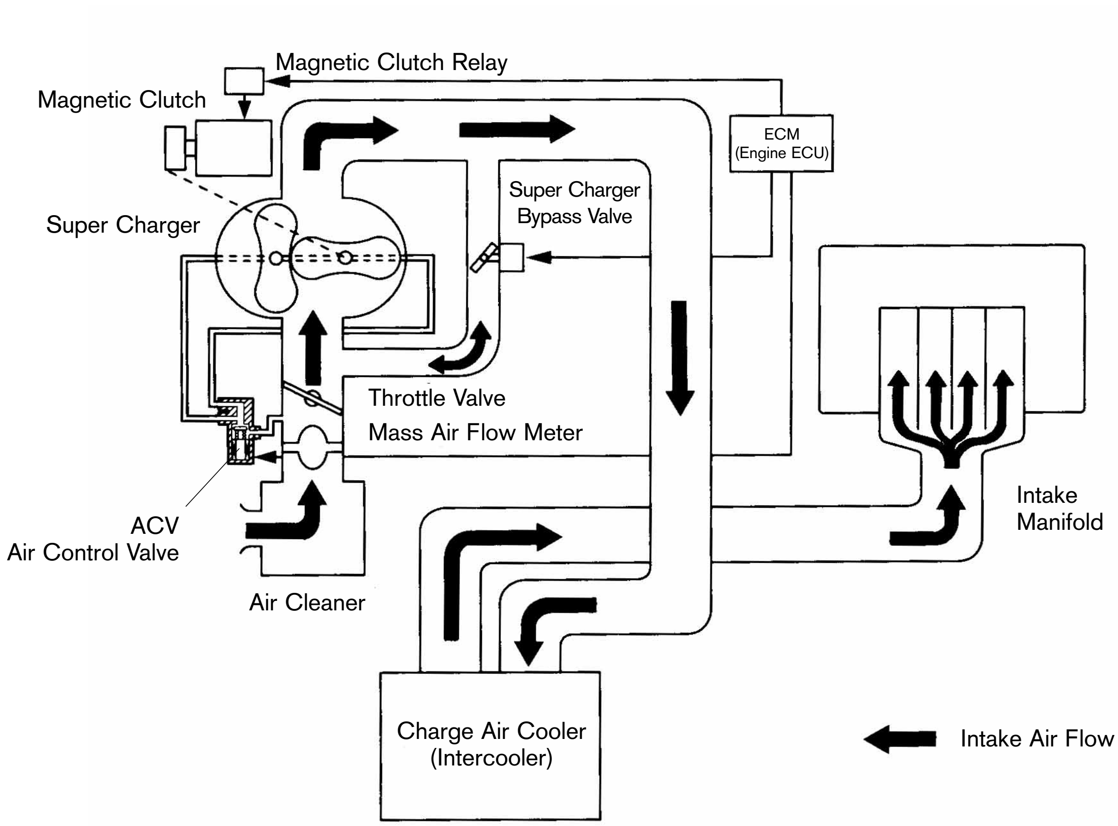
Before removing the turbocharger, plug the intake and exhaust ports and the oil inlet to prevent the entry of dirt or other foreign material.

Use caution when removing and reinstalling the turbocharger assembly. Do not drop it or bang it against anything or grasp it by easily deformed parts, such as the actuator or rod, when moving it.

When replacing the turbocharger, check for the accumulation of carbon sludge in the oil pipes and, if necessary, clean out or replace the oil pipes.

When replacing the turbocharger, put 20 cc (0.68 fl.oz.) of oil into the turbocharger oil inlet and turn the compressor wheel by hand several times to spread oil to the bearings.

When overhauling or replacing the engine, cut the fuel supply after reassembly and crank the engine for 30 seconds to distribute oil throughout the engine. Allow the engine to idle for 60 seconds.


Magnetic Clutch Relay
Magnetic Clutch
ECM
(Engine ECU)
Super Charger
Super Charger
Bypass Valve
Throttle Valve
Mass Air Flow Meter
ACV
Air Control Valve
Air Cleaner
Intake
Manifold
Charge Air Cooler
(Intercooler)
Intake Air Flow

Supercharging System

In the supercharging of a system, the supercharger pumps air into the cylinders. The supercharger is driven by a V-ribbed belt. This allows the supercharger to deliver boost pressure nearly instantly producing high horsepower at low engine rpm range.

The ECM determines supercharger boost pressure, based on engine running conditions, by operating the magnetic clutch, supercharger bypass valve, and Air Control Valve (ACV).

Supercharger speed is proportional to engine speed.

Supercharger Assembly

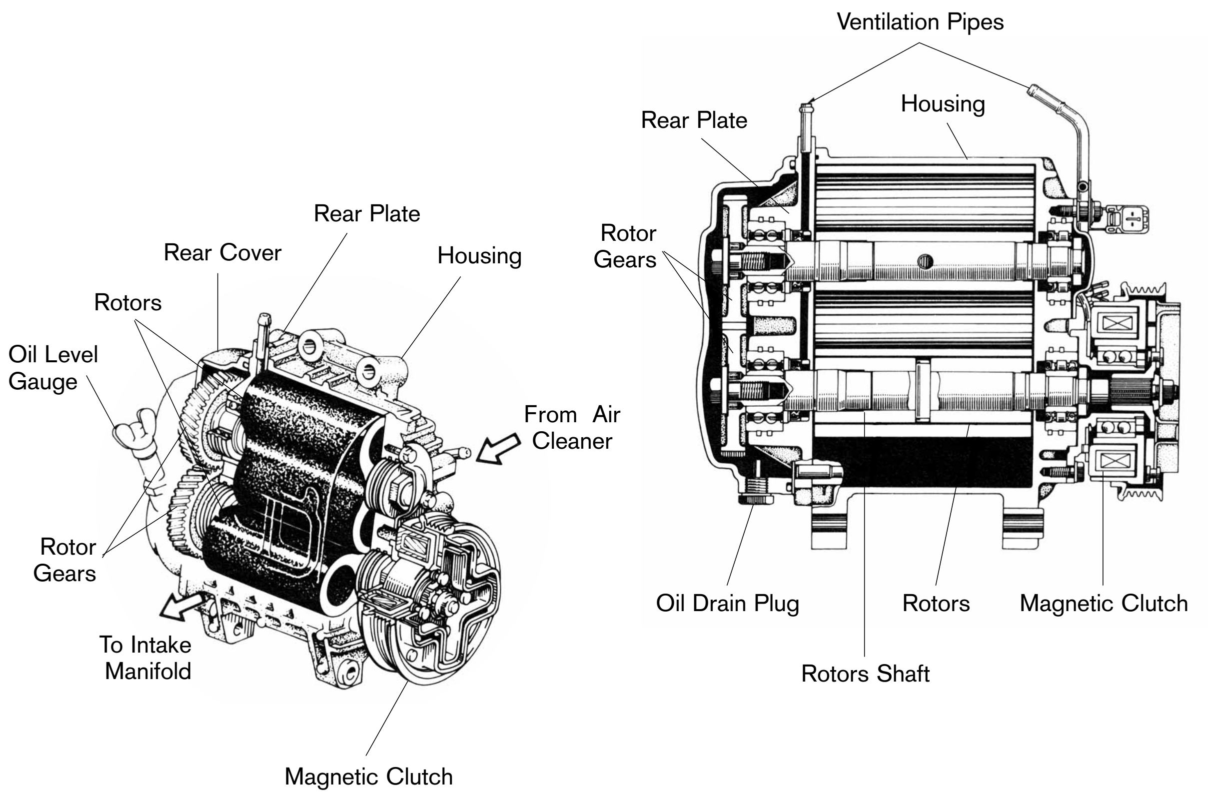


Fig. 9-20

T852f352/T852f353

Supercharger

The major components of the supercharger are a magnetic clutch, two rotors, two rotor gears, a housing, a rear plate and rear cover. The supercharger has its own oil supply and requires a special oil for lubrication. The oil level must be checked periodically.

Supercharger Operation

Power is transmitted from the engine crankshaft pulley to a V-ribbed belt and the magnetic clutch, and finally to the lower rotor shaft. The upper and lower rotor shafts are geared together. The two rotors turn in opposite directions and force air between the housing and rotors as they rotate. Air is pumped out four times per rotor revolution.

Pump Action of the Rotors

Viewed from rear.

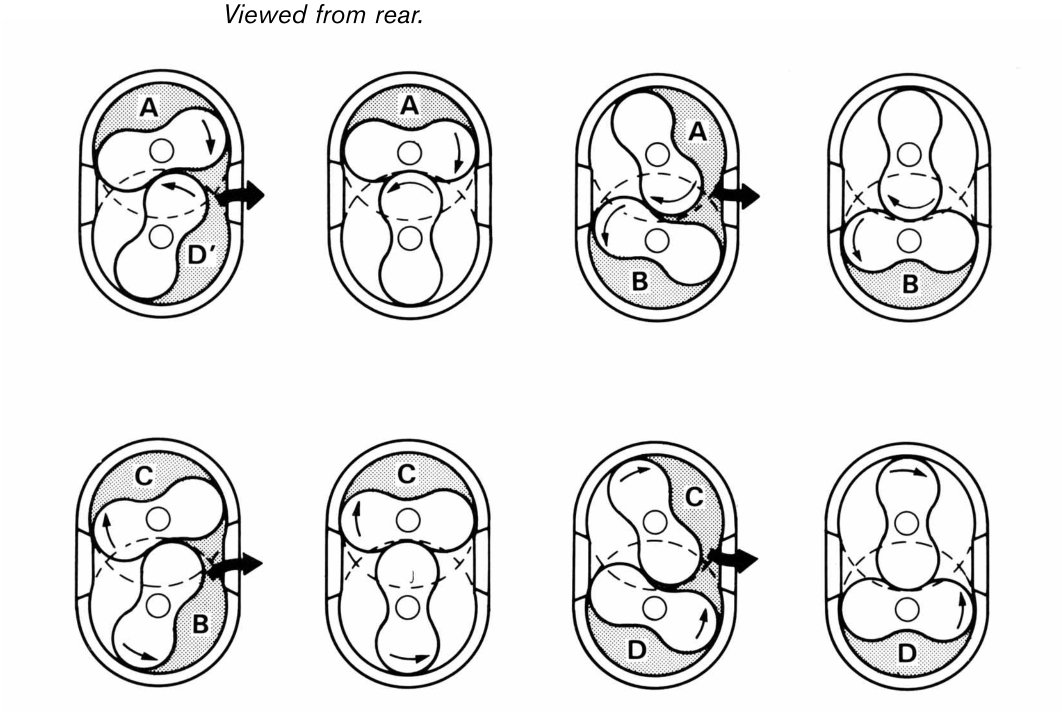


Fig. 9-21

T852f354

Rotors and Housing Assembly

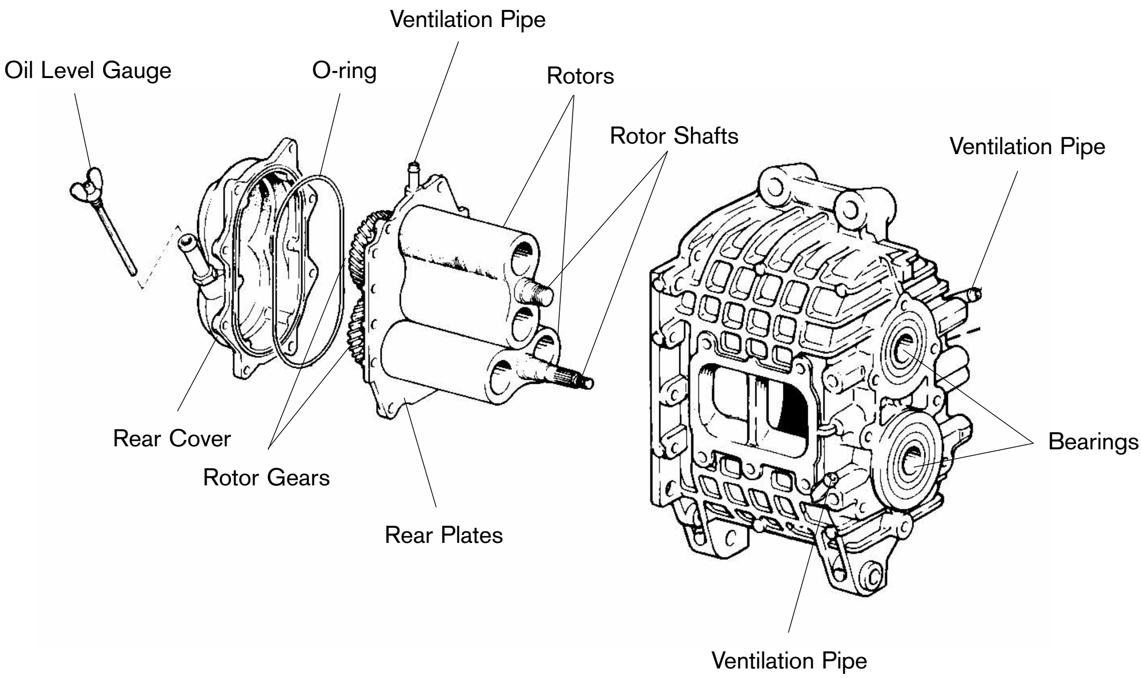


Fig. 9-22
T852f355

A rotor and gear are fitted to each of the two rotor shafts, which are in turn fitted to the rear plate via bearings. The rotors are made of aluminum, which is coated with a special fluoresin compound. The housing is made of aluminum. An air inlet duct is connected to the right and an air outlet duct to the left. Bearings are located in the front of the housing to support the rotor shafts.

The rotors are press-fit onto the rotor shafts and then fixed in position by pins and serations. The gears are pinned integrally to the rotor shaft so that the original rotor-to-rotor orientation will not be lost. For this reason, they cannot be disassembled. Component parts are therefore supplied as an assembly, with rotors and gears fitted to the rear plate as illustrated.

Rotor and Gear Assembly

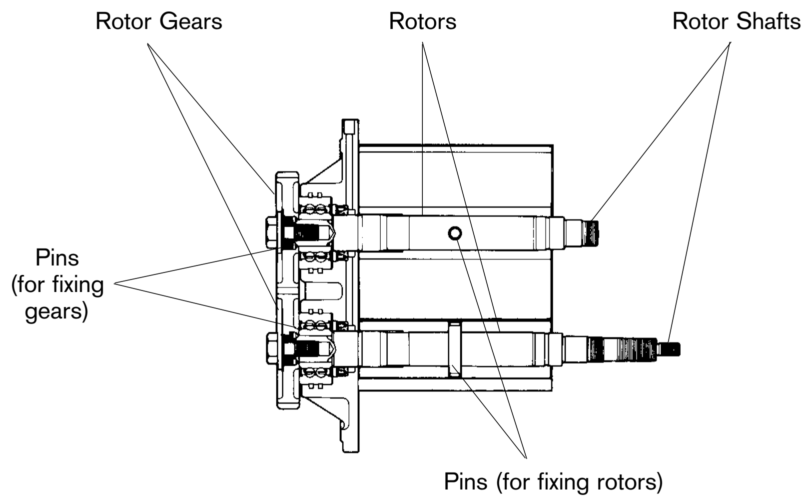


Fig. 9-23

T852f356

Ventilation Pipes

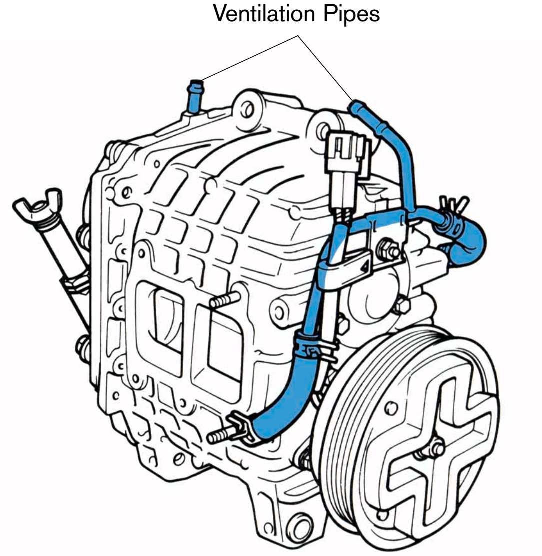


Fig. 9-24

T852f357

Ventilation Pipes

The gears and rear bearings are lubricated by Toyota brand supercharger oil. The front bearings are lubricated by grease. The pressure in the housing varies while the engine is operating. Ventilation pipes are provided to prevent oil leakage from the rear cover or grease leakage from the front bearings due to pressure fluctuation. Introduction of atmosphere into the ventilation pipes is controlled by the opening and closing of the Air Control Valve (ACV).

Magnetic Clutch

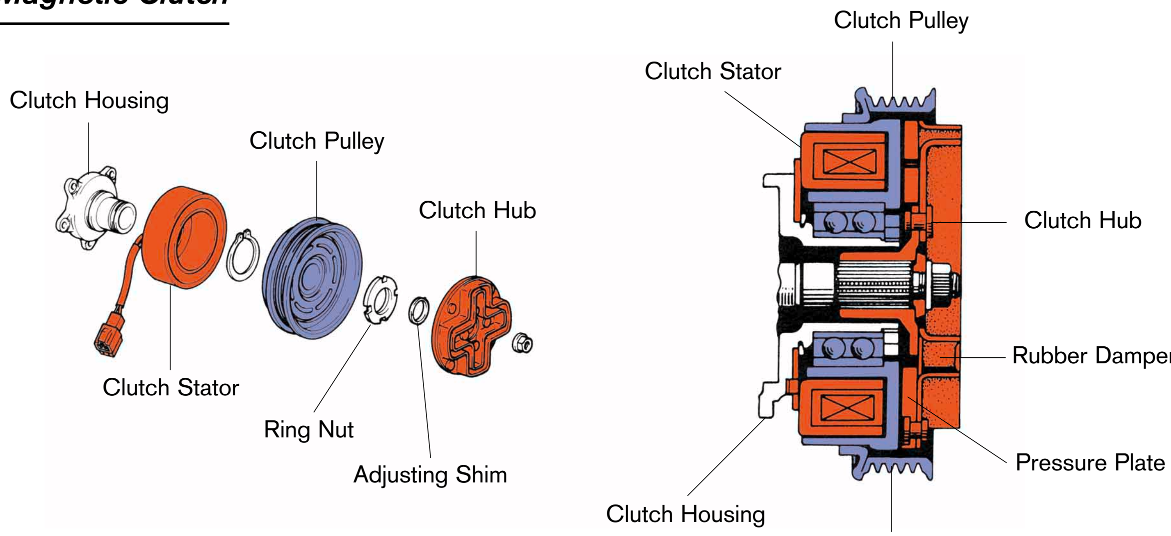


Fig. 9-25

T852f358

Magnetic Clutch

The magnetic clutch is turned on and off by the ECM. It is turned off to stop the supercharger when the engine is running under a light load. The magnetic clutch consists of the clutch stator, the clutch pulley, and the clutch hub. The clutch pulley turns around the clutch housing on a bearing incorporated in the pulley. The clutch hub is splined with the rotor shaft and turns as one complete unit. There is a rubber damper between the boss of the clutch hub and the pressure plate to allow the plate to move in the axial direction. When the magnetic clutch turns on or off, the rubber damper absorbs the shock due to the movement of the plate. The clutch stator is a solenoid. When the magnetic clutch is turned on, the pressure plate is pressed against the clutch pulley. Normally, a 0.5 mm (0.0197 in.) clearance is provided between the clutch hub and clutch pulley, as shown. A larger clearance due to wear, etc., may cause noise. The clearance is adjusted by changing the thickness of the adjusting shim.

The ECM turns the magnetic clutch on under the following conditions:

- Throttle valve opening angle is more than a certain angle (that is, during acceleration).
- Engine speed and intake air volume per engine revolution have increased.

Magnetic Clutch Operation

The magnetic clutch is on in the shaded area in the graph to the right (engine under heavy load).

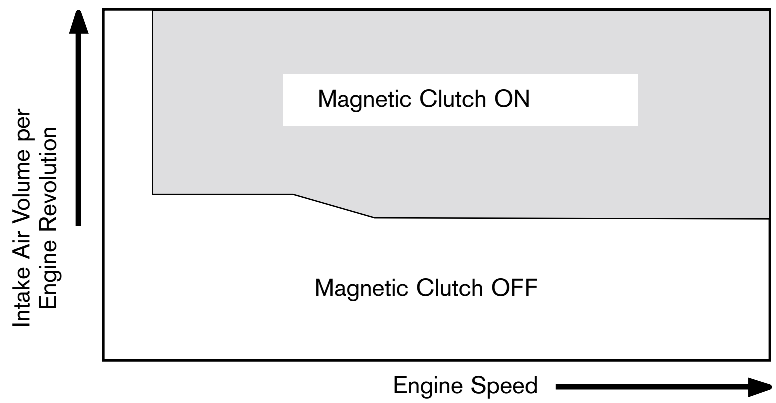


Fig. 9-26
T852f360

Air Control Valve

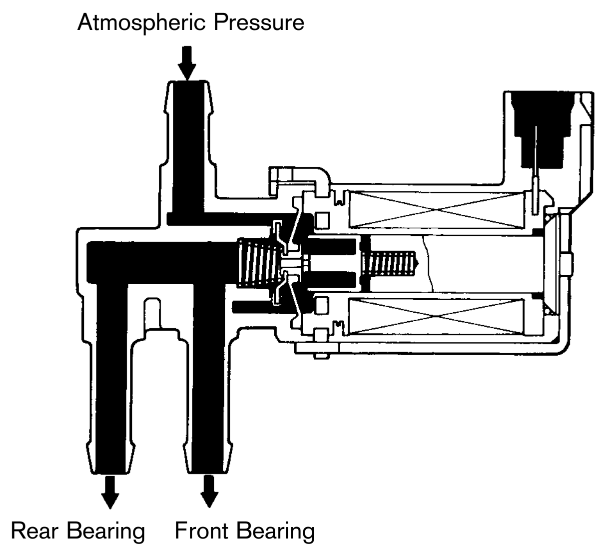


Fig. 9-27
T852f361

Air Control Valve (ACV)

In accordance with the signals received from the ECM, the ACV brings the pressure at the front and rear bearings closer to the atmospheric pressure. This prevents the bearing grease and oil from leaking out due to pressure fluctuation inside the supercharger housing.

Supercharger Bypass Valve

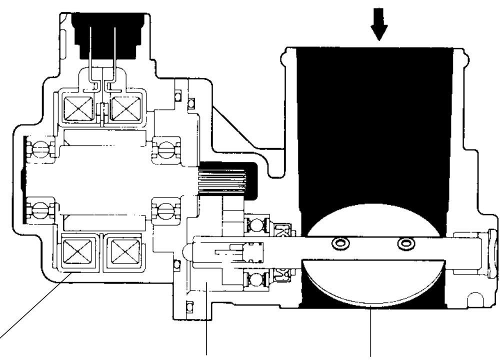


Fig. 9-28

T852f362

Supercharger Bypass Valve

The supercharger discharge rate is regulated by a step motor type bypass valve which controls the amount of air that bypasses the supercharger. The step motor type supercharger bypass valve consists of a step motor, which is under the direct control of the ECM, and a valve that is driven by gears. In accordance with the running condition of the engine the ECM controls the step motor to regulate the amount of intake air to bypass and thus optimize the supercharger discharge rate. Compared to the 4A-GZE engine which uses a vacuum type supercharger bypass valve, the 2TZ-FZE engine with the step motor type supercharger bypass valve produces torque that is more linear in relation to the throttle opening angle.

Circuit Inspection

Input Signals

Sensors produce different types of signals, that are either analog (variable voltage) or digital signal (on or off). The ECM will measure either voltage, amperage, or frequency of these signals.

Analog and Digital Signals

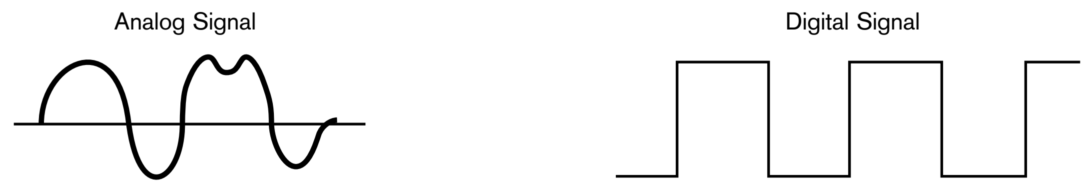


Fig. A-01
T852f363

Analog Signal

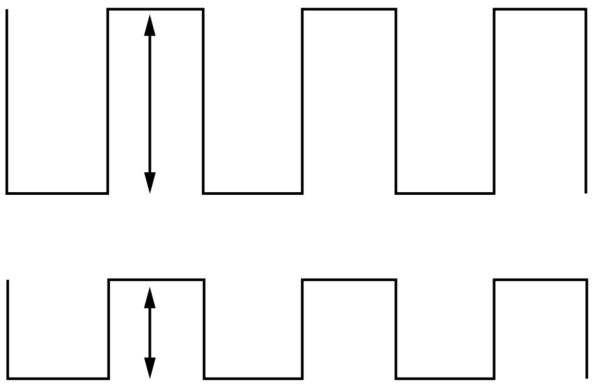
An analog signal is a variable signal and is usually measured by voltage or frequency. The voltage of the signal can be at any given point in a given range.

Digital Signal

A digital signal has only two states; high or low. This signal is often measured in volts or frequency. Digital signals are useful for indicating on/off, yes/no, high/low, or frequency. A digital signal is a signal that stays high or low for an extended period of time, sometimes called a discrete signal. Typically in circuits that involve switches, such as the Stop Lamp signal and Park/Neutral switch signal, the ECM is looking for a change in mode. Some sensors, such as the MRE speed sensor produce a digital signal and the ECM is measuring the frequency.

Amplitude

Amplitude is a measurement of strength, such as voltage. Amplitude can be measured from peak to peak, or from a reference point.



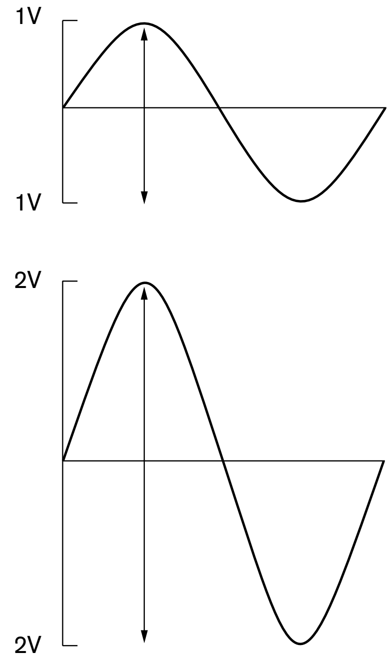


Fig. A-02

T852f364/T852f380

Frequency

Some signals are measured by frequency. A frequency is defined as the number of cycles per second. A cycle is a process that repeats from a common starting point. The unit for measuring frequency is called Hertz (Hz).

Frequency should not be confused with period. A period is the time it takes for the signal to repeat and is expressed as time. A 1 Hz signal lasts 1 second. A 2 Hz signal has a period of 0.5 seconds.

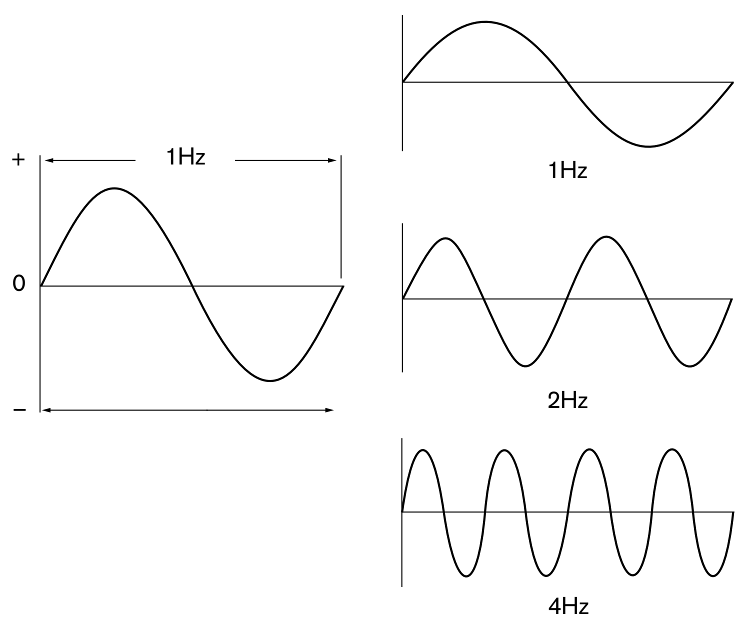


Fig. A-03

T852f365/T852f381

DC Voltage

Direct current is where the current flows in one direction. Though current flow and voltage can be variable, the direction always remains the same. The DVOM must be in the DC scale to measure DC voltage.

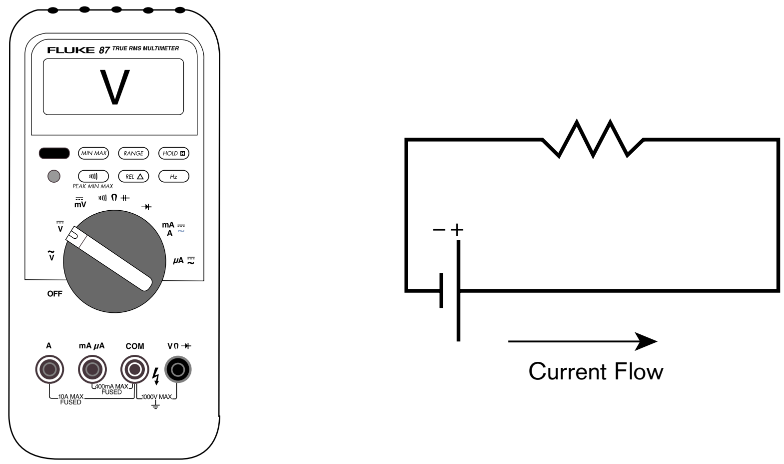


Fig. A-04

T852f380/T852f387

AC Voltage

Alternating current is where the direction of current flow changes. Current will travel from positive to negative, and then reverse course going to negative then positive. The DVOM must be in AC scale to measure AC voltage. There are different methods for measuring AC voltage and some DVOMs use what is known as a True RMS (Root Mean Square) to measure voltage. It is important for you to realize that the meter specified by the manufacturer must be used to obtain accurate results when compared to manufacturer's specifications.

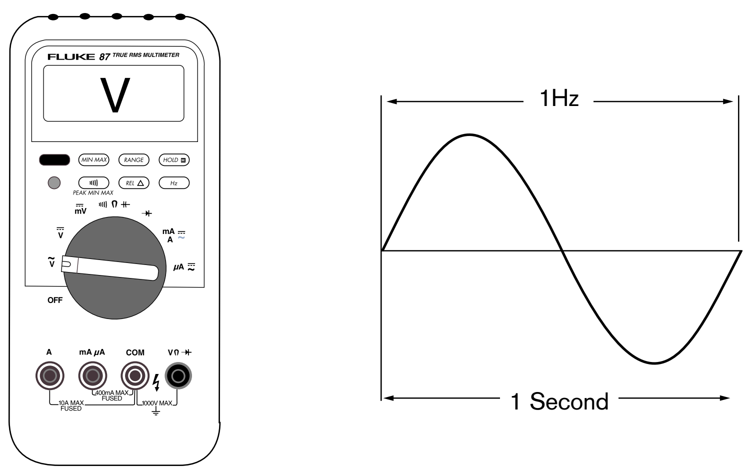


Fig. A-05

T852f388/T852f365

Output Signals and Circuits

To correctly interpret an oscilloscope pattern and DVOM reading, the technician needs to know the type of output circuit and how the test device is connected to the circuit.

Power Side Switched Circuit

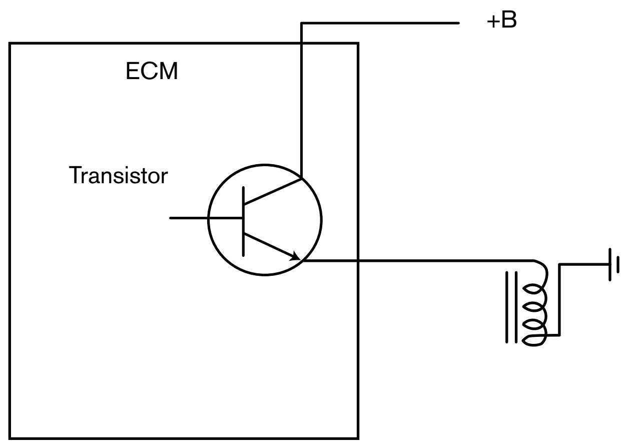


Fig. A-06

T852f366

Power Side Switched Circuit

A power side switch circuit will have voltage applied to the device when the circuit is switched on. When the transistor (think of the transistor as a switch) is turned on, current and voltage are applied to the device turning it on. The transistor is between power and the device. This is why they are commonly called power or power side switched circuits.

Ground Side Switched Circuit

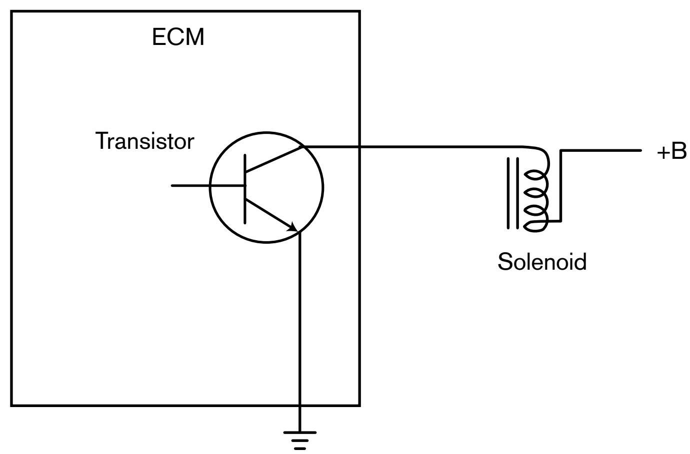


Fig. A-07

T852f367

Ground Side Switched Circuit

A ground side switched circuit has the transistor (switch) placed between the device and ground. When the transistor is turned on, the circuit now has a ground and current flows in the circuit. When the transistor is turned off current flow stops. Note that there is voltage present up to the transistor whenever the transistor is off.

Square Wave Duty Ratio Signals

When A and B are equal in length, the pulsewidth is 50%. This is a true square wave signal. A voltmeter connected to this circuit will measure half the supply voltage. The signal is said to have a low duty ratio when the on time is less than 50%.

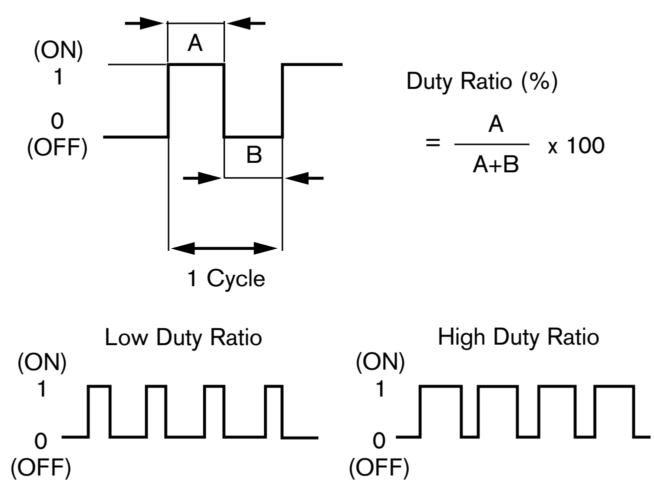


Fig. A-08

T852f368

Output Control Signals

Many devices, such as fuel injectors, EVAP purge, EGR VSV, rotary solenoid, alternator field circuit, etc. need to be modulated so that the desired output is achieved. There are a variety of control signals that can be used to regulate devices. Typically, the control signal changes the on/off time. This type of signal is often referred to as a pulse width modulated (PWM) signal and the on time is referred to as the pulsewidth. The duty cycle is the time to complete the on/off sequence. This can be expressed as a unit of time or as a frequency. The duty ratio is the comparison of the time the circuit is on versus the time the circuit is off in one cycle. This ratio is often expressed as a percentage or in milliseconds (ms).

PWM Signal

Each signal has the same frequency, only the pulsewidth has changed. The low duty ratio will have a lower current output.

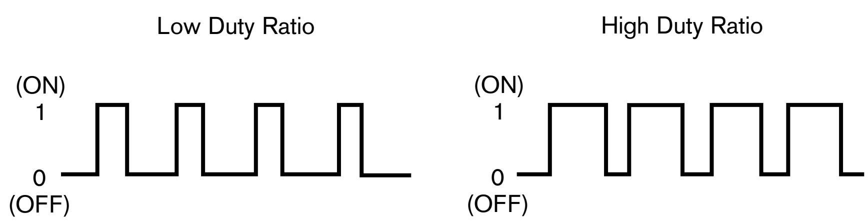
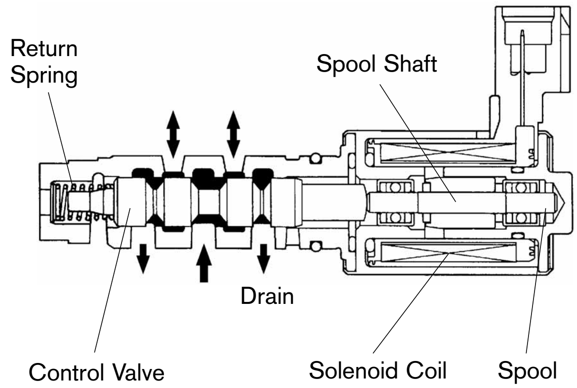


Fig. A-09

T852f368

Duty Ratio Solenoid

As the duty ratio (On time) increases, current flow through the solenoid increases moving the control valve. Oil pressure is then applied to the component that needs to be regulated, such as the variable valve timing mechanism, or lock-up control. In this example, Oil pressure increases as current increases. Other duty ratio solenoids can work in the opposite manner. Increasing current will decrease oil flow.



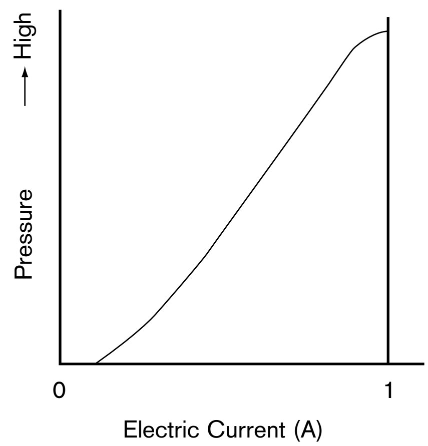


Fig. A-10

T852f370/T852f371

Fixed Duty Cycle Variable Duty Ratio (Pulse Width Modulated) Signal

This type of output control signal is defined by having a fixed duty cycle (frequency) with a variable duty ratio. With this type of signal only the ratio of on to off time varies. The ratio of on to off time modulates the output.

Variable Duty Cycle Variable Duty Ratio Signal

Duty cycle frequency has changed.
Duty ratio has changed.

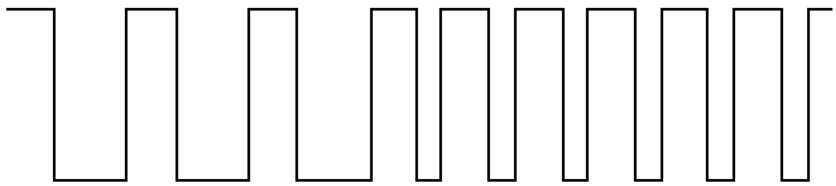


Fig. A-11

T852f372

Variable Duty Cycle/Variable Duty Ratio Signal

This signal varies the frequency of the duty cycle and the duty ratio. An excellent example is the signal used to control the fuel injector. As engine RPMs increase the fuel injector activation increases. As engine load increases, the duration of the fuel injector increases. It is easy to observe this type of control signal on the oscilloscope. With the oscilloscope connected to the fuel injector ECM terminal, as the engine RPMs (frequency) increase there will be more fuel injector cycles on the screen. As engine load increases, the on time (pulsewidth) also increases.

Measuring and Interpreting Signals

Oscilloscopes and many DVOMs can measure the pulsewidth, duty ratio, and frequency. For the technician to correctly interpret the reading oscilloscope line trace, the technician needs to know how the DVOM/oscilloscope is connected and the type of circuit.

Measuring Available Voltage On a Ground Side Switched Circuit

When the circuit is on, the DVOM will measure nearly 0 volts at the ECM.

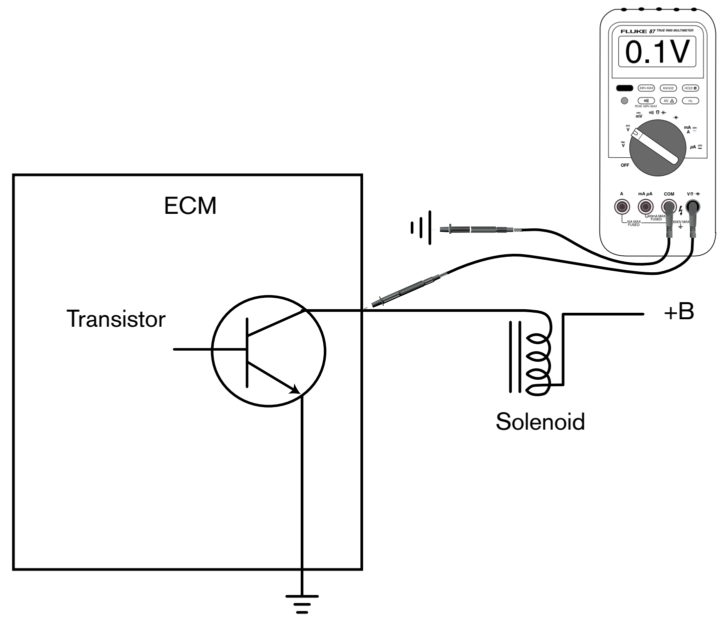


Fig. A-12
T852f382

Ground Side Switch Voltage Pattern Interpretation

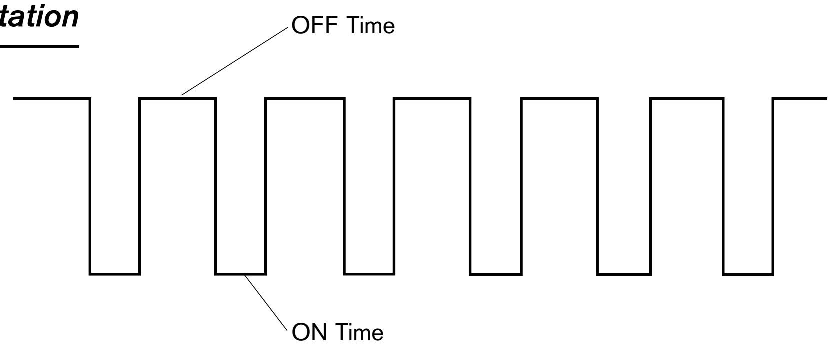


Fig. A-13
T852f373

Ground Side Switch Circuit Interpretation

With an oscilloscope connected at the ECM on a ground side switched circuit, the on time will be represented by the low (nearly 0 volts) voltage line trace. The voltage trace should be at supply voltage when the circuit is off and nearly 0 volts when the circuit is on. The on time (pulsewidth) is amount of time at 0 volts. If trace line does not go to nearly 0 volts, there may be a problem with the ground side of the circuit.

A DVOM in many cases can be substituted for the oscilloscope. When using a DVOM with a positive (+) or negative (-) trigger, select negative (-) trigger. Then the DVOM reading will represent the on time, usually as a percentage or in ms. On the voltage scale, the DVOM will read +B when the circuit is off and nearly 0 volts when the circuit is on.

Measuring Across the Load

Connecting at the ECM is the most common point used in the Repair Manual procedures. However, it is also possible to connect the oscilloscope or DVOM across the device. If this is done, the interpretation is different. The DVOM will read 0 volts when the circuit is off, and nearly +B when the circuit is on.

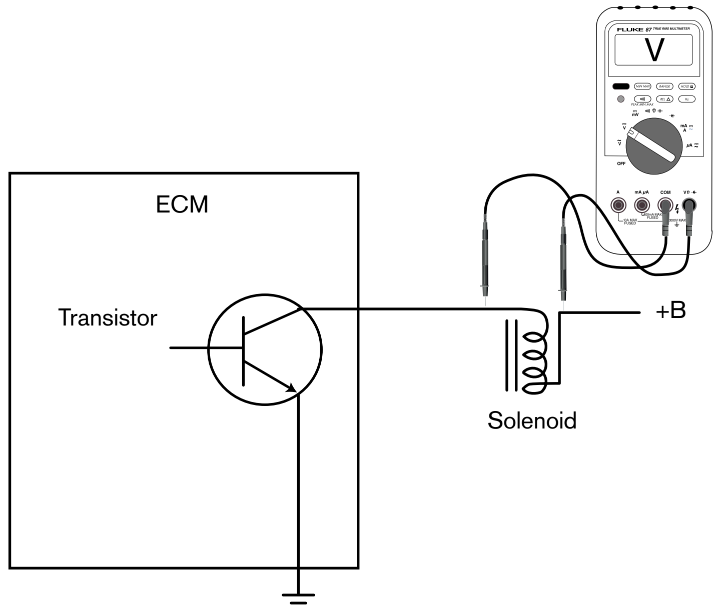


Fig. A-14
T852f383

Measuring Across the Load Pattern Interpretation

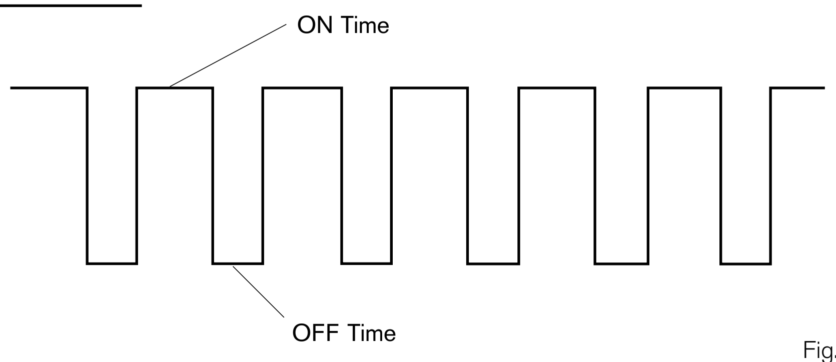


Fig. A-15
T852f373

Measuring Available Voltage on a Power Side Switched Circuit

When the circuit is on, the DVOM will measure +B at the ECM.

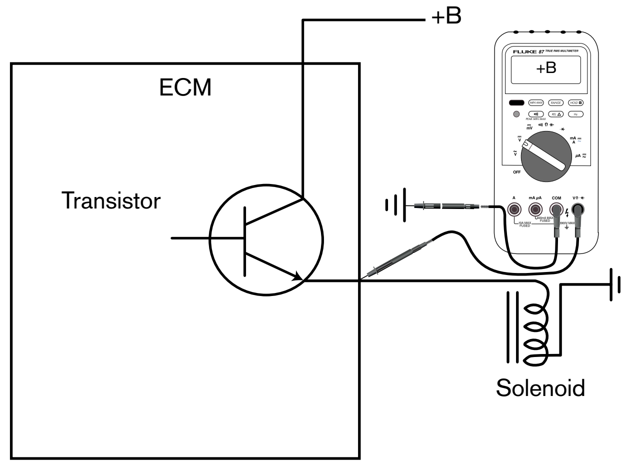


Fig. A-16

T852f384

Pattern Interpretation for a Power Side Switched Circuit

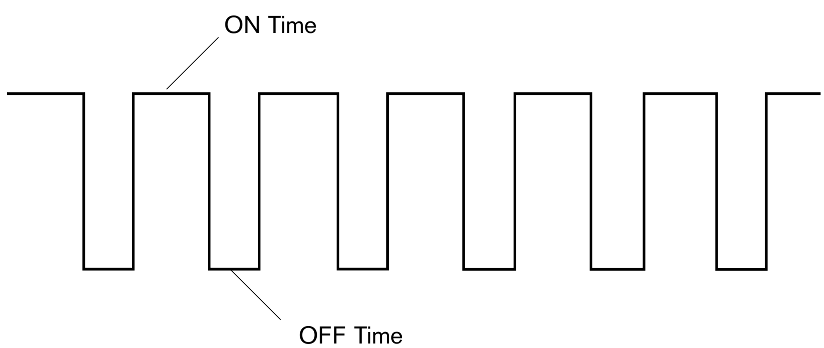


Fig. A-17

T852f373

Power Side Switch Circuit Interpretation

With an oscilloscope/DVOM connected at the ECM on a hot side switched circuit, the on time will be represented by the high (supply voltage) voltage line trace. The voltage trace should be at supply voltage when the circuit is on and at 0 volts when the circuit is off. The on time (pulsewidth) is the amount of time at supply voltage. If trace line does not go to supply voltage, there may be a problem with the supply side of the circuit.

When using a DVOM select positive (+) trigger. Then the DVOM reading will represent the on time, usually as a percentage or in ms.

Checking Circuit Operation Across The Load

The DVOM will measure nearly +B volts when the circuit is on.

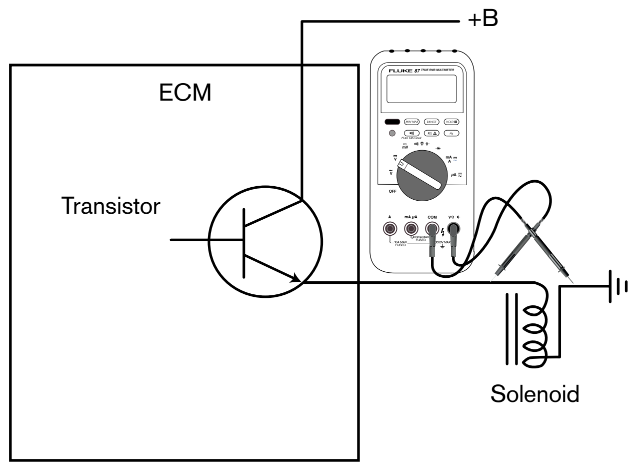


Fig. A-18
T852f369

Normally Closed Solenoid

Most solenoids are normally closed. This means that when they are off, they prevent the passage of fluid, air, vacuum, etc. When turned on, the passage opens.

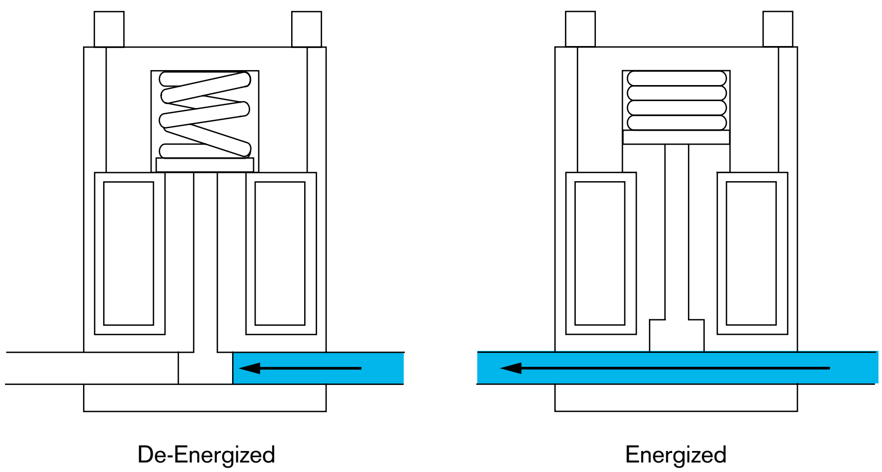


Fig. A-19
T852f374/T852f375

Normally Open Solenoid

When off, the passage in the solenoid is open.

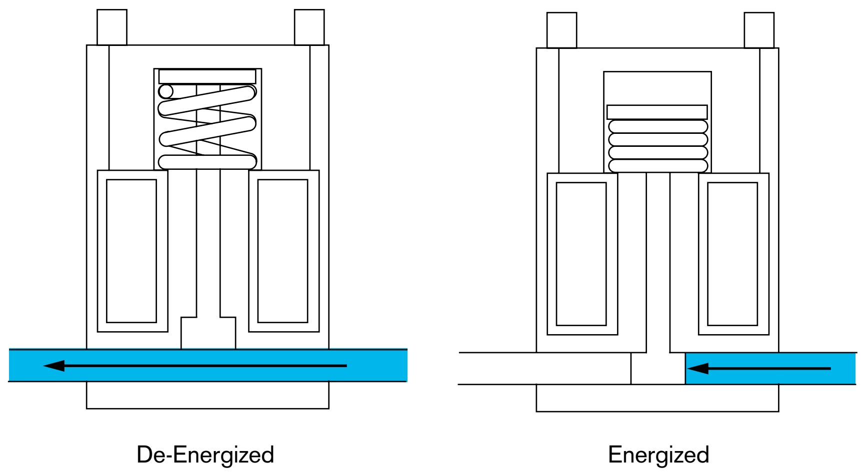


Fig. A-20

T852f376/T852f377

Solenoids

A solenoid is a component that is used to move something or control fluid flow. A solenoid consists of spring loaded valve, a coil, and housing. When the coil is energized, the magnetic field will pull the valve towards the center of the magnetic field. When the coil is turned off, the spring will return the valve to its resting position. There are a variety of solenoids used for engine control systems. It is important for the technician to know what type of solenoid is being used to determine operation and diagnosis. The following is explanation of the different types.

Two-Way VSV

Normally closed, Two-Way VSV.

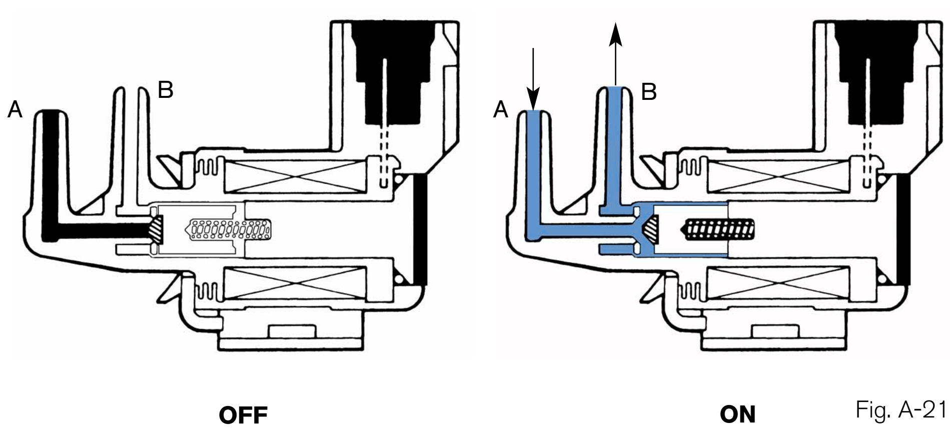


Fig. A-21

T852f378/T852f379

Vacuum Switching Valves (VSV)

VSVs are used in variety of applications. It is useful to know what type of VSV is being used for operational and diagnostic knowledge.

Two-way VSVs are commonly used in a variety of systems and can be of the normally open or normally closed type.

Two-way VSV	OFF	ON
Normally Closed	Closed	Open
Normally Open	Open	Closed

Two–Way VSV Operation Checks

For a normally closed VSV, air pressure is applied to a passage. Air flow should be greatly restricted. Next, the VSV is energized. Air should pass through freely. A restricted passage indicates the VSV has become plugged from debris or has failed.

For a normally open VSV air pressure is applied to a passage. Air should pass through freely. A restricted passage indicates the VSV has become plugged from debris or has failed. Next, the VSV is energized and air pressure is applied to the passage. Air flow should be greatly restricted.

For both VSVs, the coil resistance is checked with an ohmmeter.

Three-Way VSV

When ON, the passage between A and B is open

When OFF, the passage is open between B and C

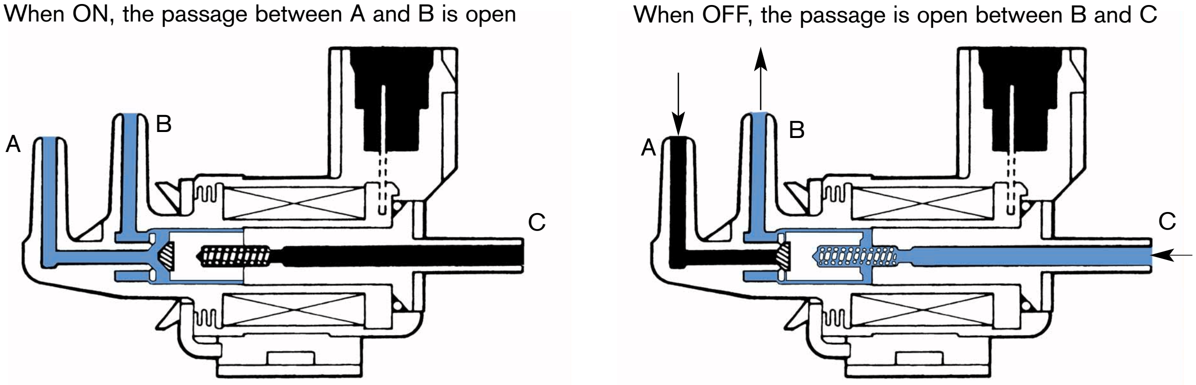


Fig. A-23

T852f089/T852f090

Three–Way VSV

A three-way VSV has three passages. When off, two passages are open and one is closed. When on, one passage will be closed and the other two opened.

Engine Control System Acronyms

Acronym	*Description*
AB1,2,3,4	Supercharger Bypass Valve
ABV	Supercharger Bypass Valve VSV
ADJ2	Ground
A/C SW	A/C Switch Signal
A/C (1)	A/C Amplifier
ACIS	Accoustic Control Intake System
ACIS	ACIS VSV
ACMG	A/C Magnetic Clutch Relay
ACT	Air Conditioning
ACV	A/C Idle Up Valve
AF +/-	Air/Fuel Ratio Sensor
AFL +/-	Air/Fuel Ratio Sensor
AFR +/-	Air/Fuel Ratio Sensor
AMC	A/C Amplifier
(+B)	Battery Power from EFI Relay
BATT	Battery Power
B/M	FR-HTR (Hi) Relay
CF	A/C Pressure Switch Relay
CG	Chassis Ground
CL +/-	Magnetic Clutch
CODE	Transponder Key Amplifier
DI	Fuel Pump Control
E1...	Ground (Earth)
EFI +/-	Traction Control ECU
EFI +/-	Throttle ECU
EFIF	
EGLS	EGR Valve Position
EGR	EGR VSV
EO1...	Ground (Earth)
EOM	Ground (Earth)
ELS	Electric Load Sensor Circuit
ELS2	Integration Relay
ELS2	Heated Mirror
ETC	Throttle ECU
EVAP	EVAP VSV
FC	Fuel Pump Relay
FPU	Fuel Pressure Up VSV
G	Distributor
G+	Camshaft Position
G22+	Camshaft Position
HT1...	Oxygen Sensor Heater Control
HTAF1...	Air/Fuel Ratio Heater
IDL	Throttle Position Switch
IGF	IGF Signal
IGSW	Ignition Switch
IGT	Igniter/Ignition Coil(s)
IMLD	Theft Deterent ECU
IMLD	To Security Indicator Light
ISCC	IAC Stepper Motor
ISCO	IAC Stepper Motor
KNK(L/R)	Knock Sensor
KS	Mass Air Flow Meter Karmen Vortex Type
LOCK IN	A/C Magnetic Clutch Lock
M+ M-	Throttle Control Motor
MREL	Main Relay
NCO +/-	O/D Direct Clutch Speed
NE+	Crankshaft Position
NE-	Camshaft/Crankshaft Circuit
NEO	ABS & Traction ECU
NSW	Starter Circuit
OD	Overdrive Switch
OIL	A/T Fluid Temp. Sensor
OMR	Engine Oil Feeder Control Motor
OMT	Engine Oil Feeder Control Mtr Relay
OX*	Oxygen Sensor
PIM	Manifold Absolute Pressure
PM1	Turbo Pressure
PMC	Waste Gate Valve VSV
PRG	EVAP VSV
PS SW	Power Steering Switch
PTNK	Vapor Pressure Sensor Signal

* Indicates more than one number possible.

Acronym	*Description*
R	Back Up Light Switch
RSC	IAC (Rotary Solenoid)
RSO	IAC (Rotary Solenoid)
RXCK	Transponder Key Amplifier
SDL	Signal Data Line
SG	Signal Ground
SDG	Signal Data Ground
SMC	Supercharger Magnetic Clutch
SPD	Vehicle Speed
STA	Park/Neutral Switch
STP	Stop Light Switch
TC	Data Link Connector 1
THA	Intake Air Temperature Sensor
TE1...	Data Link Connector 1
THG	EGR Temperature
THW	Engine Coolant Temperature
THWO	A/C Amplifier

Acronym	*Description*
TPC	Vapor Pressure Sensor VSV
TRC +/-	Traction Control ECU
TXCT	Transponder Key Amplifier
VC	Voltage Control
VG	Mass air Flow Meter Hot Wire Type
VPA*	Accelerator Pedal Position
VS	Mass Air Flow Meter (Vane Type)
VSV1	Intake Air Control VSV
VSV2	Exhaust Gas Control Valve
VSV3	Exhaust Bypass VSV
VTO1	Throttle ECU
VTO2	Throttle ECU
VTA*	Throttle Position
W	Malfunction Indicator
#10 - #80	Fuel Injectors

* Indicates more than one number possible.

Description	*Acronym*
A/C Switch Signal	A/C SW
A/C Amplifier	A/C (1)
A/C Amplifier	AMC
A/C Amplifier	THWO
A/C Idle Up Valve	ACV
A/C Magnetic Clutch Lock	LOCK IN
A/C Magnetic Clutch Relay	ACMG
A/C Pressure Switch Relay	CF
A/T Fluid Temp. Sensor	OIL
ABS & Traction ECU	NEO
Accelerator Pedal Position	VPA*
Acoustic Control Intake System	ACIS
ACIS VSV	ACIS
Air Conditioning	ACT
Air/Fuel Ratio Heater	HTAF1...
Air/Fuel Ratio Sensor	AF +/-
Air/Fuel Ratio Sensor	AFL +/-
Air/Fuel Ratio Sensor	AFR +/-
Back Up Light Switch	R
Battery Power	BATT
Battery Power from EFI Relay	(+B)
Camshaft Position	G+
Camshaft Position	G22+
Camshaft/Crankshaft Circuit	NE-
Crankshaft Position	NE+
Data Link Connector	CG
Data Link Connector 1	TC
Data Link Connector 1	TE1...
Distributor	G
EGR Temperature	THG
EGR Valve Position	EGLS
EGR VSV	EGR
Electric Load Sensor Circuit	ELS
Engine Coolant Temperature	THW
Engine Oil Feeder Control Motor	OMR
Engine Oil Feeder Control Mtr Relay	OMT
EVAP VSV	EVAP
EVAP VSV	PRG
Exhaust Bypass VSV	VSV3
Exhaust Gas Control Valve	VSV2
FR-HTR (Hi) Relay	B/M
Fuel Injectors	#10 - #80
Fuel Pressure Up VSV	FPU
Fuel Pump Control	DI
Fuel Pump Relay	FC
Ground	ADJ2
Ground (Earth)	E1...
Ground (Earth)	EO1...
Ground (Earth)	EOM
Heated Mirror	ELS2
IAC Stepper Motor	ISCC
IAC Stepper Motor	ISCO
IAC (Rotary Solenoid)	RSC
IAC (Rotary Solenoid)	RSO
IGF Signal	IGF
Igniter/Ignition Coil(s)	IGT
Ignition Switch	IGSW
Intake Air Control VSV	VSV1
Intake Air Temperature Sensor	THA
Integration Relay	ELS2
Knock Sensor	KNK(L/R)
Magnetic Clutch	CL +/-
Main Relay	MREL
Malfunction Indicator	W
Manifold Absolute Pressure	PIM
Mass Air Flow Meter Hot Wire Type	VG
Mass Air Flow Meter Karmen Vortex Type	KS
Mass Air Flow Meter (Vane Type)	VS
O/D Direct Clutch Speed	NCO +/-
Overdrive Switch	OD
Oxygen Sensor	OX*
Oxygen Sensor Heater Control	HT1...
Park/Neutral Switch	STA
Power Steering Switch	PS SW

* Indicates more than one number possible.

Description	*Acronym*
Security Indicator Light	IMLD
Signal Data Ground	SDG
Signal Data Line	SDL
Starter Circuit	NSW
Stop Light Switch	STP
Supercharger Bypass Valve	AB1,2,3,4
Supercharger Bypass Valve VSV	ABV
Supercharger Magnetic Clutch	SMC
Theft Deterrent ECU	IMLD
Throttle Control Motor	M+ M-
Throttle ECU	EFI +/-
Throttle ECU	ETC
Throttle ECU	VTO1
Throttle ECU	VTO2

Description	*Acronym*
Throttle Position	VTA*
Throttle Position Switch	IDL
Traction Control ECU	EFI +/-
Traction Control ECU	TRC +/-
Transponder Key Amplifier	CODE
Transponder Key Amplifier	RXCK
Transponder Key Amplifier	TXCT
Turbo Pressure	PM1
Vapor Pressure Sensor Signal	PTNK
Vapor Pressure Sensor VSV	TPC
Vehicle Speed	SPD
Voltage Control	VC
Waste Gate Valve VSV	PMC

* Indicates more than one number possible.