



**SUBARU**

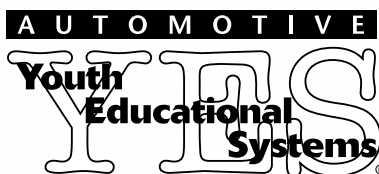
QUALITY DRIVEN® SERVICE



# Technicians Reference Booklet

## Fuel Injection and Engine Management

Module 406



January 2007

MSA5P0161C

Technical Training



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This book is revised with material from New Model Update 913 thru 916.

# Fuel Injection and Engine Management (406)

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## Introduction

This Technicians Reference Booklet contains information about Subaru Fuel Injection and Engine Management systems. It is not intended to be a stand alone publication on the operation, diagnosis, or repair of any system or component. The objective of this class is to provide training that will assist you with properly diagnosing and repairing the Subaru vehicle in a timely manner the first time. Coverage of information will begin with Subaru Legacy.



*Subaru Models*

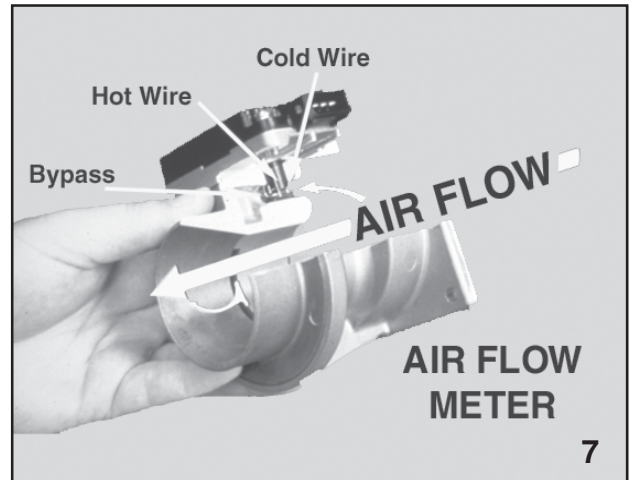
Only the differences of other models will be reviewed and supplemental information will be provided for you to take back to the dealership.

## Air Induction System

The Air Induction provides the correct amounts of air to the cylinders under a variety of operating conditions and performance demands. Components include:

- Air Induction Piping
- Mass Air Flow Meter
- Throttle Body
- Idle Air Control Valve

The Air Induction Piping delivers air from the air filter to the Throttle body , Idle Air Control Valve and the PCV system. Fitting to the components of the Air Induction System must be air tight to prevent unmetered air from entering the intake manifold.

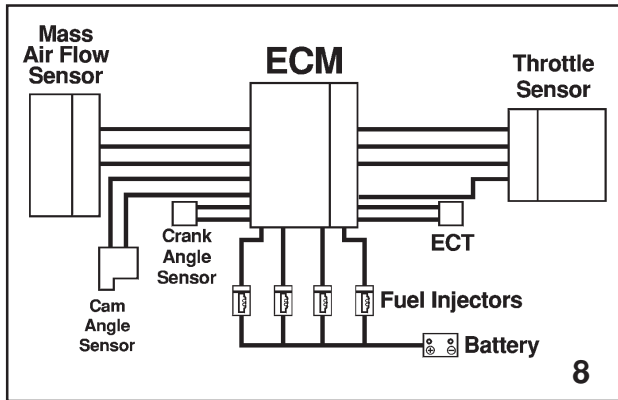


*Air Flow Meter*

Monitoring the amount of air inducted is the main function of the Mass Air Flow Meter. Described as a "Hot Wire" type air flow meter containing no moving parts, the Subaru Mass Air Flow Meter obtains information by monitoring the voltage of a single wire which is exposed to the incoming air flow. There are actually two wires exposed to the air flow. The "Hot Wire" which is positioned downstream of the cold wire to prevent any influence to the cold wire. Engine Control Module logic monitors the temperature of both wires by knowing their resistance values and voltage in the wire. The ECM will attempt to maintain a fixed difference in the temperature of these two wires. The amount of voltage applied to the "Hot Wire" is what finally determines the value of the signal generated or "Air Quotient".

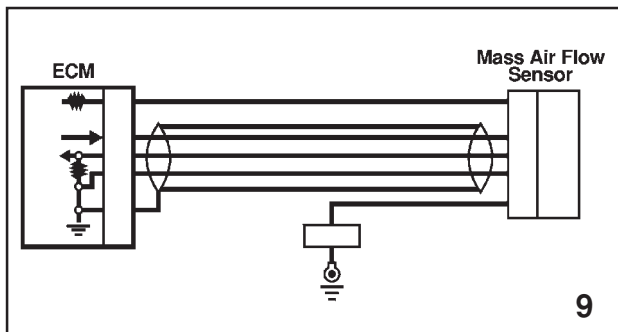
Air Quotient (QA), is one of the input signals to the ECM that determines the amount or length of time fuel is injected. Two other inputs are the throttle position signal, generated by the throttle position switch (TPS) and the engine speed (EREV), which is a processed signal by the ECM from input of the crank and cam angle sensors.

# Fuel Injection and Engine Management (406)



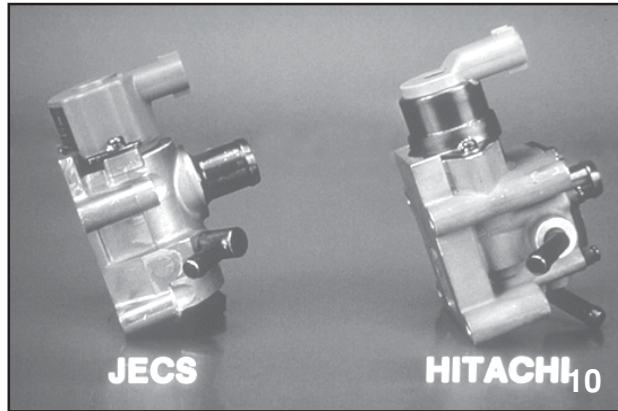
*Fail-safe Schematic*

Fail-safe results, the action taken by the ECM in the event a component is not operating within established parameters, will force the ECM to determine injection duration using TPS and EREV only.



*Mass Air Flow Sensor Circuit*

Testing is performed by observing resistance and voltage values. QA Value can be monitored using the select monitor. QA value should increase with engine speed and decrease to approximately 1 volt as engine speed approaches idle. Fail-safe value will result in a constant signal which is not effected by engine speed.



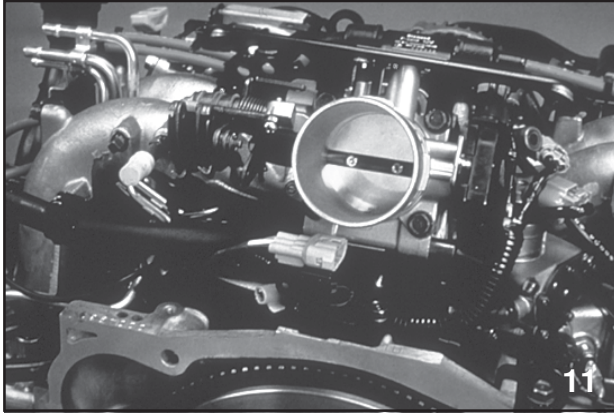
*Idle Air Control Valves*

The installation of improper replacement parts will result in a driveability or no start condition. Verify with your parts department using Vehicle Identification and Production Date numbers as necessary. For example earlier production Legacy Vehicles were equipped with either a JECS or HITACHI produced air flow meter dependent on whether they were Automatic or Standard shift transmission vehicles.

**NOTE: IN EARLY OBD II SYSTEMS A DTC P0507 (IDLE CONTROL SYSTEM RPM HIGHER THAN EXPECTED) COULD BE SET IF THE ACCELERATOR OR CRUISE CONTROL CABLE WAS NOT PROPERLY ADJUSTED. USUALLY THE CABLE IS TOO TIGHT. CABLE ADJUSTMENT WAS PART OF THE PDI AND SHOULD BE CHECKED DURING 60K CHECKUPS.**

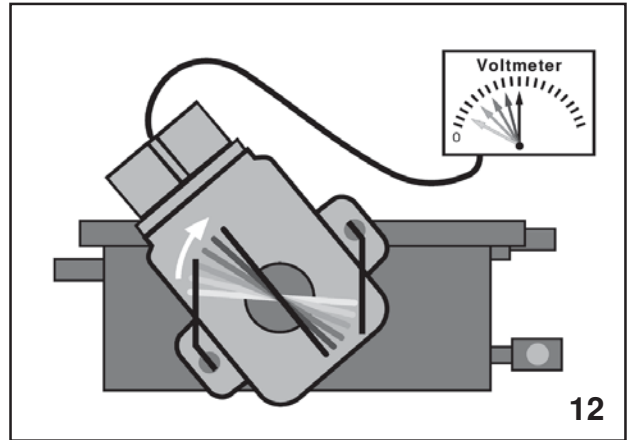


# Fuel Injection and Engine Management (406)



*Throttle Body with Accel Cable & TPS*

The Throttle Body regulates the amount of air into the intake manifold, controlling off idle engine speed. Operation of the throttle body is accomplished from the movement of the accelerator cable. Coolant flows through the base of the throttle body to prevent ice from forming. The throttle body is factory set and no adjustment should be attempted to the throttle plate. Adjustment of the throttle cable is suggested at PDI and Periodic Vehicle Maintenance.



*Potentiometer Operation*

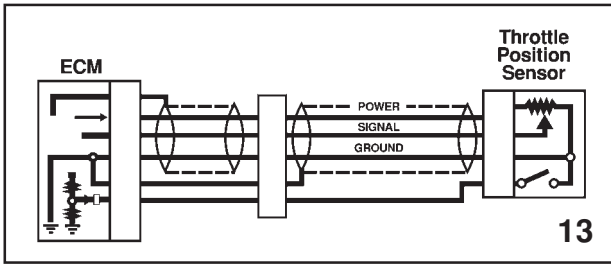
The Throttle Position Switch is mounted to the throttle body and engages to the throttle shaft. Any movement of the throttle shaft results in the movement of a contact inside the ECM that is acting with a potentiometer. At idle the resistance value is high so the voltage signal at the moveable contact is low. As the throttle is depressed the resistance value decreases and the voltage at the moveable contact increases. The voltage signal which ranges from .3 to 5 volts, is used by the ECM to determine the position of the throttle in degrees of opening. The Legacy also used a TPS where the voltage ranged from approximately 5 volts at idle and decreased as the throttle was depressed.

An idle switch is also provided which signals idle and off idle to the ECM.

Adjustment is possible through the use of elongated mounting holes.

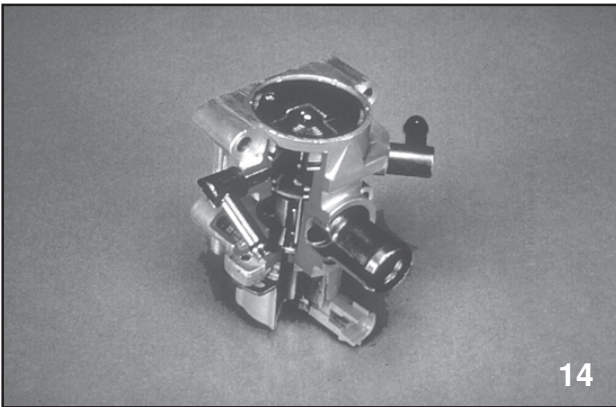
Fail-safe operation results in a fixed TPS voltage signal while the ECM uses the idle switch, QA and EREV to control injection duration.

# Fuel Injection and Engine Management (406)



*Throttle Position Sensor Circuit*

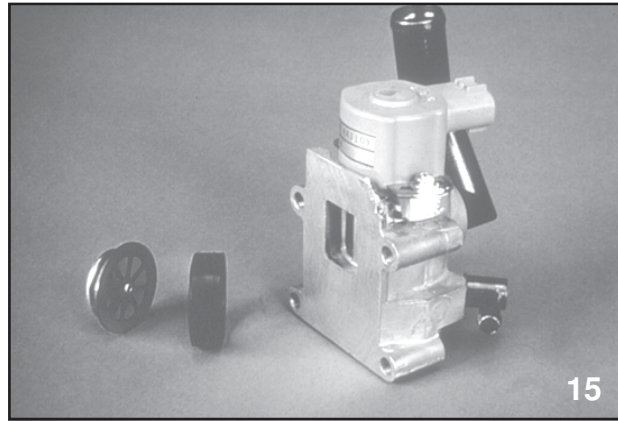
Testing is performed by observing voltage and resistance values. The Select Monitor on earlier models will display THV or throttle voltage and illuminate an LED when the idle switch signal is present. Newer models in addition will indicate throttle opening in degrees.



*Idle Air Control Valve*

Idle Air Control Valve (IAC) operation controls all idle speeds. Construction includes an air cut valve, duty control valve, intake air passage and a coolant passage. These component parts create a dual control over the IAC. The air cut valve is influenced by the temperature of coolant flowing through the IAC. A bimetallic spring is utilized to act on the air-cut valve, opening the valve when coolant temperature is low increasing air flow and idle speed. When coolant temperature is high the bimetallic spring closes the air cut valve and decreases airflow and idle speed.

Duty control valve operation is achieved by utilizing two electrical coils, one to open the valve and the other to close it. The ECM controls the ground circuits of the two coils and controls them with a duty signal, pulsing the ground circuits.

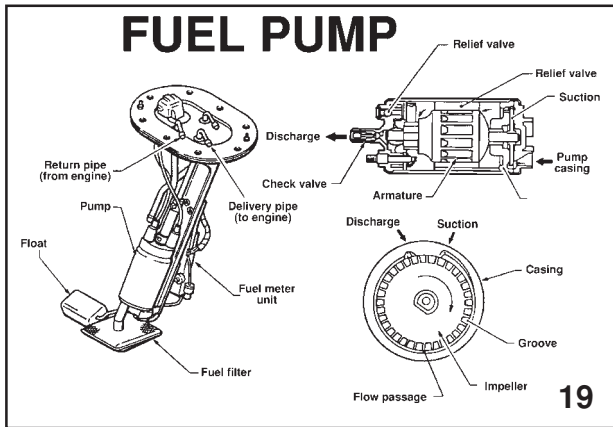


*Turbo Idle Air Control Valve*

IAC duty ratio can be monitored with the select monitor. Higher duty ratio will keep the valve open longer increasing idle speed. Lower duty ratio provides lower idle speeds. Optimum idle speed for all engine conditions is part of the ECM logic and will increase or decrease IAC duty ratio as necessary to maintain the correct idle speed.



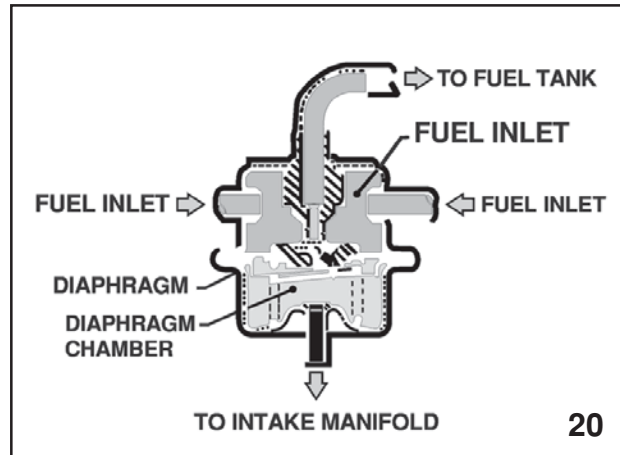
# Fuel Injection and Engine Management (406)



*Fuel Pump*

The fuel sending units, one on each side of the tank are wired in series to provide the fuel gauge with correct information to show correct fuel level.

The fuel pump creates pressure by moving the fuel through a series of impeller vanes and centrifugal force. Pressurized fuel flows through the clearance between the armature and the magnet of the motor to the discharge port of the pump. If the pressure output is too high a relief valve opens and the pressurized fuel exits the pump to the tank. When the pressure returns to normal the relief valve will close.

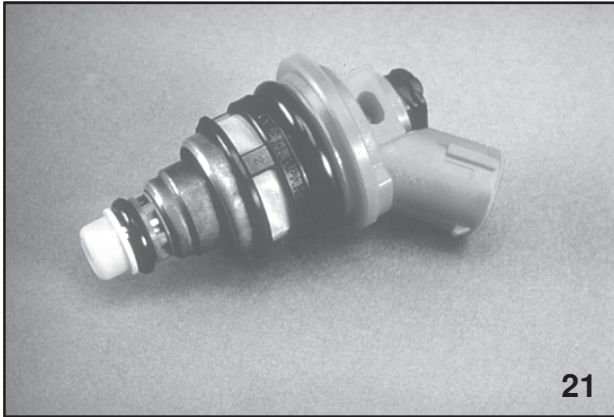


*Fuel Pressure Regulator*

Fuel pressure regulator operation controls fuel pressure by adjusting the size of a passage, through spring tension and manifold pressure, that allows fuel to return to the tank. When manifold pressure is high during acceleration the opening is small allowing less fuel to return to the tank. This provides higher fuel pressure at the injectors. During conditions of low manifold pressure the opening is large allowing more fuel to return to the tank, reducing the fuel pressure at the injectors. A check valve in the regulator maintains pressure in the fuel system after the engine is turned off.

**CAUTION: THE FUEL SYSTEM IS ALWAYS UNDER PRESSURE. DISCONNECT THE FUEL PUMP AND START THE ENGINE TO REMOVE THE PRESSURE. ALLOW THE ENGINE TO RUN UNTIL IT STALLS AND ATTEMPT TO RESTART. TURN THE KEY OFF. THE SYSTEM IS NOW SAFE TO OPEN. FOLLOW ALL SAFETY PROCEDURES OUTLINED IN THE APPROPRIATE SUBARU SERVICE MANUAL ON THE STIS WEB SITE.**

# Fuel Injection and Engine Management (406)



*Fuel Injector*

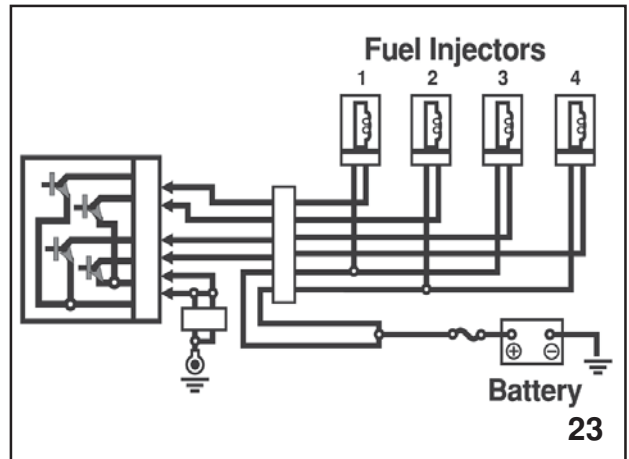
The fuel injector is described as a galley or side feed type, that delivers fuel to the intake manifold.

Control is achieved by varying the ground signal of the injector. This is accomplished by the ECM. A magnetic field develops inside the injector when the ground is established. The magnetic field lifts a plunger off of its seat and fuel under pressure enters the injector and exits through the tip of the injector. The design of the tip creates the proper spray pattern that results in the best mixing with air in the manifold.



*Tip Design*

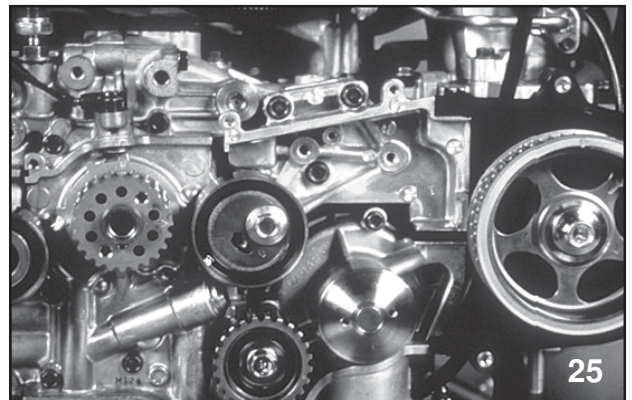
The time or length of grounding of the injector circuit is referred to as injection duration. The select monitor will display injection duration as "TIM". (Injection Duration)



*Fuel Injector Circuit*

## Sensors

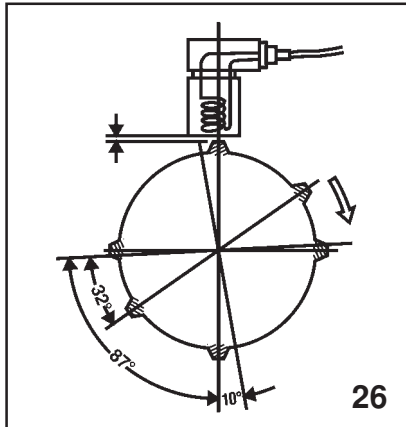
Crank angle sensor operation determines crankshaft position and speed by sensing pulses created by a reluctor passing through a magnetic field. The reluctor is machined to the back side of the crankshaft timing belt sprocket. The shape of the reluctor teeth is very important to the strength and clarity of the signal produced. A chip or deformation on any tooth can result in a driveability or no start condition. The signal generated is A/C and varies from approximately .5 to 1.5 volts.



*Crank Angle Sensor*

The crank angle sensor is made from a permanent magnet and a coil of wire. Do not drop the crank angle sensor as the magnet may be damaged or the shape of the sensor which can alter the signal generated.

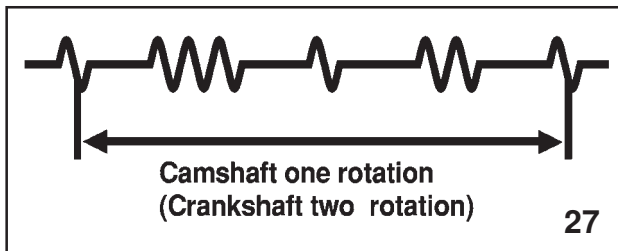
# Fuel Injection and Engine Management (406)



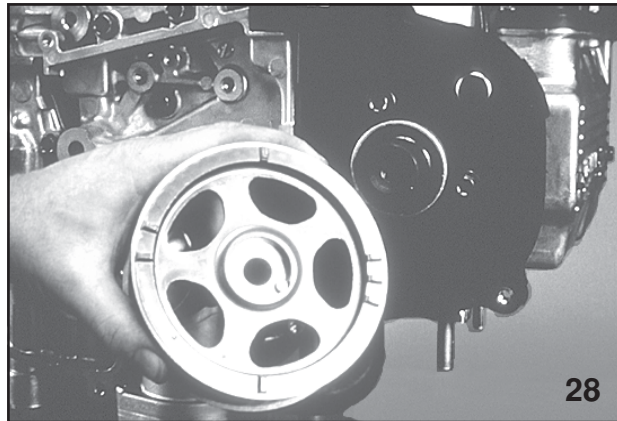
*Crank Angle Sensor Reluctor Construction*

The crank angle reluctor has 6 teeth making two sets, each having teeth set at 10, 65 and 97 degrees BTDC.

The ECM uses the crank angle sensor input to influence or control the fuel and ignition systems. (Determines engine rpm, fuel injection timing, dwell and timing advance.)

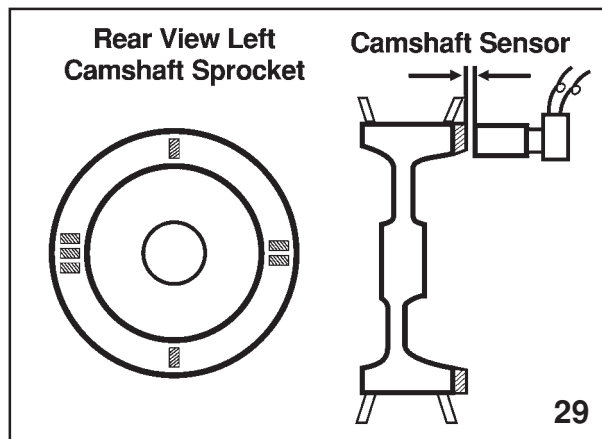


*Cylinder Discrimination Signal*



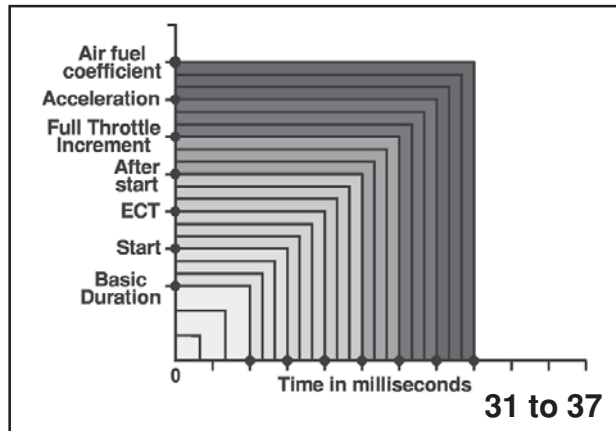
*Cam Angle Sensor and Reluctor*

The cam angle sensor in operation functions the same as the crank angle sensor. The value of the A/C signal is slightly lower and the signal pattern is different. Cam angle sensor reluctor teeth are located on the back side of the left side camshaft sprocket. The ECM uses the cam angle sensor to determine fuel injection sequence and to reference the #1 cylinder.



*Cam Angle Sensor Air Gap*

## Fuel Injection Logic



*Injection Duration*

The amount of fuel injected or duration is determined by the following:

**BASIC DURATION + CORRECTION FACTORS + VOLTAGE CORRECTION**

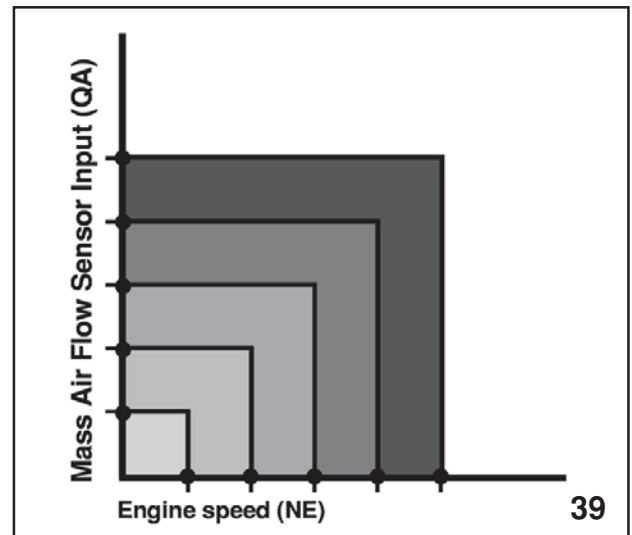
Basic duration is determined by comparing QA and engine speed.

Correction factors include:

- Start increment
- Coolant temperature
- After start
- Full increment
- Acceleration
- Air, fuel coefficient

Voltage correction compensates for the injectors time lag affected by battery voltage.

## Learning Control

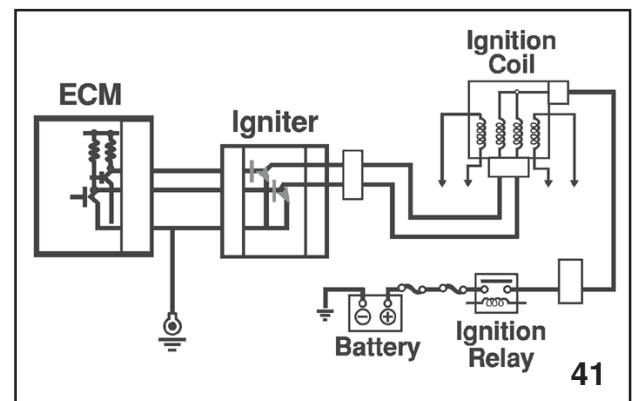


*Basic Duration*

The amount of air monitored by the mass air flow meter or QA compared to the engine rpm is memorized by the ECM. This results in a representation of engine load.

Engine load is used to update Basic duration.

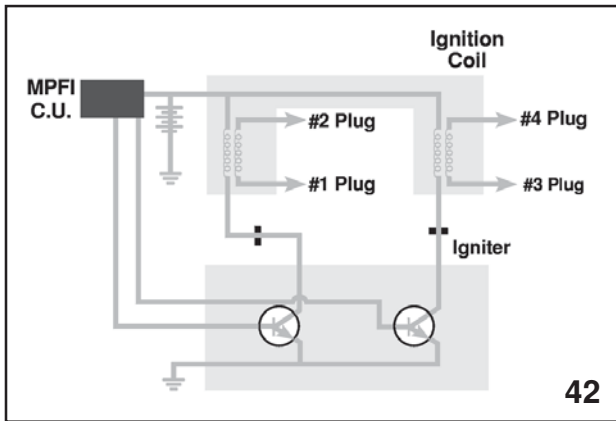
## Ignition System Control



*Ignition Circuit*

The distributorless (direct ignition) system uses the crank and cam angle sensor inputs processed by the ECM to control ignition and ignition timing. This system uses a coil pack that houses two coils that separately supply secondary voltage to two cylinders.

# Fuel Injection and Engine Management (406)

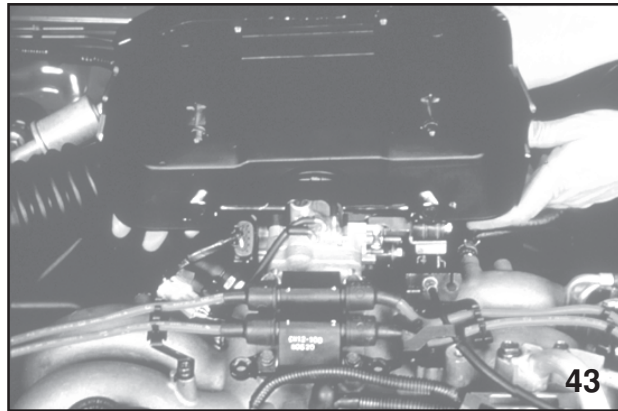


*Ignition Coil Construction*

Cylinders #1 & #2 - Forward coil  
#3 & #4 - Rear coil

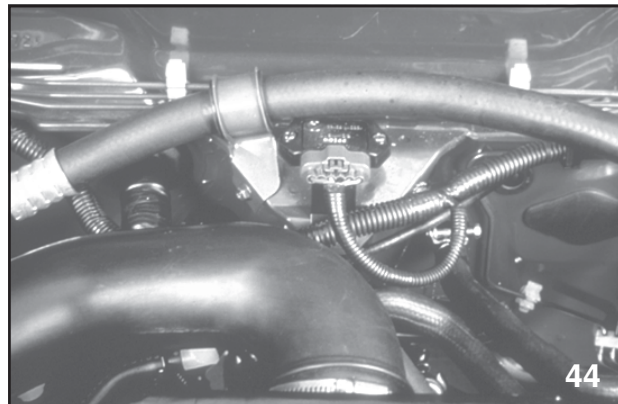
The secondary voltage is sent to the spark plugs of two cylinders simultaneously, one cylinder will be on the power stroke and the other on exhaust stroke.

**CAUTION: DURING CYLINDER "POWER BALANCE" TESTS DO NOT ALLOW FUEL TO ENTER THE EXHAUST SYSTEM. ALWAYS DISCONNECT THE APPROPRIATE FUEL INJECTOR HARNESS, DO NOT SHORT SECONDARY VOLTAGE TO THE CYLINDER. SHORTING THE SECONDARY VOLTAGE WILL ALLOW FUEL TO ENTER THE CYLINDER. THE SPARK PLUG MAY FIRE ON THE EXHAUST STROKE WHEN IGNITION IS RESTORED. THIS MAY CAUSE SEVERE DAMAGE TO THE EXHAUST SYSTEM. NEVER START THE ENGINE WITH THE EXHAUST REMOVED AS THE CYLINDER FIRING ON EXHAUST STROKE MAY IGNITE UNBURNED FUEL.**



*Ignition Coils*

The coils are controlled by the ignitor. Ignitor construction is composed of two transistors that control the ground circuits of the primary windings of the coils. Transistors in the ECM control the ignitor. The ignitor is necessary because of the amperage flow through the primary windings would damage the ECM.

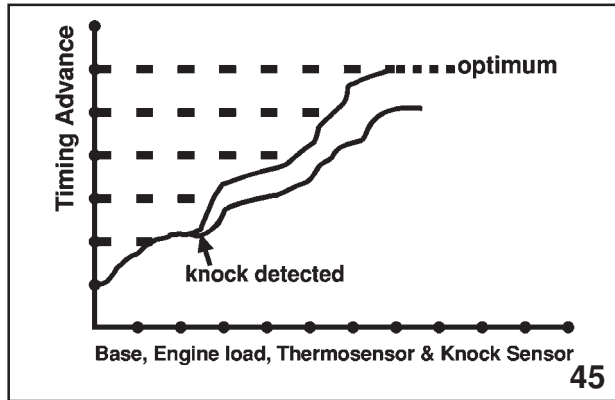


*Ignitor*

Signals from the cam and crank angle sensors are received by the ECM. At engine start the ignition timing is fixed at 10 degrees BTDC. After engine start ignition timing is influenced by the mass air flow meter, coolant temperature, knock sensor and engine load.



# Fuel Injection and Engine Management (406)

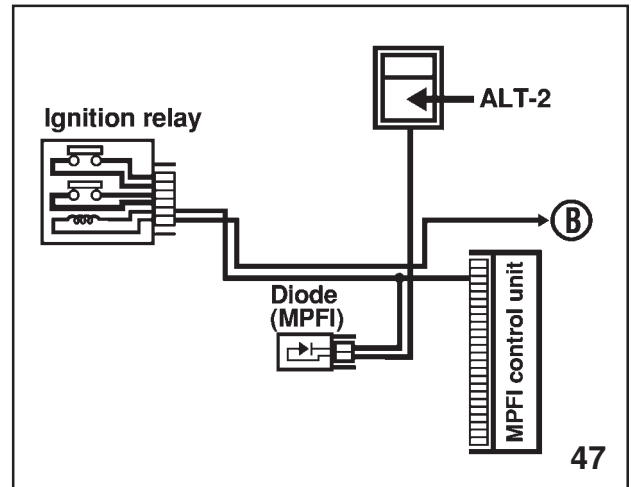


Timing Advance Logic

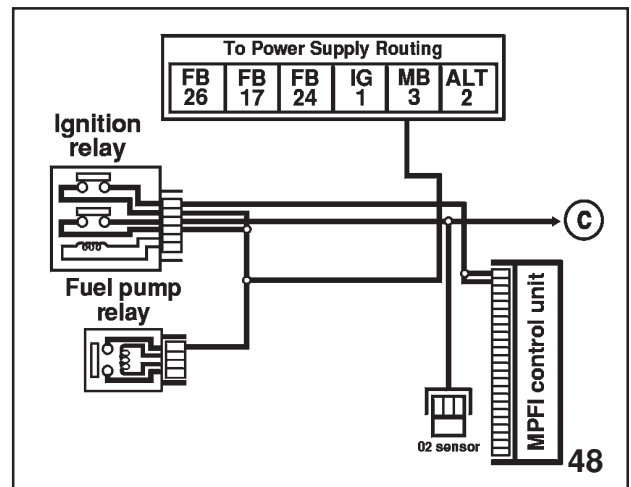
Optimum ignition timing is stored in the ECM. Timing is controlled to be just below the time of engine knock.

Engine knock is detected by the Knock Sensor. The sensor contains a piezo electric element that generates a small A/C voltage signal when a vibration at the correct frequency is present on the engine block surface. The signal that is created is used by the ECM to influence ignition timing.

## Power Supply



Ignition Relay Coil Power



Ignition Relay Power Distribution

## Self Diagnosis System

Self diagnosis has four modes:

**U-check** - monitors components necessary for start up. The check engine light will be illuminated during normal vehicle operation when a problem is detected.

**Read Memory** - Used at the dealer to read past trouble codes. Activated by using the black connectors located under the driver side kick panel, and following the procedures outlined in the Subaru Service Manual on the STIS web site.

**D-check** - Used at the dealer to check the present condition of all MPFI components. Activated by using the green connectors located under the driver side kick panel, and following the procedures outlined in the Subaru Service Manual on the STIS web site.

**Clear memory** - Clears all codes in ECM memory. Activated by using the green and black connectors located under the driver side kick panel, and following the procedures outlined in the Subaru Service Manual on the STIS web site.



*Select Monitor and Service Connector*

In both D-check and Read Memory modes, the control unit outputs trouble codes by using the Check Engine Light. Long flashes equal 10 and short flashes equal 1. By adding together the numerical equivalent of the flashes, you can identify the correct trouble codes. Multiple trouble codes are outputted in chronological order. You will find a list of trouble codes in the Subaru Service Manual on the STIS web site. Always refer to the appropriate MY Subaru Service Manual on the STIS web site when identifying trouble codes.

If the self-diagnostic system does not output trouble codes indicating a fault in the MPI system, suspect components may be checked using the check procedures found in the appropriate MY Subaru Service Manual on the STIS web site.

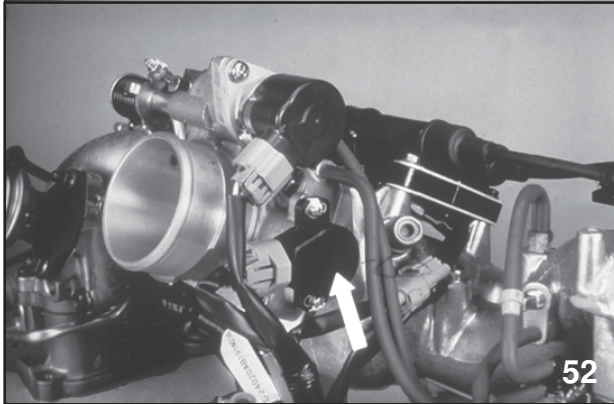
Self Diagnosis for other Subaru models are similar, however, test connector shapes may be different. Consult the appropriate Subaru Service Manual on the STIS web site for connector location and diagnosis procedures.

# Fuel Injection and Engine Management (406)

## Impreza 1.8 Liter

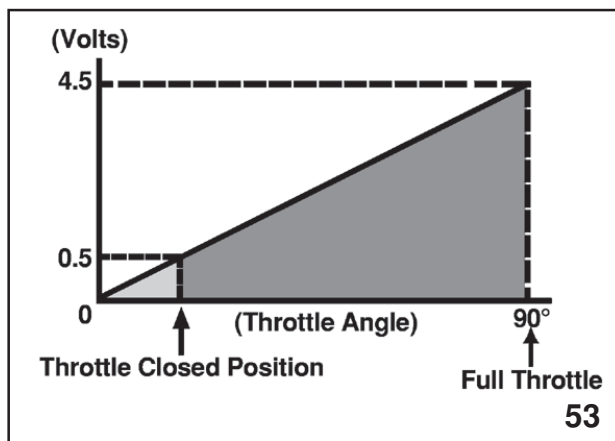
The Impreza 1.8 Fuel and Engine Management system differs from the Legacy in the following:

- TPS
- IAC
- Throttle Body
- Fuel Tank
- Power Supply

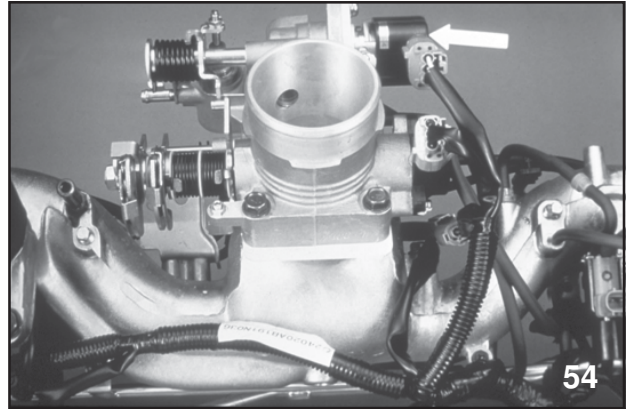


*Throttle Position Sensor*

The Throttle Position Sensor is connected to the throttle body similar to Legacy. The major difference is the way the idle signal is generated. Impreza uses a "soft idle control", a .5 volt signal that comes from the moveable contact and the potentiometer. Throttle position signal and idle can be observed with the Select Monitor.

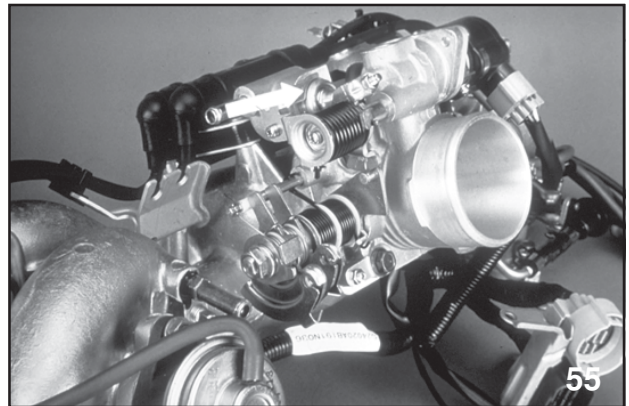


*Control Soft Operation*



*Idle Air Control Valve*

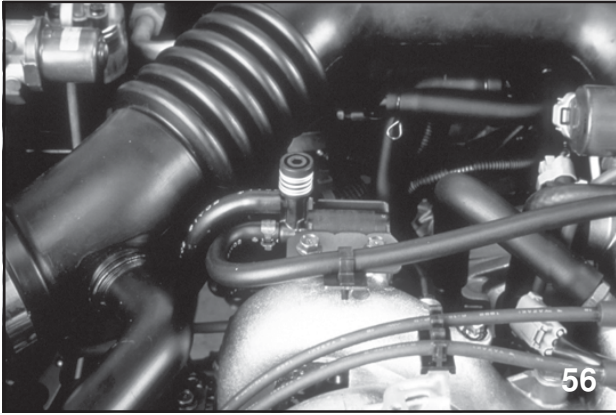
Throttle body size and shape differs from Legacy and serves as a mounting for the IAC valve. The IAC valve uses a Duty Control Valve operated from an ECM duty ratio. Control of idle speed during all engine operating conditions is performed by the Duty Control Valve.



*Throttle Body with Wax Pellet*

However, during cold engine operation it is assisted by a coolant sensitive device that contains a wax pellet. The wax pellet contracts when it is cold and expands when it is heated. During cold operation a spring loaded lever resting on the end of the pellet moves toward the pellet. The opposite end of the lever is cam shaped.

# Fuel Injection and Engine Management (406)

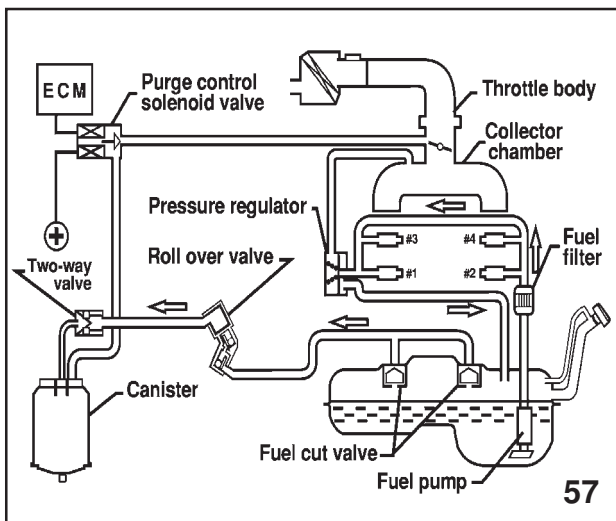


A/C IAC

As it moves upward it pushes on the throttle shaft, mechanically increasing the idle speed. Increasing coolant temperature expands the pellet relaxing the force applied to the throttle shaft. There is also an A/C IAC that allows additional air flow by pass the throttle plate to compensate for load the air conditioner places on the engine.

**CAUTION: THE A/C IAC IS FACTORY SET, DO NOT ADJUST. THIS VALVE WILL BE ACTIVATED WHEN THE AIR COMPRESSOR IS ENGAGED FROM AN ECM SIGNAL.**

The fuel tank design and capacity does not make it necessary to use a jet pump to transfer fuel on the 1.8 liter engine vehicle.



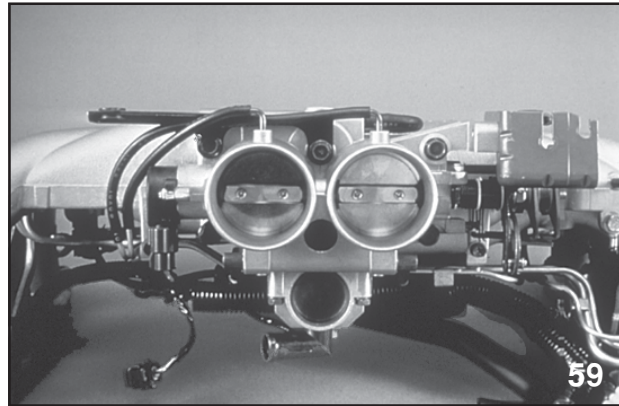
1.8 Impreza Fuel Supply System

## SVX

Differences of the SVX fuel injection and engine management system include:

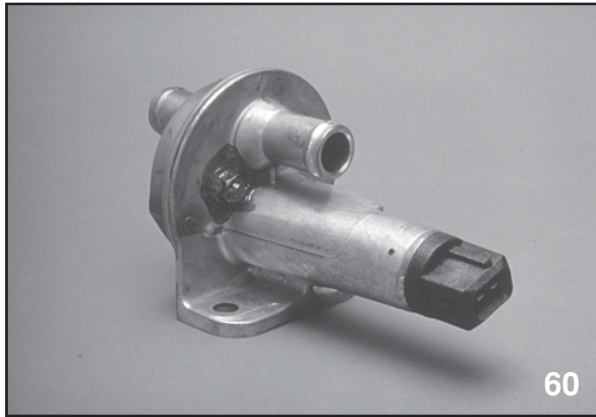
- Air Induction
- Ignition
- Sensors
- Fuel Supply
- Power Supply

The Air Induction system components of the SVX include an Idle Air Control Valve, Auxiliary Air Control Valve and piping. An Inertia Resonance Induction system is also employed to improve low to mid range torque.



Throttle Body and Manifold

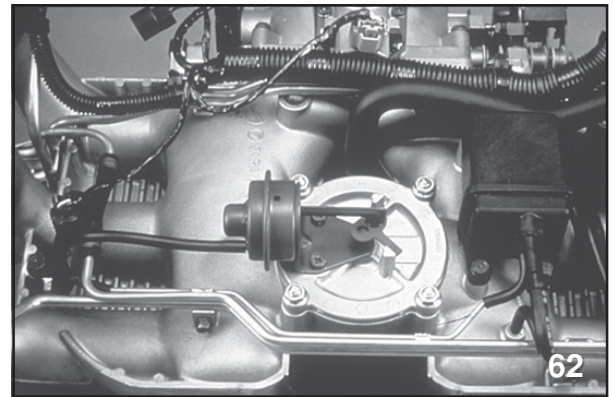
IAC valve operation is accomplished with a duty signal from the ECM which acts on the Duty control valve. The IAC controls base idle, compensates for additional engine load conditions, such as A/C operation, and assists the Auxiliary Air Valve with cold idle control. Auxiliary valve construction includes a rotary valve, bimetallic spring and heater.



*Auxiliary Air Valve*

Cold engine operation results in the bimetallic spring forcing the rotary valve open to increase airflow bypassing the throttle plate. The heater becomes active after the engine is started heating the bimetallic spring. As the spring changes tension the rotary valve is gradually moved to the closed position reducing idle speed.

## Inertia Resonance Induction System (IRIS)



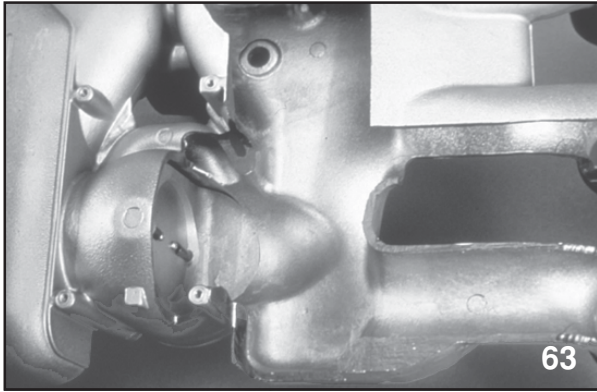
*Intake Manifold (Underside)*

Iris system components include:

- IRIS Valve
- Vacuum Tank
- Check Valve
- Solenoid

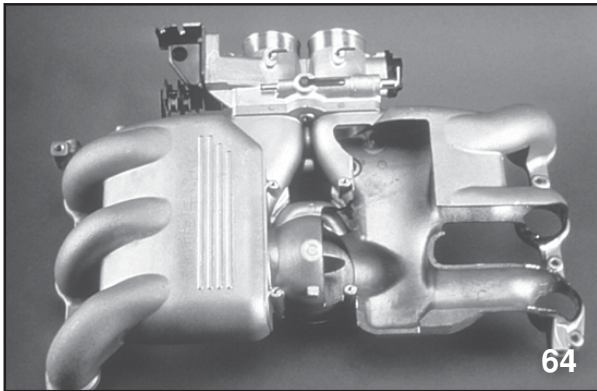
The solenoid provides a vacuum pathway from the IRIS valve to the vacuum storage tank to close the valve and to the atmosphere to open it. Vacuum storage is accomplished with the storage tank and is maintained there with the use of a check valve, for conditions of low manifold vacuum.

# Fuel Injection and Engine Management (406)



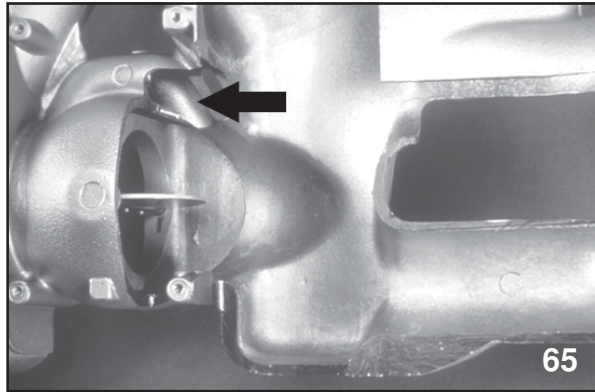
*IRIS Valve (Closed)*

IRIS operation includes two modes. Mode one is active from low to approximately 4200 RPM. The IRIS valve is closed separating the two sides of the intake manifold. Construction of the intake manifold includes a resonance tube that in mode one synchronizes the intake pulses. Simply stated the air filling one cylinder will continue to move after the intake valve has closed. That air will push the air in front of it into the next cylinder in the firing order. In mode one the resonance tube guides the moving air to the opposite side of the manifold as the firing order is 1-6-5-4-3-2.



*IRIS Valve (Open) with Resonance Tube*

The IRIS valve is closed because the volume of air in mode one is moving too slow for the valve to be effective. Resonance tube operation maintains the speed of the moving air, keeping the pushing effect at maximum.



*Resonance Tube*

Air flow volume in mode two is too great for the small size of the resonance tube, so just above 4200 rpm the IRIS valve opens and guides the air as in mode one.

## SVX Ignition

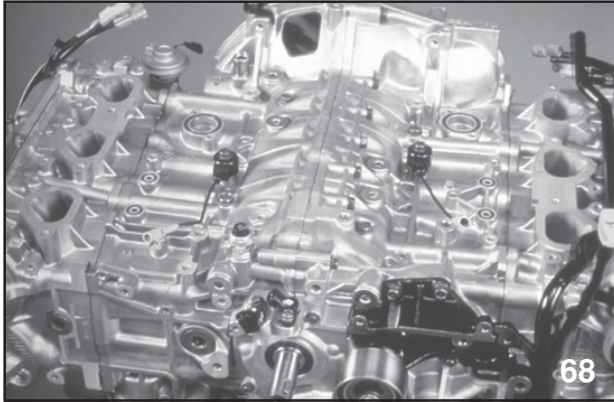


*Ignition Coil and Spark Plug*

The ignition system of the SVX uses a coil for each of the six cylinders. Coil mounting is accomplished by a captured bolt that goes through the valve cover into the cylinder head. Primary and secondary windings are contained in the coil with a spring loaded contact that completes the secondary circuit to the spark plugs.

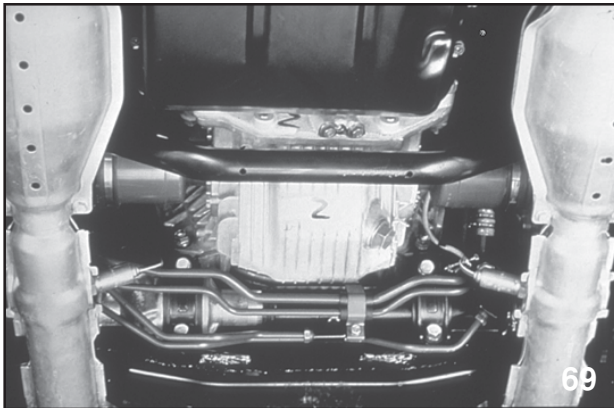
The primary circuit is controlled by an ignitor that pulses the ground circuit from a signal generated in the ECM.

# Fuel Injection and Engine Management (406)



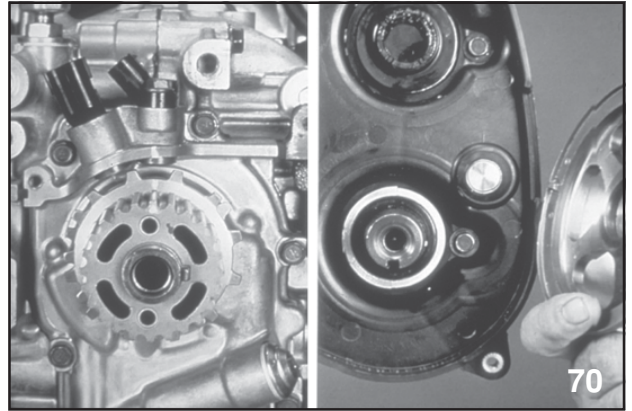
*Knock Sensor Locations*

The Knock sensors are located on each side of the engine. If either sensor detects a knock the overall ignition timing is reduced.



*Oxygen Sensors*

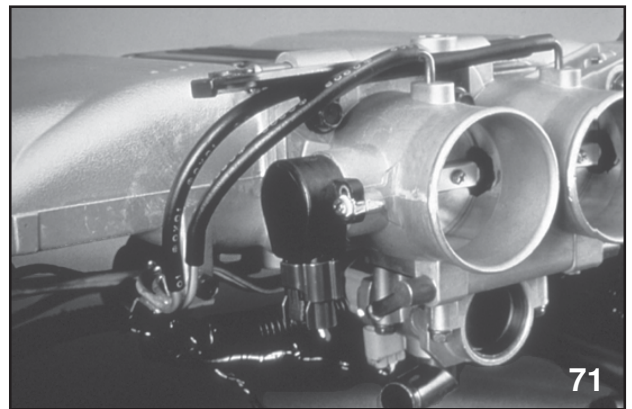
Oxygen sensors are located in the left and right side exhaust pipes ahead of the catalytic converters. Separate alpha readings are available for display on the select monitor.



*Crank and Cam Angle Sensors*

Two crank angle sensors are installed above the crankshaft sprocket. Crank sensor #1 determines crankshaft position and Crank sensor #2 determines the next cylinder in the firing order.

Cam angle sensor input is used with the crank angle sensor to discriminate between cylinders.



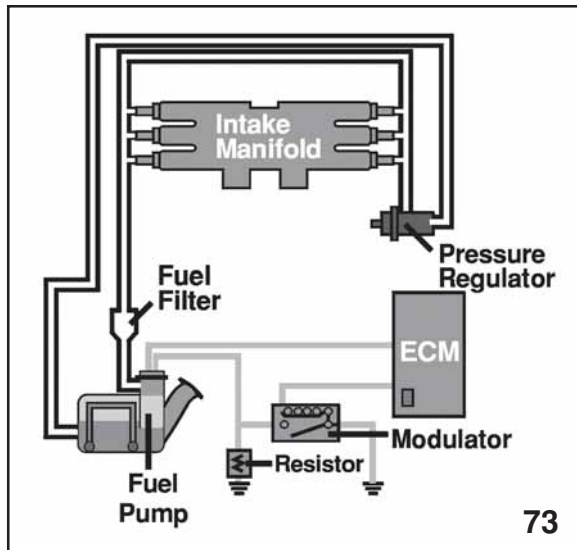
*Throttle Sensor*

Throttle sensor operation is more similar to Impreza than Legacy. An idle switch is not used rather a reference voltage of approximately .5 volts is used. The voltage will increase as the throttle moves toward wide open with a maximum of 5 volts. A return spring inside the TPS provides a smooth drop voltage as the throttle is released to idle.

# Fuel Injection and Engine Management (406)

## SVX Fuel Delivery System

The fuel pump system located inside the fuel tank is similar to the Legacy. It receives its basic power supply from the fuel pump relay.



*Fuel Delivery System*

An electronic volume control system has been added which reduces fuel evaporation by creating less fuel agitation through the fuel system during low fuel demand driving conditions.

The electronic fuel pump “modulator Unit” is located under the right side of the package shelf. It completes the ground circuits for the fuel pump. There is a direct ground and a resistance ground.

A fuel pump resistor is located next to the fuel pump modulator. It is wired to the pump in parallel with the modulator.

The ECM monitors injector pulse width and engine speed in order to reduce fuel flow during low load and low RPM conditions. The ECM signals the modulator to send the fuel pump ground through the resistor, providing minimum fuel flow during low load conditions. Under high load/high RPM conditions, the ECM signals the “modulator unit” to supply a direct ground to the fuel pump, providing a high fuel flow condition.

## Fuel Tank Components

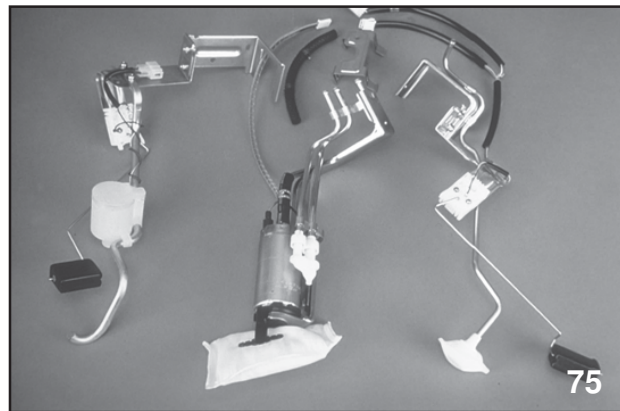
The fuel tank is a saddle tank design made of resin. This provides a weight savings as well as corrosion resistance. It is located under the rear seat area.

The tank design allows for air space which eliminates the need for a fuel separator. It forms a 10 liter air chamber at the top of the tank.

The fuel shut off valve is part of the tank cover assembly. The valve incorporates a float which prevents liquid fuel intrusion into the vapor hose to the charcoal canister.

Example: Fuel slosh during hard driving

Fuel tank components are serviceable with the tank in vehicle. They are accessed through a large opening in the top of the tank similar to the Legacy.

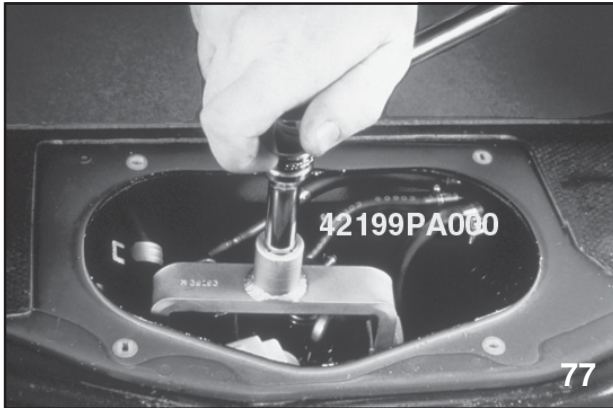


*Sending Units Assemble and Pump*

In addition to the fuel pump, there are two sending units mounted inside the fuel tank; a main unit and a sub unit. The main unit incorporates a low fuel sensor. The function and diagnostics for the sending units is similar to the Legacy.



## Fuel Tank Servicing

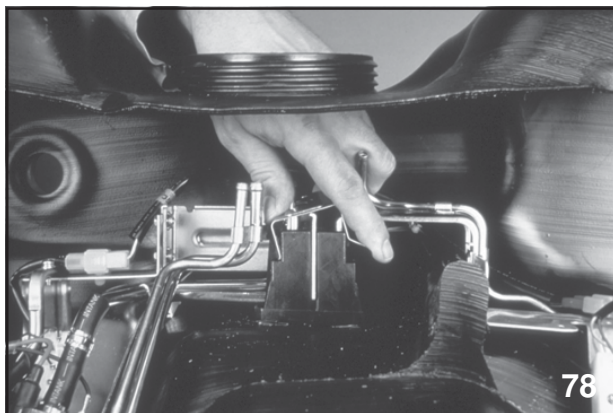


*Removing Spanner Ring*

Remove all of the fuel tank components in order. Start with the spanner ring using service tool #42199PA000. Then remove the cover after disconnecting the fuel hoses from the pipes in the tank.

**NOTE: MARK THE HOSES SO THEY CAN BE CORRECTLY REINSTALLED ON THE DISCHARGE "D" AND THE RETURN "R" LINES.**

Disconnect the 2 electrical connectors for the fuel pump and the fuel gauge sending unit. Push the wires back into the tank and remove the crossover hose with its retaining clips.



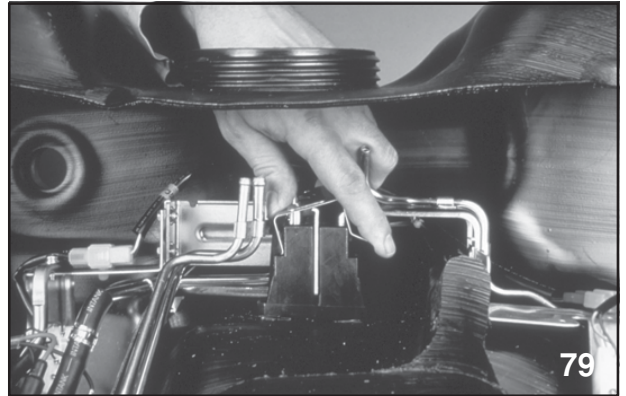
*Sub Assembly Retaining Clamp*

Now reach inside the tank and remove the metal retaining clamp by lifting the two tabs on the left side of the clamp.

**NOTE: THERE ARE THREE ASSEMBLIES INSIDE THE TANK. EACH ASSEMBLY COMES OUT SEPARATELY AND IN ORDER.**

## Sub Assemblies

Lift the right hand sending unit assembly from the molded bracket and temporarily set it aside inside the tank. Then lift the fuel pump assembly from the molded bracket.



*Removing Fuel Pump*

Remove the fuel pump assembly by gently rotating it back and forth. Then gently rotate the right hand sending unit clockwise in order to just clear the tank. Next, disconnect the electrical connector from the sending unit and remove the right hand sending unit from the tank.



*Removing Sending Unit*

Gently rotate the left hand sending unit counter clockwise until it is upside down. Remove the assembly with the wiring harness attached.

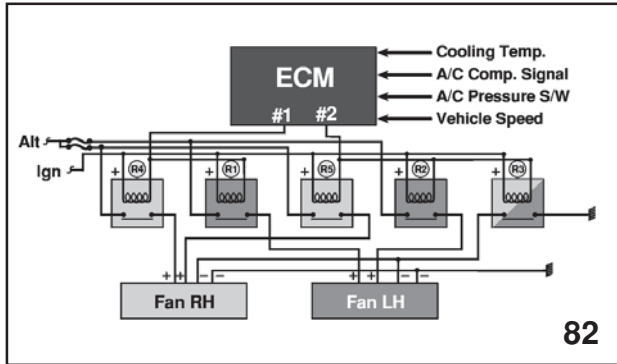
**CAUTION: WHEN REMOVING THE SENDING UNITS, USE CARE SO AS NOT TO BEND THE FLOAT ARMS. THIS CAN AFFECT THE FUEL GAUGE CALIBRATION.**

For reassembling the fuel tank components, reverse the order of disassembly.

# Fuel Injection and Engine Management (406)

## Radiator Fan Control

The radiator fan uses five (5) relays which are located in the main fuse box behind the battery. They are 4 pole (NO) type relays.



*Fan Control Schematic*

The three speed, dual fan operation allows for quieter operation during idle conditions and it allows for increased air flow during other operating modes.

Example: Slow speed driving

The two 3 speed 160 Watt Fans each have two (2) B+ control wires and two (2) ground wires. The relays are controlled by the ECM. The ECM provides 2 separate control signals (signals #1 and #2) to the fan relays. Signal #1 determines low speed for the left hand and right hand fans. Signal #2 determines "medium speed" and signals #1 and #2 combined provide high speed.

Several ECM inputs determine the fan operating speeds:

- Coolant temperature
- A/C compressor "ON/OFF" condition
- A/C Pressure switch
- Vehicle speed

## Relay Control Circuit

Battery B+ power is provided by the ignition switch to all of the relay coils. ECM signal #1 supplies grounds to relay coils #1 and #4 (low speed). Signal #2 grounds relay coils #3, #2 and #5.

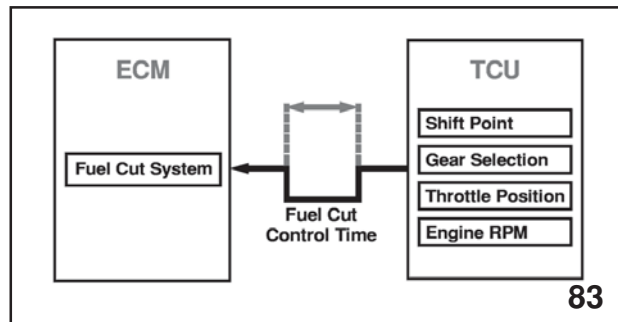
## Motor Control Circuit

Relays #1 and #4 supply B+ power to one positive terminal of each fan motor. Relay #1 powers the left hand motor and relay #4 powers the right hand motor. Relays #2 and #5 (mid speed) supply B+ power to the other positive terminal of each fan motor. Relay #5 supplies the right hand motor and relay #2 supplies the left hand motor. Relay #3 supplies an additional ground to both the left hand and right hand motors.

Two (2) fused (20A) circuits supply B+ power for each motor relay power supply circuit. A fuse protection function is part of the ECM fan control section. It initially limits the fan to start from low speed. Then it goes through medium to high speed during hot start-up conditions.

By gradually increasing the fan speed from Low to Medium and then to High, a large current surge across the fuses is prevented.

## Torque Reduction System



*Torque Reduction System*

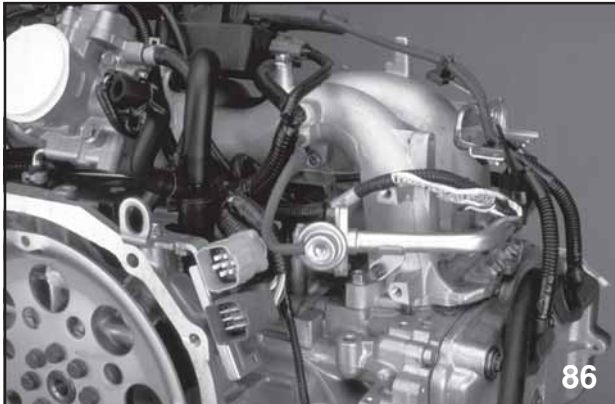
The 3.3L ECM differs from the 2.2L ECM in the following ways. It has a torque reduction system networked between the TCM and the ECM which reduces shift shock during upshifts when the engine is under a high RPM load (above 6000 RPM or at WOT). ECM momentarily activates fuel cut at the time of the shift. Also has a "soft" control program for enhanced idle speed control. Provides smoother, more precise idle speed control.

## 1999 Enhancements

The fuel injection and engine management control system for the 1999 model year will be designated L MPI and D MPI. EXCEPT LEGACY 2.5 PHASE 1, WHICH WILL USE THE SAME FUEL AND ENGINE MANAGEMENT SYSTEMS THAT WERE EQUIPPED ON THE 1998 MODEL YEAR VEHICLES. These sequential systems are similar in design sharing most operating and diagnostic functions. The most noticeable difference is the D MPI system, which is California Specification, uses new style air assist injectors.

## D MPI

The air assist fuel injector is supplied with fuel from a supply rail, which is connected to the top of the injector.



*Fuel Supply Rail*

Referred to as top feed, this style injector internally functions the same as injectors used on previous model years.



*Air Assist Injector*

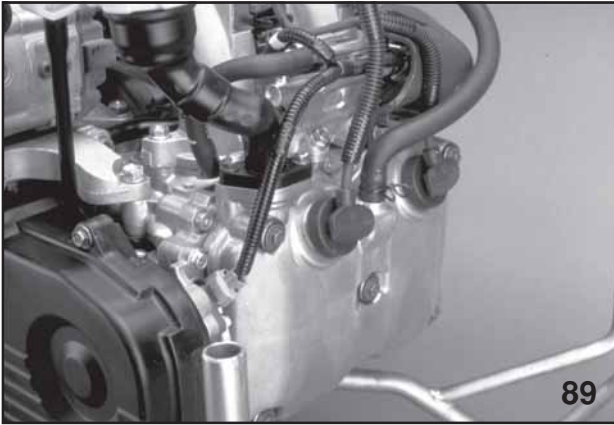
Externally the injector is sealed at the top and bottom with O-rings and double lip seals. Additionally the air assist injector is supplied with air from the Idle Speed Control Valve.



*Idle Speed Control Valve*

This air is used to provide faster atomization of the fuel, providing lower emission output and improved driveability. The air from the ISC is delivered through a passage made into the intake manifold to the bottom of the injector.

# Fuel Injection and Engine Management (406)

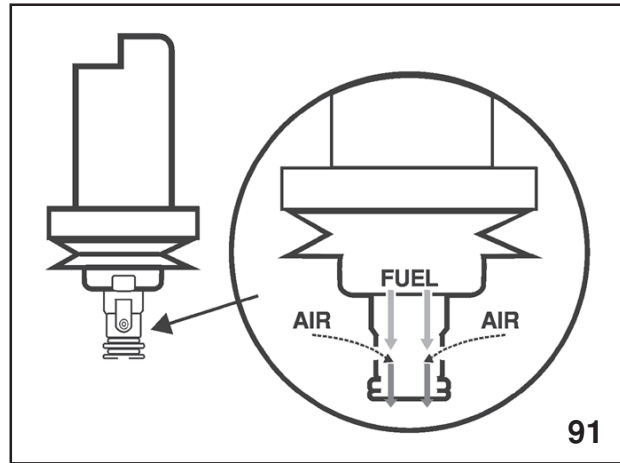


*Air Assist Supply Rail*

The negative pressure area below the injector is constantly filled with the more positive pressure air from the ISC. The air must travel through a chamber attached to the bottom of the injector.

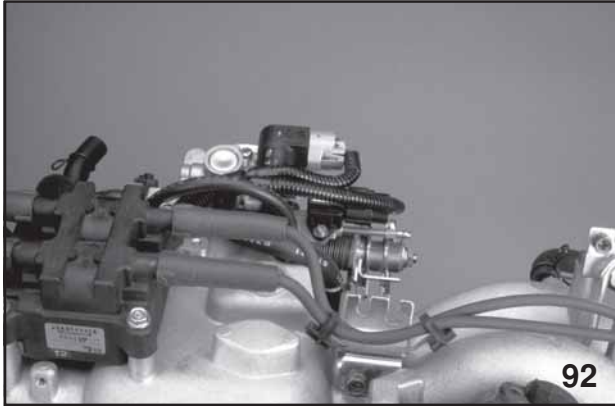


*Injector AA Chamber Tip*



*AA Chamber (Air Inlets)*

The chamber has 4 small holes that meter the air into the fuel stream, beginning the atomization process when the injector is turned on. Looking through the two lower holes of the chamber the four holes of the injector are visible.



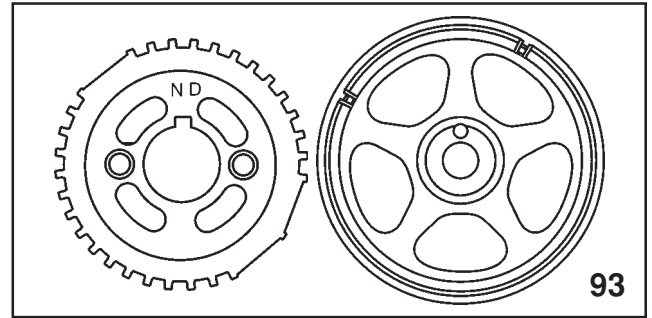
*Idle Speed Control Valve*

The Idle Speed Control Valve of the D MPI system is a rotary type controlling all idle speeds. The electrical operation of the ISC itself includes a closing coil and an opening coil. The close coil is always on, trying to close the rotary valve. The opening coil is controlled by a signal or duty ratio from the Engine Control Unit, adjusting the ISC to maintain the correct engine idle speed. Part of the controlled air bypasses the throttle plate effecting idle speed. The remainder is delivered to the injectors.

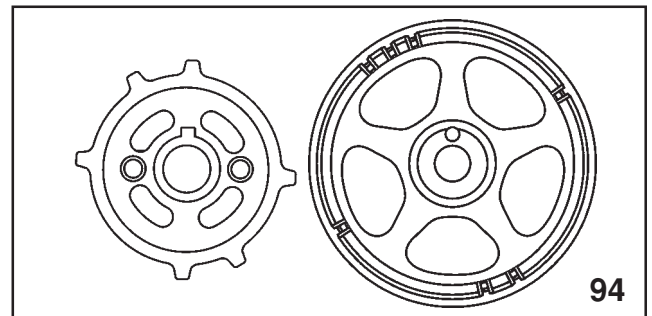
Off idle engine operation results in a larger amount of air delivered to the injectors.

The Pressure Sensor of the D MPI system is a strain type sensor. A set of resistors is mounted to the diaphragm inside the sensor. Changes in pressure of the intake manifold alter the shape of the diaphragm and to the resistors. The changing resistance value is sent to the engine control unit as an input signal.

## Crankshaft and Camshaft Reluctors

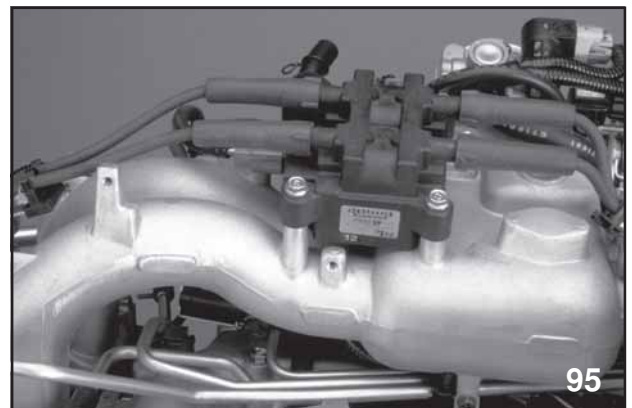


*D MPI*



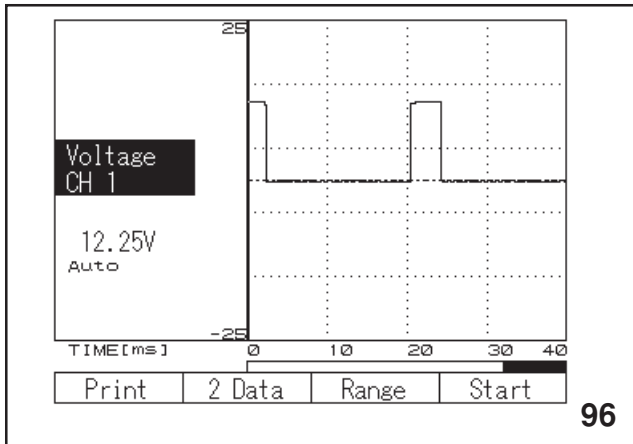
*L MPI*

The crankshaft and camshaft reluctor of the D MPI system are used to influence ignition and injection timing. The number of teeth on the two reluctors differs from those of the L MPI. Installation of incorrect components will result in a no start condition. The additional teeth assist the Engine Control Unit to shorten the time for cylinder discrimination and improve accuracy of misfire detection.

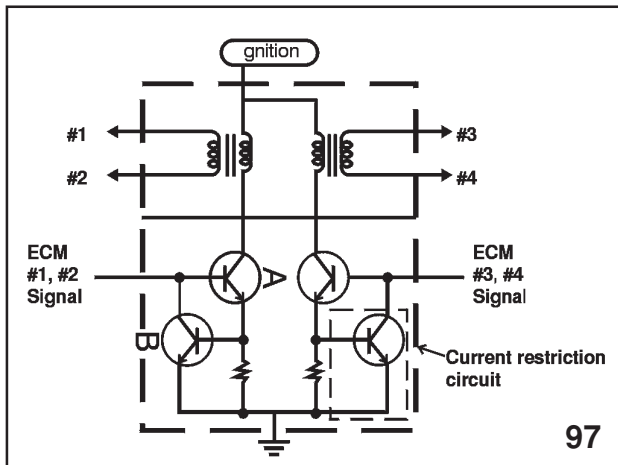


*Ignitor Coil*

The ignition coil and ignitor are now one unit. A 12-volt square wave signal is sent to the coil from the ECM to control the ignitor. The ignitor in turn controls the coil primary winding.

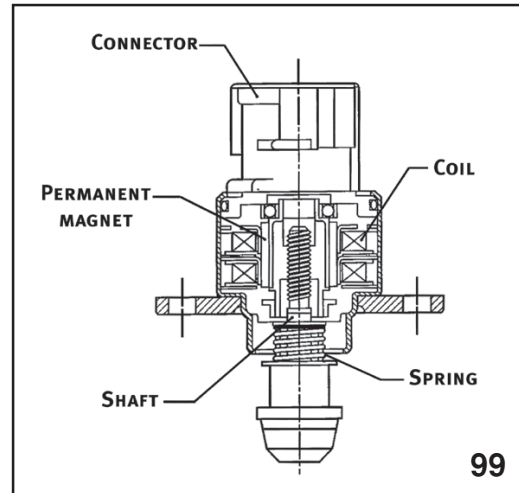


*ECM to Coil Signal*



*Ignition Coil Construction*

## L MPI



*Idle Air Control Solenoid Valve*

The injectors of the L MPI system are sealed to the fuel rail and intake manifold in the same manner as the D MPI. Missing is the atomization chamber located below the injector. Operation and diagnostic procedures are also shared.

The ISC of the L MPI system is a stepping type solenoid valve, which consists of coils, shaft, permanent magnet, spring and housing. The housing is built into the throttle body.

In operation current flows sequential through a series of paired coils which are arranged to react with the permanent magnet that is fixed to the shaft. The ECM controls the polarity of the coils, which effects the position of the permanent magnet. This action rotates the threaded shaft of the ISC increasing or decreasing the depth of the air-sealing surface.

When replacing or installing the ISC it must be initialization accomplished by turning on the ignition with the engine off for at least three seconds. The engine may now be started.

# Fuel Injection and Engine Management (406)

The pressure sensor and pressure sources switching solenoid are of the style used in 1998 Subaru vehicles, sampling atmospheric pressure at start up and then cycling over to measure manifold pressure.

The coil and knock sensor of the L MPI are also sheared with the D MPI.

The throttle position sensor functions the same as the D MPI except it is adjustable.

The L MPI system utilizes an Air flow meter with the same operating characteristics of the Air Flow Meter used on the 1998 Model Subaru vehicles.

Oxygen sensors of the L MPI are the same as used on the 1998 model year vehicles.

## 2000 Enhancements

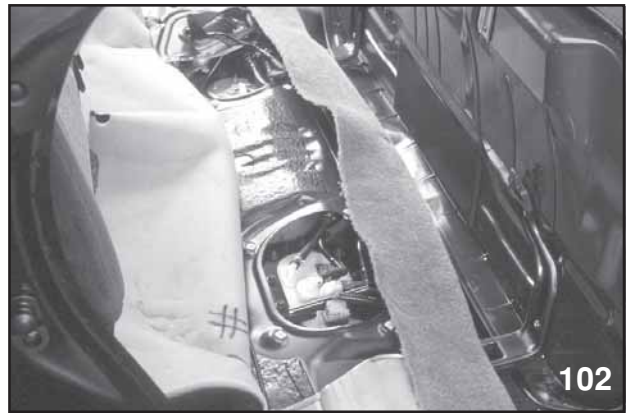
The fuel tank and ORVR components have been relocated on the vehicle. This makes necessary movement of key fuel system plumbing. On such movement involves this new hose.



*Vent Control Piping*

This hose is routed from the fuel neck to the vent control valve located on the driver's rear of the fuel tank. The routing carries the hose through the inner fender into the passenger compartment. The hose is protected by a metal cover, which must be removed to gain access to the quick connector. The quick connector must be disconnected before the fuel tank is lowered.

Movement of the fuel tank is accompanied by a change in the fuel pump assembly design and location. The fuel pump assembly and sub pump pick up assembly are now accessed from under the rear seat. The pumps are located on the lower level of the fuel tank which makes it necessary to remove the fuel from the tank before removing the fuel pump or sub pump pickup assemblies. **Failure to remove fuel from the tank will result in fuel being introduced into the passenger compartment.**



*Fuel Pump (Under Seat)*

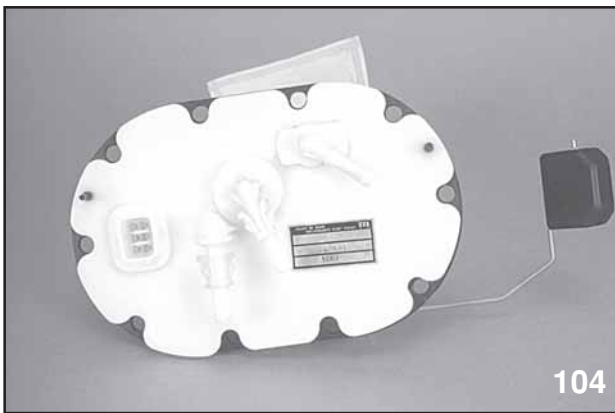
A fuel drain is located on the passenger side, front of the fuel tank. Use of this drain will lower the fuel from the high side of the tank and totally drain the passenger side of the saddle tank. The sub pump pickup side, (the drivers side) of the tank, will remain full. Consult the appropriate Subaru Service Manual on the STIS web site for the proper procedure for draining all fuel from the fuel tank.

# Fuel Injection and Engine Management (406)



*Fuel Drain Plug*

The body of the new fuel pump assembly is resin based. The gasket for the assembly has two location prongs that must be pulled into the outer cover.

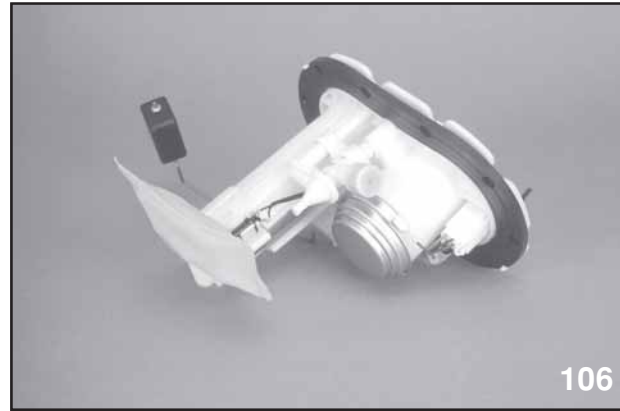


*Fuel Pump (Top View)*



*Fuel Pump (Float Arm View)*

This round housing is designed to accept a fuel filter however; the North American market will not use a filter located on the fuel pump.



*Fuel Pump (Static Strap View)*

The small wire connected to cap area of the fuel pump housing carries static charges away from the pump body to vehicle ground.

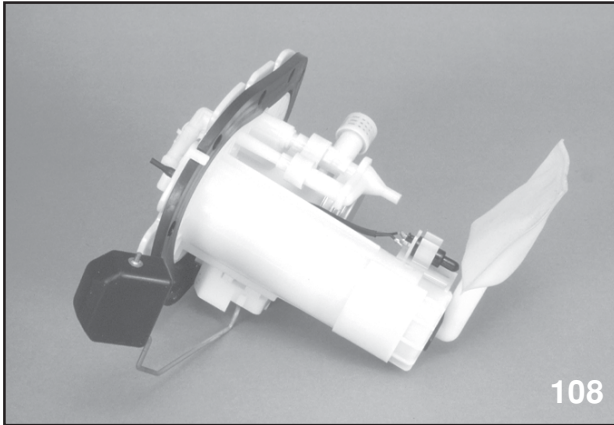


*Static Strap Close-up*

The low fuel level sensor operation has been enhanced. The sensor itself works the same however, the low level when sensed triggers a circuit located in the fuel gauge to maintain the low level indicator illumination until the tank has had fuel added.

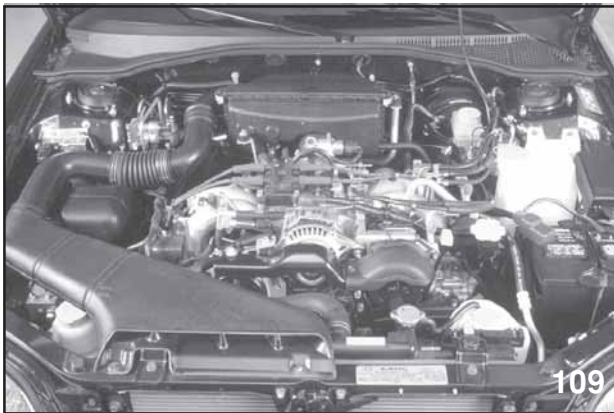


# Fuel Injection and Engine Management (406)



*Fuel Level Sensor*

All Legacy vehicles will be equipped with phase 2 2.5 liter engines using the D MPI fuel systems, (California Spec) making the 2000 model Legacy a 50 state car.



*Engine Compartment*

Two fuel systems will be used for the 2000 model year, the AAI UJ and AAI ND systems.

The AAI UJ system will be equipped on the Legacy automatic, Impreza 2.5 liter, and all Forester models.

The AAI ND system will be equipped on the Legacy manual transmission and Impreza 2.2-liter models.

The ND system closely resembles the D MPI system that is currently equipped on 1999 California spec models with changes only to the ECM logic.

The UJ system has two new components, an AAI Air Assist Solenoid Valve and an Intake Air Temperature and pressure sensor.

The Air Assist Solenoid Valve is connected to the inlet side of the ISC, which requires the Air Assist Solenoid Valve to regulate the air to the base of the injector. The ND system regulates the air to the base of the injector with the ISC.

At idle the Air Assist Solenoid Valve is on allowing 20L/min per injector of air to flow. Off idle conditions result in the Air Assist Solenoid Valve turning off allowing only 5L/min per injector of airflow.

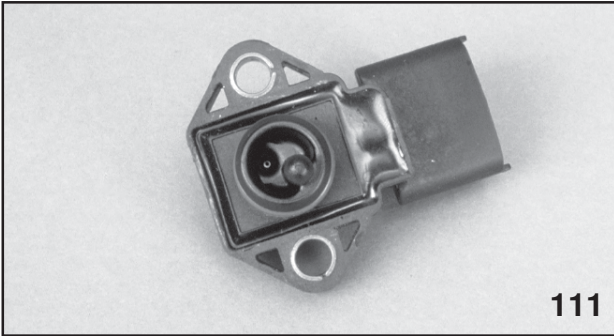


*Air Assist Solenoid Valve*

The new Intake Air Temperature and pressure sensor monitors the absolute pressure and the temperature of the air in the intake manifold. The measured temperature and pressure of the air is then converted into electrical signals and sent to the ECM. The ECM uses those signals from the sensor to control the fuel injection amount as well as the injection and ignition timing.

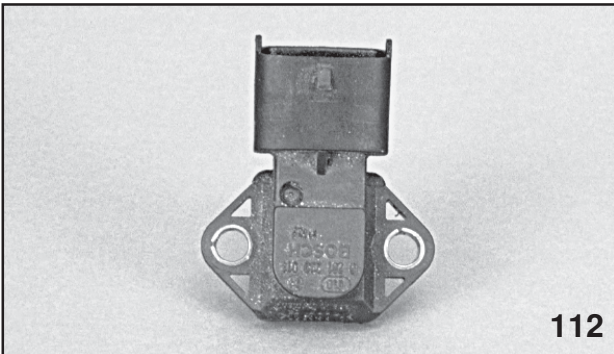
Only the UJ system continues to use the Atmospheric pressure sensor located on the right strut tower. This sensor works with the AFR to monitor air density.

# Fuel Injection and Engine Management (406)



*Intake Air Temperature and Pressure Sensor (Bottom View)*

The intake manifold pressure sensor is connected directly to the throttle body, and constantly measures the absolute pressure of the intake manifold. The pressure that is measured is converted into an electrical signal, and is sent to the ECM. The ECM controls the fuel injection and ignition timing based on the intake manifold absolute pressure signal from the pressure sensor.



*Intake Air Temperature and Pressure Sensor (Top View)*

The air induction housing provides air to the throttle body and begins to form the turbulence needed in the combustion chamber for proper air fuel mixing.



*Air Induction Housing*

The throttle position, idle speed control motor, and ignition coil have not been changed.



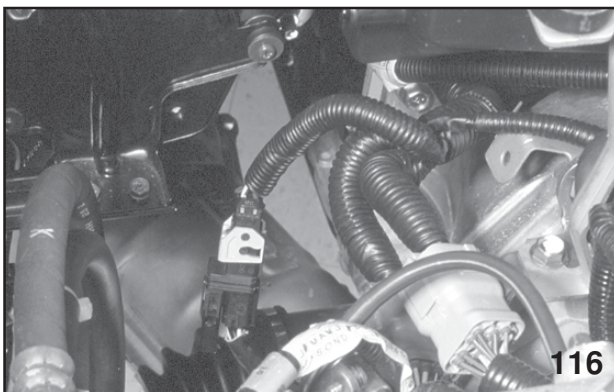
*TPS*

The throttle position, idle speed control motor, and ignition coil have not been changed.



*AFR Sensor*

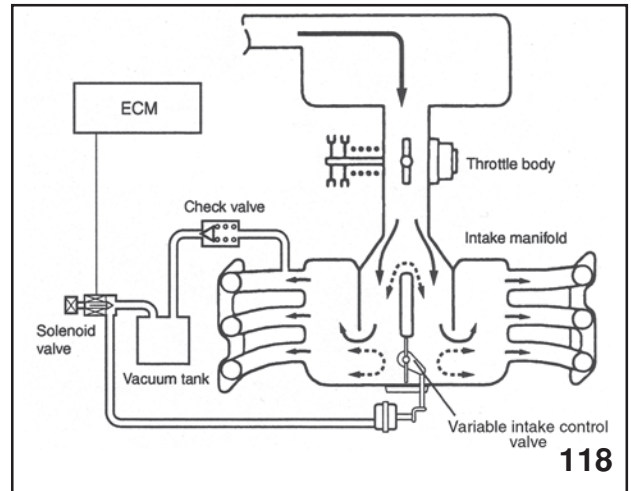
A new type air fuel ratio sensor is used on the UJ system. The harness includes a new-style locking mechanism. Position the locking mechanism as shown and gently separate the vehicle harness from the sensor harness.



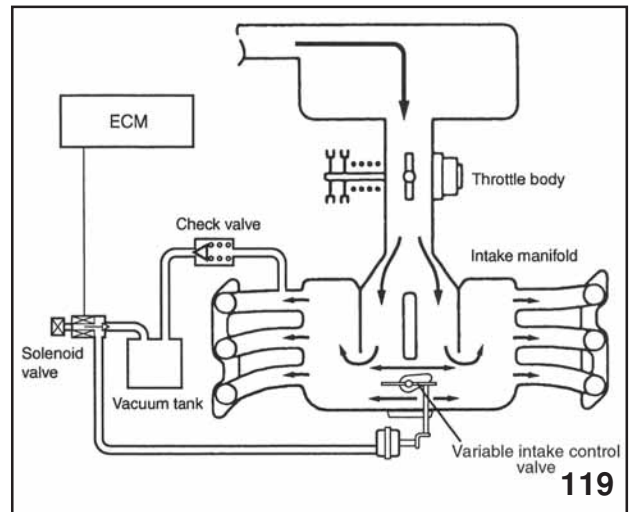
*AFR Sensor Harness*

The sensor harness includes an electrical compensation device that allows for manufacturing tolerances.

## 2001 Legacy Enhancements



*Variable Intake Control Valve Closed*



*Variable Intake Control Valve Open*

The variable Induction control system opens and closes an airflow valve which is located in the middle of the intake manifold. This action joins or separates the LH and RH sides of the intake manifold.

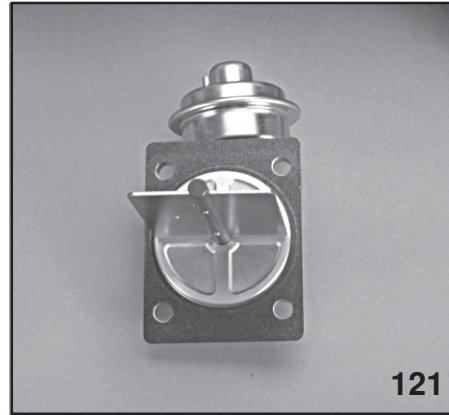
Components of the system include the airflow valve, vacuum tank, check valve, solenoid and associated piping.

# Fuel Injection and Engine Management (406)

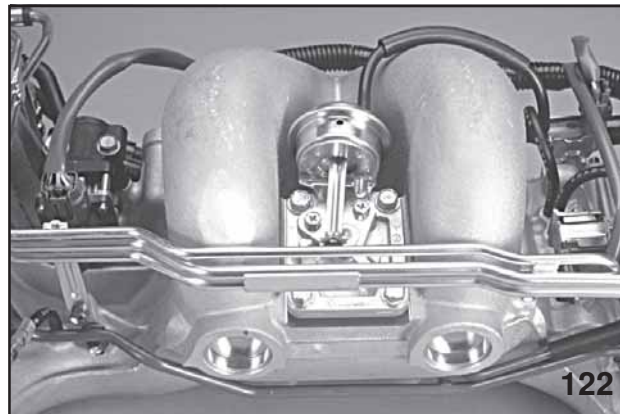
The airflow valve closes during the low to middle engine speeds to control the resonance effect and opens during high engine speeds to increase the inertia effect.

Resonance effect is created during the intake stroke when the intake valve begins to open. The combustion chamber contains a large negative pressure created by the exhaust stroke. This negative pressure will enter the intake runner through the open intake valve creating a shock wave as it is traveling at sonic speeds. This will create a resistance to the flow of the new air charge into the combustion chamber. Left uncontrolled this resistance would spread to all parts of the intake manifold and decrease airflow and overall engine performance. Keeping the airflow valve closed during low to middle speed engine operation will keep the resonance effect isolated to one side of the intake.

As the engine crosses beyond mid-range the inertia effect becomes strong enough to overpower the resonance effect and the airflow valve is opened. This will allow air moving on the LH side of the manifold to assist the RH side.



*Variable Intake Control Valve*



*Variable Intake Control Valve Location*

## Variable Intake Control Valve Operation

	Open	Closed
Engine Off	●	
Engine Idling	●	
Light Engine Load any RPM	●	
Heavy Load < 3600RPM		●
Heavy Load > 3600RPM	●	

120

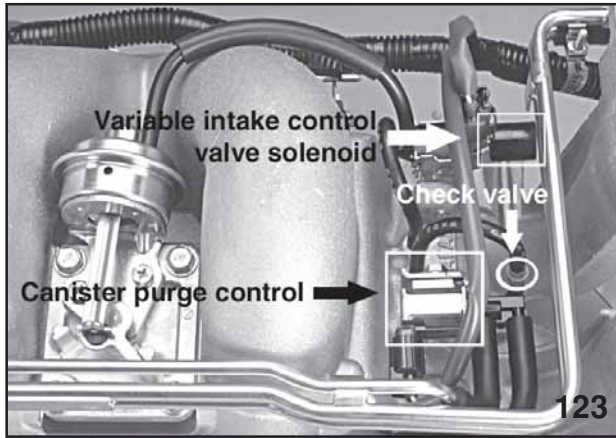
*Variable Intake Control Valve Chart*

The variable intake control valve is positioned on the under side of the intake manifold.

The valve is controlled by the variable intake control solenoid which receives its operating signals from the ECM. The vacuum storage for the solenoid is built into the manifold as a separate tank.

When a signal from the ECM is generated to the solenoid the vacuum in the reservoir tank is routed from the solenoid to the variable intake control valve. This action will close the valve and in the event of low manifold vacuum, the check valve will keep the vacuum to the variable intake control valve steady. When the ECM is ready to open the variable intake control valve the solenoid will be turned off and vent the vacuum from the variable intake control valve to the atmosphere.

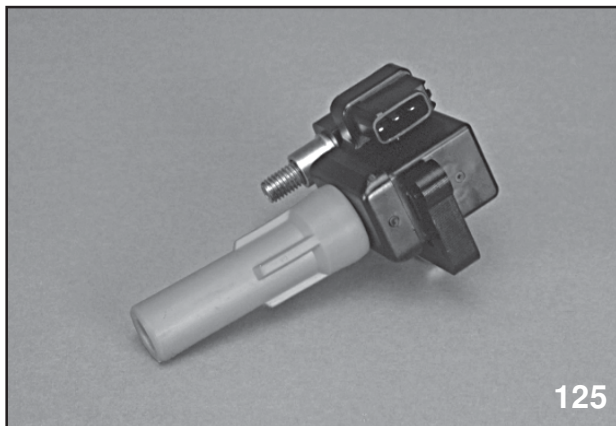
# Fuel Injection and Engine Management (406)



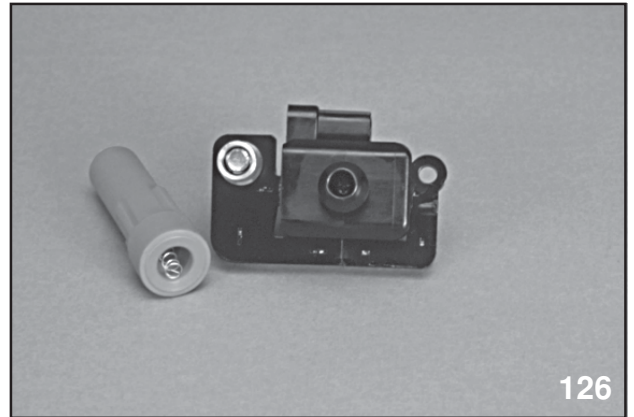
Component Location



Intake Manifold

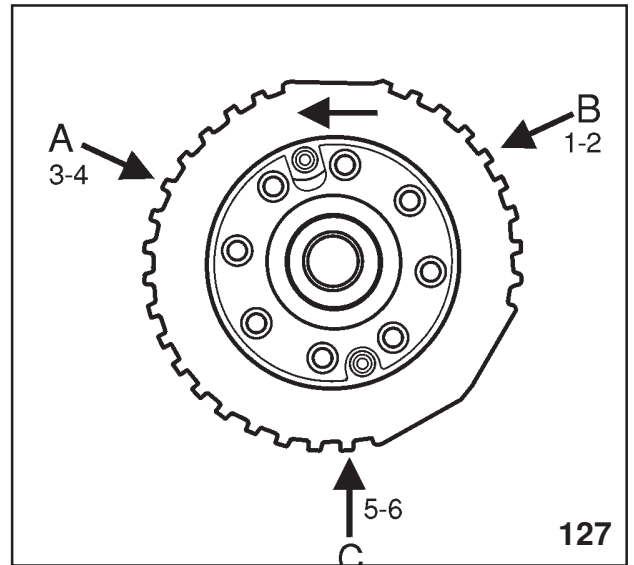


Ignition Coil Complete



Ignition Coil and Spring Contact (Apart)

Direct ignition coils are used for each cylinder. They contain the ignitor, current control circuit as well as the primary and secondary windings. A 12 square wave sent from the engine control module turns the primary circuit on and off.



Crankshaft Reluctor

## Cylinder - Cam Signal

- 1-Yes
- 6-No
- 3-Yes
- 2-No
- 5-Yes
- 4-No

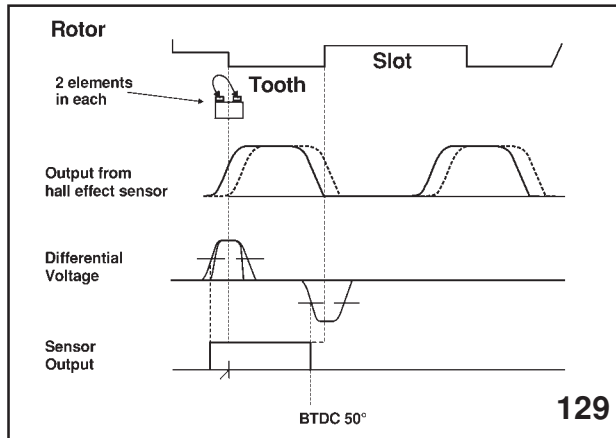
# Fuel Injection and Engine Management (406)

The new crank angle sensor is mounted to the flywheel end of the crankshaft. This end of the crankshaft has less torsional vibrations and offers a more stable signal generating area, providing very accurate crankshaft signals.

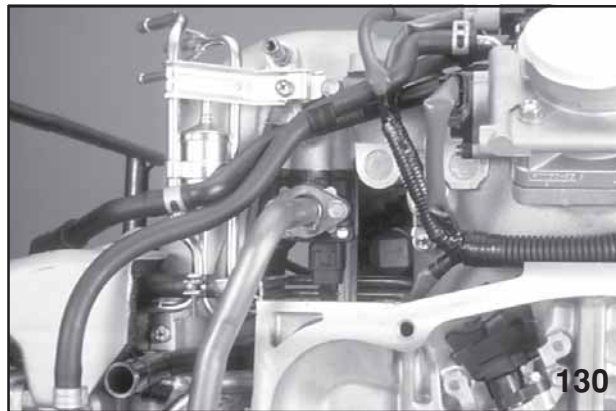
As the crankshaft rotates the reluctor produces 30 pulses which are sent to the ECM. The indicated reluctor teeth represent the signals for cylinders.

As the signals from the crank angle sensor are produced they will have a cam signal associated to them every other revolution. Position A without a cam signal is cylinder 4 and with a cam signal is cylinder 3. Position B without a cam signal is cylinder 2 and with a cam signal is cylinder 1. Position C without a cam signal is cylinder 6 and with a cam signal is cylinder 5.

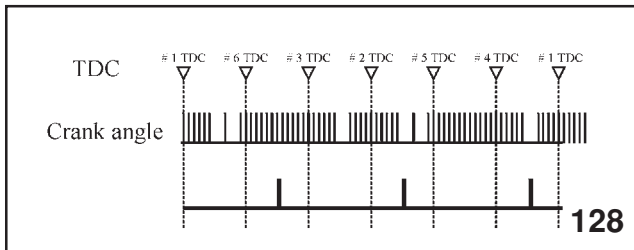
The right bank intake camshaft has a reluctor built onto the end. The new camshaft sensor uses this reluctor to help determine injection and ignition timing.



Cam Angle Signal Pattern



EGR Pipe

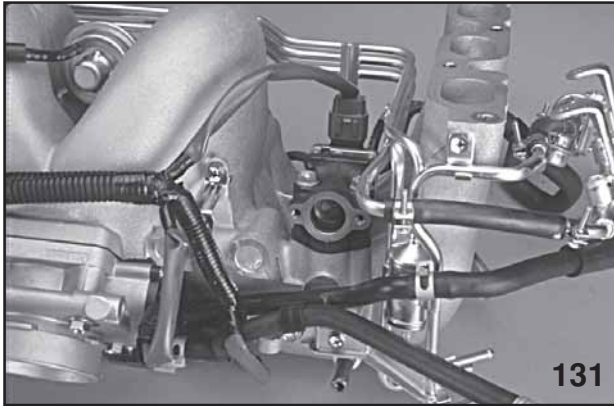


Crank Angle Graph

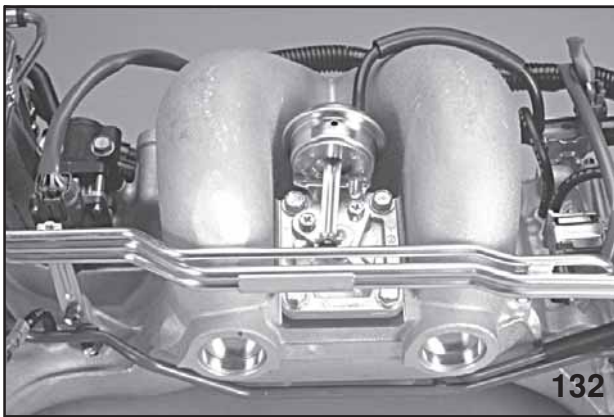
The cam sensor consists of two elements or windings that sense the slot on the cam shaft reluctor. The sensor also contains an integrated chip that produces a square wave output signal (5 volts).

The integrated chip measures the time lag between the beginning and ending of the signals picked up by the two elements, (Hall effect) and converts this information into the output signal.

# Fuel Injection and Engine Management (406)



*EGR Valve*



*EGR Harness*

An electronic Exhaust Gas Recirculation valve is utilized on the EZ-3.0 Engine. The ECM controls the number of steps (stepping motor) the valve is opened. Each step will allow a certain amount of exhaust gas to flow through the valve. The ECM will check the performance of the valve (OBDII) by opening the EGR valve to a specified number of steps. The resulting manifold pressure changes are monitored to determine if the performance of the valve is in specifications.

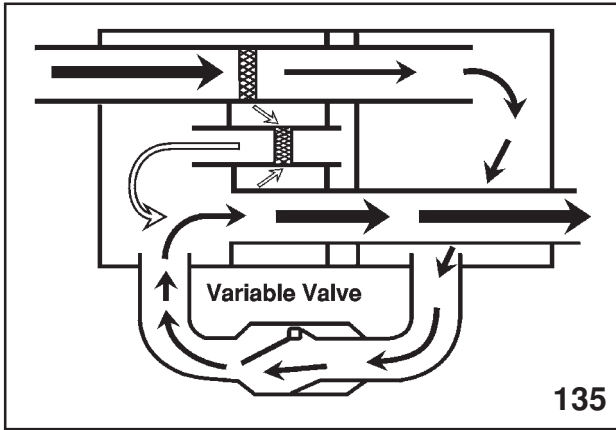


*Muffler*

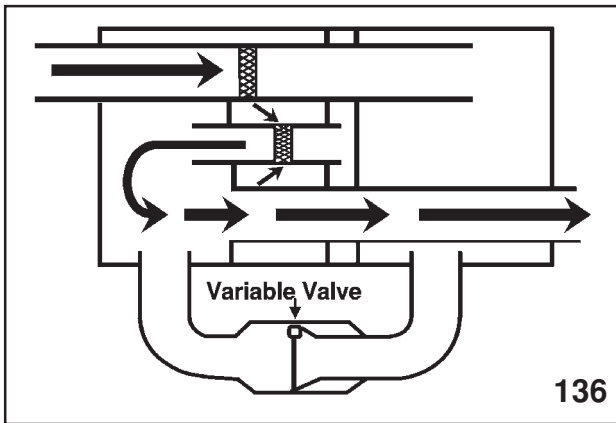


*Muffler Bypass Valve*

The muffler equipped on the EZ-3.0 Engine is designed with a bypass valve that opens when the exhaust pressure exceeds 45 mm HG. This occurs around 2400 RPM. The bypass valve allows parts of the exhaust to go around some of baffles inside the muffler instead of through them. The result is increased engine performance.



*Bypass Valve Operation  
(High Engine Speed)*



*Bypass Valve Operation  
(Low Engine Speed)*

## 2002 Impreza Enhancements



*Tumble Generator Valve Rail*



*Tumble Generator Valve Motor*

The EJ-2.0 is equipped with a tumble generator valve at each intake runner. This new system uses a shaft for each side of the engine that is driven by a stepper motor. The movement of the shaft is monitored by a sensor on the opposite end.



# Fuel Injection and Engine Management (406)



*Vent Hose*



*Bottom View of Intake*



*Tumble Generator Valve Position Sensor*

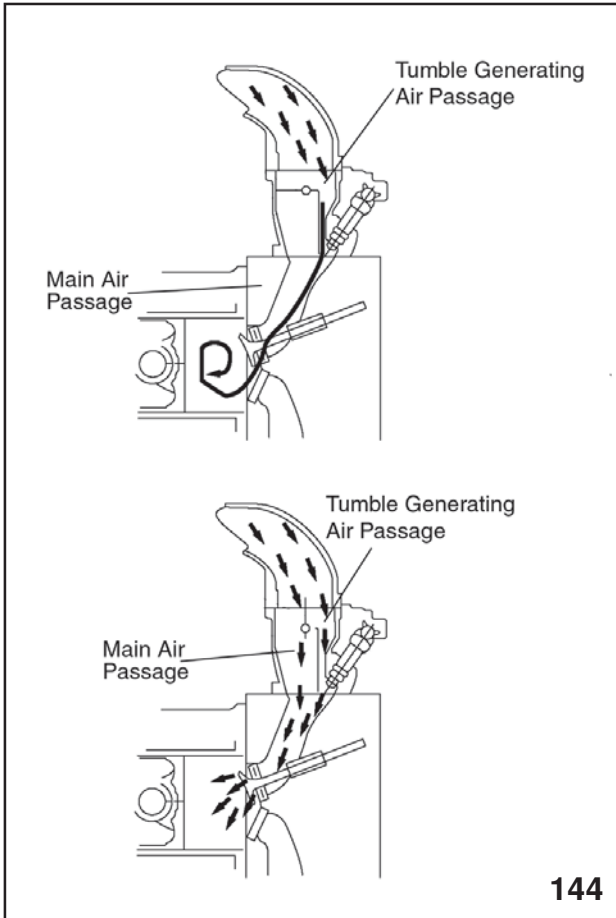
The shaft operates the tumble generator valve, which is a plate similar in design to the throttle plate. At idle the plate is closed (dependant on coolant temperature and time from engine start). Off idle the plate is open.



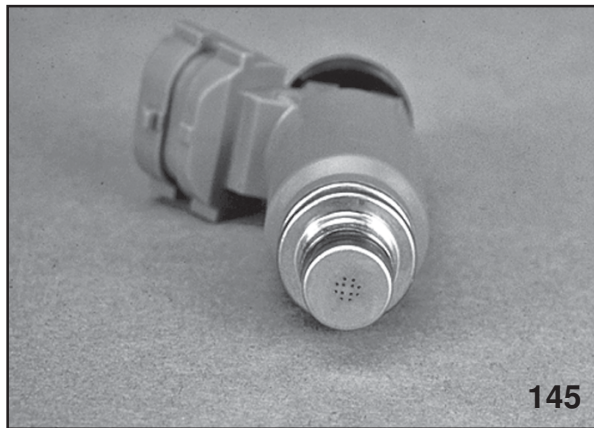
*TGV Channel*

When the plate is closed the main air passage through the intake runner is blocked. This will force all air necessary for engine operation during idle to flow through the bypass channel. This action helps to mix the air fuel mixture by producing a tumbling effect to the incoming air, resulting in a cleaner operating engine while idling.

# Fuel Injection and Engine Management (406)



*Tumble Generator Valve Operation*

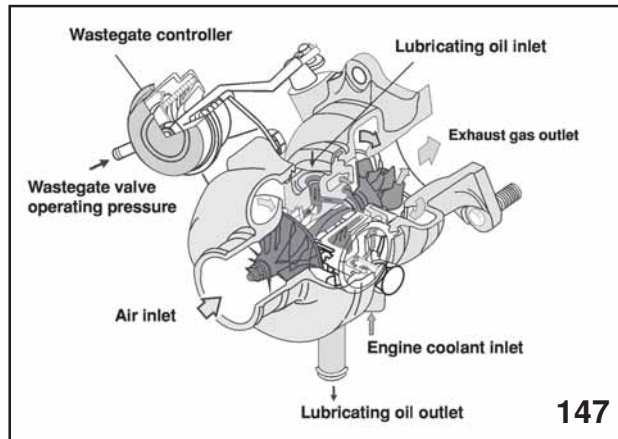


*Injector*

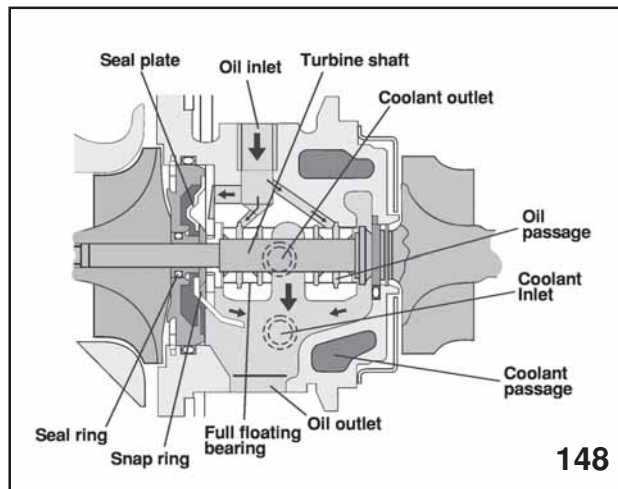
The new fuel injector is a top feed type with 12 holes. The new hole pattern produces a finer spray of fuel which assists with lowering the overall emission output of the vehicle. (No air assist on Turbo models.)

## Turbocharger

The introduction of the 2.0 liter engine to North America reintroduces the Turbocharger which was last used on the 1994 Legacy 2.2 liter. The new Turbocharger and fuel system have been designed to produce higher engine performance and lower exhaust emissions.



*Turbocharger (Artwork)*



*Turbocharger Housing (Artwork)*

# Fuel Injection and Engine Management (406)

The Turbocharger consists of two sections, an exhaust side and an induction side. The exhaust side has a turbine wheel with vanes that are shaped to harness the exhaust gas energy. This drives the turbine and center shaft. On the induction side there is an impeller wheel attached to the center shaft which also has vanes but shaped in the opposite direction. The movement of the wheel compresses the induction air as it rotates. Increasing engine speed and load increases the level of kinetic energy in the exhaust gas making the turbine rotate faster. This causes the impeller, which is attached to the common center shaft, to also rotate faster creating greater compression of the induction air. Rotational speeds of the turbine are in the range of 20,000 rev/min. at idle to 150,000 – 200,000 rev/min. at full power. As a result of these very high operating speeds and temperatures, makes lubrication and cooling of the center shaft bearings of prime importance.

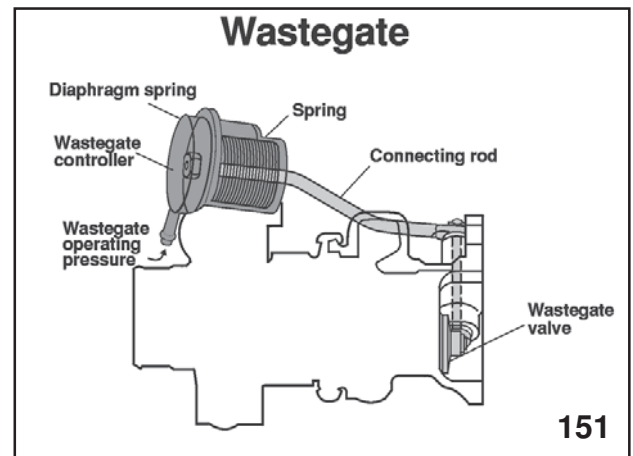


*Coolant Connection and Oil Return*



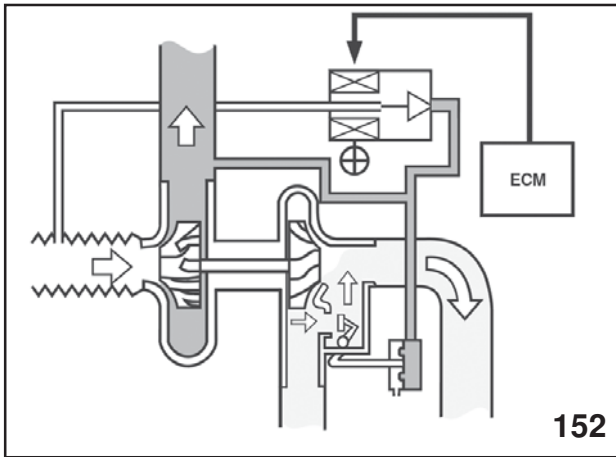
*Oil Supply and Connection*

The shaft bearings are lubricated by a constant supply of engine oil. An oil cooler positioned above the oil filter transfers heat from the oil to the engine coolant. Further cooling of the Turbocharger is achieved by coolant fed from the right cylinder head to coolant passages around the exhaust turbine bearing.



*Wastegate (Artwork)*

# Fuel Injection and Engine Management (406)



*Wastegate Operation (Artwork)*

Due to the limited strength of the engine there is a limit to the amount of boost pressure that can be used. The limiting of boost pressure is achieved by the use of a 'wastegate', which bypasses the exhaust gas around the turbine wheel when the desired level of boost is reached.



*Wastegate Actuator*



*Wastegate Valve*

The ECM references a boost pressure map programmed into Read Only Memory (ROM) after first reading the input signals. By calculating the actual boost pressure, and after compensating for engine temperature and atmospheric pressure, the ECM is able to provide an output duty ratio signal to the Wastegate Control Solenoid. This regulates the amount of pressure applied to the wastegate controller diaphragm by leaking off boost pressure to the inlet side of the turbine.



*Wastegate Duty Solenoid*

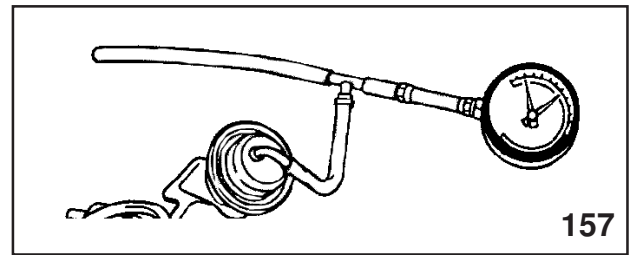
The wastegate controller (in response to the Duty Solenoid) opens the wastegate flap valve to bypass exhaust gas and so decrease the rotating energy of the turbine keeping the boost pressure to the desired level.

When operating at increasing altitudes, the atmospheric pressure becomes lower and therefore the difference between the desired level of boost pressure and atmospheric pressure becomes greater. To maintain the same level of boost pressure the air must be compressed more which requires more turbine rotating energy. Therefore less boost pressure is applied to the wastegate controller via the solenoid valve and boost remains constant.

However, at very high altitudes the extra compression of the air at maximum boost causes a too high intake air temperature even after intercooling and engine knock will occur. Therefore it is necessary to decrease the maximum boost pressure at very high altitudes.

## Turbocharger Testing

### Wastegate Control



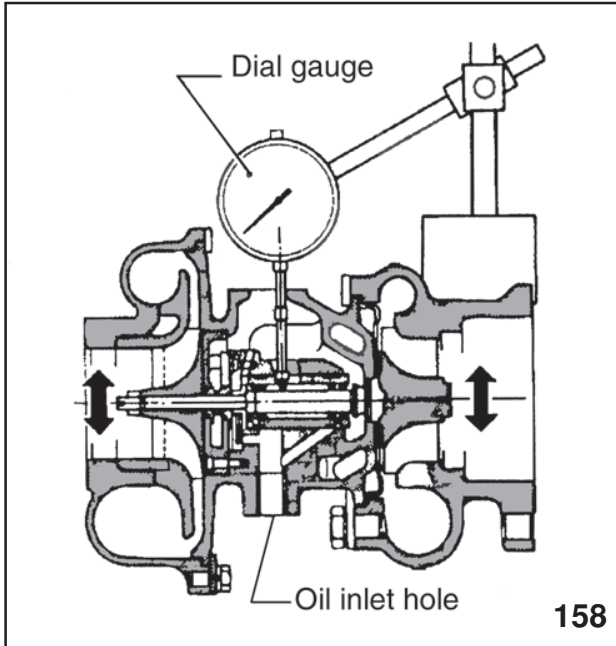
*Pressure Gauge Connection*

Attach a regulated pressure supply directly to the wastegate actuator hose connection.

The actuator should begin to open at approx. 50.0 - 60.0kPa. (7.2 - 8.7 p.s.i.)

Check all associated hoses for damage or loose connection.

The Turbocharger should be visually inspected for any damage to the compressor or turbine wheels. Check for any oil that may be present in the turbine housing. A small amount of oil due to crankcase 'blow by' is acceptable in the compressor housing.

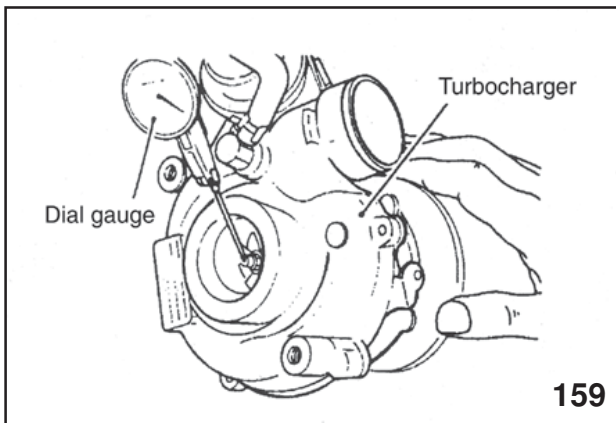


*Radial Movement Check*

Before testing the electronic components in the boost control system, be sure that the wastegate is operating correctly.

Utilizing a dial gauge, measure the radial movement of the turbine shaft by accessing it through the oil outlet hole. Radial play should not exceed 0.17mm. (.006 inches)

To measure the axial movement of the turbine shaft, place the dial gauge against the end of the shaft at the turbine end, and push against the compressor end of the shaft. Axial play should not exceed 0.09mm. (.003 inches)



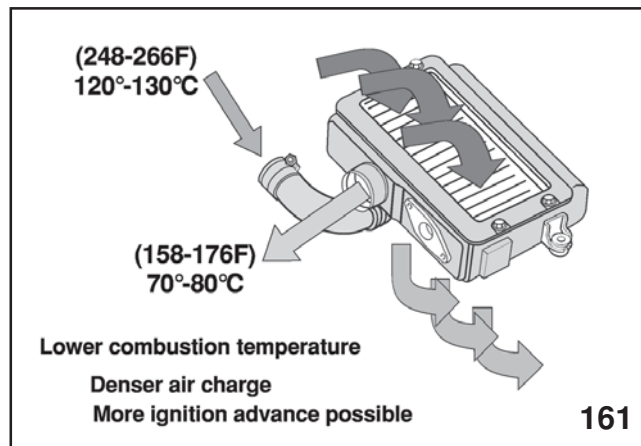
*Axial Movement Check*

## Intercooler

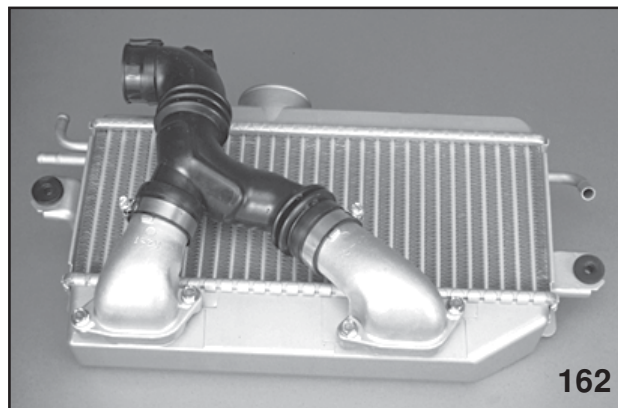
The Turbocharger compresses the intake air by using wasted exhaust gas energy. The Turbocharger turbine is driven by exhaust gas, causing the compressor wheel to rotate. By compressing the intake air, the volumetric efficiency of the engine is greatly improved.

The compression of the intake air by the Turbocharger causes an increase in air temperature, so an intercooler is located between the Turbocharger and the intake manifold. The intercooler reduces the temperature of the intake air from 248-266°F (120°-130°C) down to 158-176 F (70°-80°C) under normal operating conditions.

An Air Bypass Valve redirects high pressures from the intercooler back to the inlet side of the Turbocharger under deceleration.



*Effects of Intercooling (Artwork)*



*Intercooler (Bottom View)*

# Fuel Injection and Engine Management (406)



*Inlet to Throttle Body*

The temperature of the intake air is increased as it is compressed by the Turbocharger. This rise in temperature causes a corresponding expansion of the air, leading to a reduction in air density. The intercooler is designed to transfer the heat of the compressed intake air to the external air flowing through as the vehicle is in motion.

There are two positive by-products of decreased air temperature and increased air density: one; a reduction in combustion chamber temperature allowing for more advanced ignition timing, and two; improved volumetric efficiency due to the increase in air mass for a given air volume. With a denser air charge into the combustion chamber, more fuel can be injected leading to greater power output.



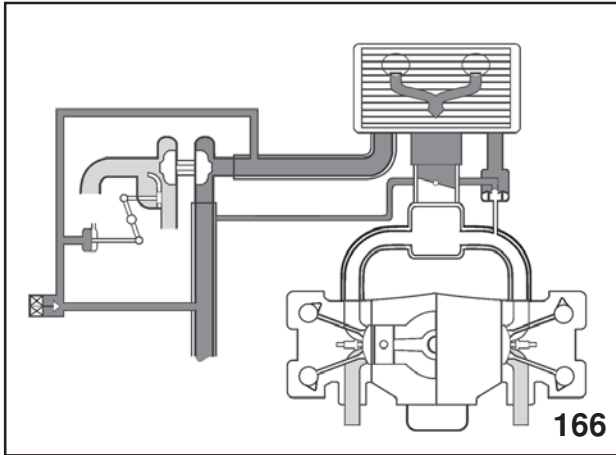
*Intercooler Location*



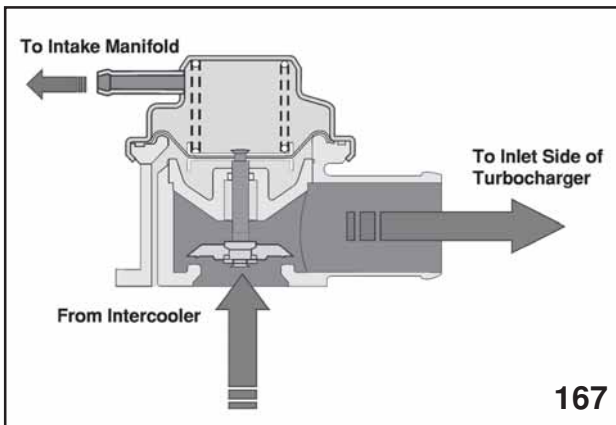
*Bypass Valve Connection*

The Air Bypass Valve is located after the Turbocharger, and provides a bypass passage for the compressed intake air back to the inlet side of the Turbocharger. When deceleration occurs immediately after a period of high engine load (high boost pressure), a large pressure differential occurs at the compressor wheel of the Turbocharger. This is due to the inertia of the Turbocharger, which still generates boost pressure even though the throttle is fully closed. This high pressure may lead to increased noise, and possibly damage the Turbocharger due to the high pressure exerted at the compressor.

# Fuel Injection and Engine Management (406)



*Air Bypass Valve Operation (Artwork)*



*Bypass Valve (Artwork)*

The upper chamber of the bypass valve is connected to the intake manifold, and the negative pressure (vacuum) during deceleration opens the valve by acting on the diaphragm.

Operation of the valve can be tested by attaching a hand held vacuum pump to the intake manifold connection. Apply a negative pressure with the pump and confirm that the valve opens.

## External Influences On Boost Pressure

### Ambient Air Temperature and Pressure

As air temperature rises, the ability of the Turbocharger to compress the air decreases. This phenomenon is directly due to the decrease in air density and the physical limitation of the Turbocharger. Even when air temperature is low, the air density (barometric pressure) may be low. Under these conditions, lower than expected boost pressures may be experienced. Again this is due to the physical limitations of the Turbocharger.

### Exhaust Diameter

The diameter of the exhaust system will vary the pressure difference across the turbine. A larger exhaust allows the Turbocharger to rotate faster, which results in higher boost pressures. Any increase in boost pressures would require 're-mapping' of the ECM programs to accommodate different air flow rates and resultant ignition change requirements. Over speeding of the turbine can lead to Turbocharger failure, particularly in conjunction with the increase in the pressure differential across the turbine.

### Fuel Octane Rating

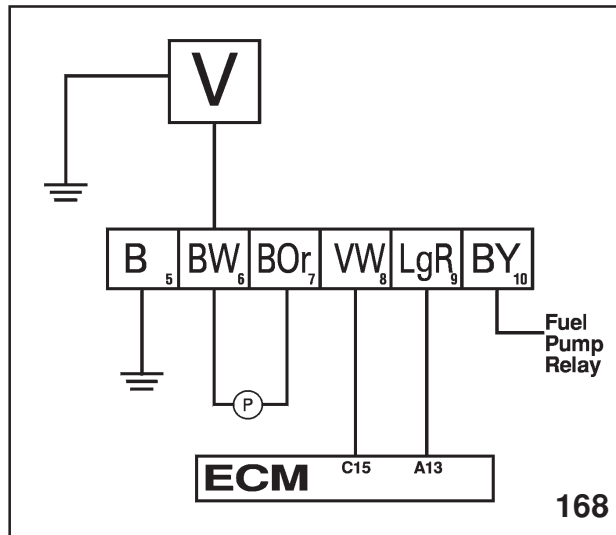
The high combustion pressures resulting from the increase in volumetric efficiency require a high-octane fuel. If the octane of the fuel is too low, knocking will occur. The end result of knocking is damage to the engine. The ECM is programmed to retard ignition timing if knocking is detected. Excess knocking will cause the ECM to enter a 'Fail-safe' mode where the boost pressure is reduced to the minimum value determined by the wastegate actuator.



# Fuel Injection and Engine Management (406)

## Turbo Lag

The pressure of the exhaust gas is low at low engine speeds. As the Turbocharger uses exhaust energy to operate, it does not respond immediately when the throttle is opened. This phenomenon is referred to as 'Turbo Lag'. In an attempt to overcome this phenomenon, design characteristics of the Turbocharger are matched to the prospective use of the vehicle.



*Fuel Pump Controller Terminal Layout*

The WRX Impreza is equipped with a fuel pump controller. This device is designed to adjust the speed and volume output of the fuel pump. The controller is located in the right rear trunk or cargo area behind the trim panel. The controller receives a 5-volt signal input from the ECM. This signal or duty ratio has 3 levels. The first level is 33% duty ratio, which produces a 5.0-volt drop on the ground circuit of the fuel pump. This results in the fuel pump operating at its slowest speed and producing the lowest volume. The ECM will select this duty ratio on a warm engine after the engine has been operating for 30 seconds (if the vehicle remains at idle). The next level or duty ratio is 67%. This duty ratio input to the controller produces a 3.4-volt drop on the ground circuit of the pump.

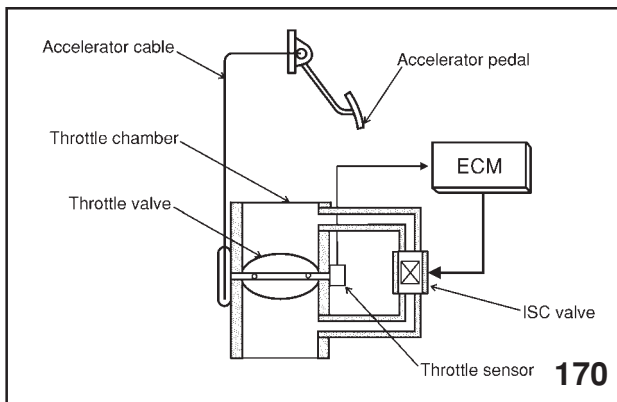
If the vehicle is cruising at a light engine load the ECM will select the 33% and increase the duty ratio to 67% upon medium to heavy acceleration. Full throttle acceleration will result in the ECM adjusting the fuel pump duty ratio to 100%. 100% duty ratio is also used for 30 seconds after a warm or cold engine start. This duty ratio will result in a .9 volt drop on the fuel pump ground circuit. This level produces the fastest fuel pump speed and largest volume output. The duty ratio will remain at 100% until the rate of acceleration has been decreased. The duty ratio at all levels operates at 81.4 HZ.

The 10-pole connector at the fuel pump controller contains 6 wires. Terminal 5 (B), a Black wire, is the ground for the controller. Terminal 6 (BW), a Black wire with a White tracer, is the ground from the fuel pump. Measure the voltage drop at this wire when checking for proper controller operation. Terminal 7 (BO), a Black wire with an Orange tracer, is the power supply to the fuel pump at battery voltage. Terminal 8 (VW), a Violet wire with a White tracer, is the ECM duty ratio signal to the fuel pump controller. Terminal 9 (LgR) a Light Green wire with a Red tracer, is also an ECM input to the fuel pump controller. This signal, approximately 10.80 volts, signals the fuel pump controller that the engine is operating. If the value of this signal drops to zero the fuel pump controller will remove the power supply from the pump and it will stop. The signal at terminal 9 will terminate after 2 seconds after the ignition has been turned on if the start signal is not received at the ECM. Terminal 10 (BY), a Black wire with a Yellow tracer is the power supply for the controller and the fuel pump. This power is received from the fuel pump relay.

## Electric Throttle Control System

### Traditional Throttle System

The traditional throttle control system used an accelerator cable to connect the throttle pedal with the throttle valve on the throttle body. Idle control was achieved with an Idle Speed Control (ISC) motor that bypassed the throttle plate to provide extra air when the conditions required idle changes. Cruise control was achieved with the help of a cruise control module that held vacuum in a diaphragm that physically held the throttle open when a driver activated cruise control.



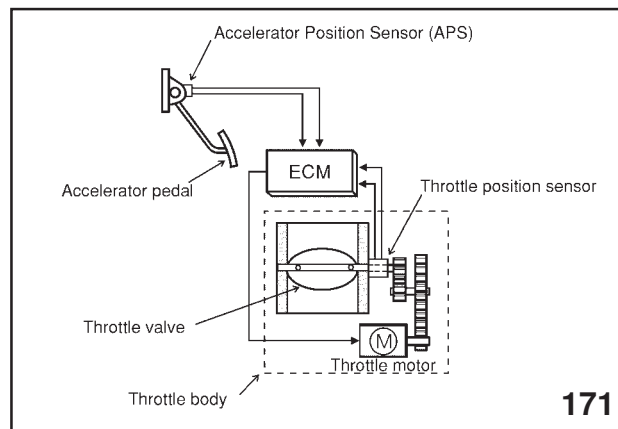
*Current Throttle System*

### Electronic Throttle Control System

The Electronic Throttle Control System dispenses with the accelerator cable that was used in the traditional system. The throttle valve opening and closing speed can be controlled by the ECM. This can produce quick acceleration without having to be proportional to the speed at which the accelerator pedal is depressed. This system has many advantages over the traditional system since the ECM can position the throttle valve for optimum performance.

Electronic control relies on a control module that uses various types of input sensors to decide on an output control of the throttle position. Relying on these sensors provides for fine-tuning and a more precise control of idle. Electronic control can include cruise control functions as part of its programming. Also, the air/fuel mixture can be precisely matched to the position of the throttle. This has an additional benefit of helping to reduce exhaust gas emissions since the air fuel mixture can be balanced so that more of it is burned in the combustion process. There is a fail-safe backup program in the event of a failure that will allow the vehicle to limp in if the system has a fault.

This system was first introduced on the 2.5L turbo STI, Baja, and Forester in 2003 model year and was also used on the midyear 2003 PZEV. (Partial zero Emission Vehicle).



*Electronic Throttle Control System*

Idle and cruise control can be incorporated into the program of the electronic throttle control system.

There is a fail safe and fail-soft system that will allow the vehicle to limp in if the system has a fault.

# Fuel Injection and Engine Management (406)

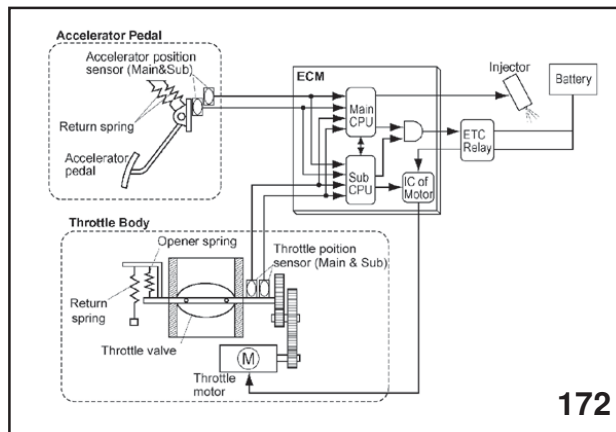
## Cruise Control Changes with ETC

Since the ECM is controlling the position of the throttle plate, there is no need for a cruise control module or a vacuum diaphragm to hold the cruise position. ETC vehicles come equipped with an electronic cruise control program built into the ETC system. One result of this is that the cruise light will flash when a problem is detected with the ETC system.

## ETC Microcomputers

The Electronic Throttle Control program inside the ECM is equipped with two parallel microcomputers; one is called the main CPU and the other is called the sub CPU. The parallel computers look at the inputs and control the output. The inputs and outputs of both microprocessors are compared to verify this system is operating correctly.

The main CPU computes the target throttle opening from the acceleration position sensors signal, while the sub CPU determines the difference between this target opening and the actual throttle opening. The ECM then drives the throttle motor to control the throttle opening. The two CPUs share sensor signals and constantly monitor each other to ensure that their computational results are correct.



ETC System Layout

## ETC System Inputs

The ETC input comes from the Acceleration Position Sensor (APS) which is mounted on the accelerator pedal. The input from the APS can be processed and the throttle motor controls the throttle opening. The ETC system has a feedback sensor mounted on the throttle body that provides information on the position of the throttle valve called the Throttle Position Sensor (TPS). The Acceleration Position Sensor and Throttle position Sensor are arranged in a dual main and sub system for improved reliability. Each sensor has a backup parallel sensor in case the primary sensor fails or has a problem with its operation.

## Acceleration Position Sensor

The Acceleration Position Sensor is mounted on the accelerator pedal inside the passenger compartment. It provides information on the movement of the accelerator pedal on two separate circuits that can provide detailed information on the position of the accelerator pedal.

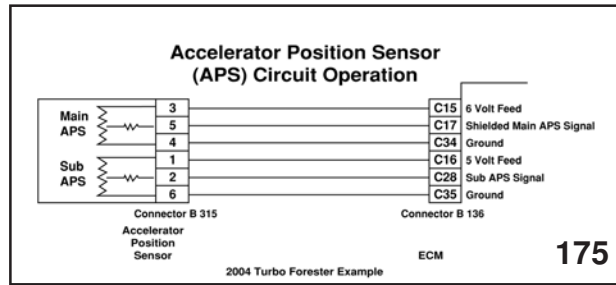


Accelerator Position Sensor

The main acceleration position sensor has three wires. Five volts is supplied to the Main sensor feed circuit. The output voltage indicating accelerator position is fed to the ECM on the Main Sensor Signal Circuit. A ground wire from the acceleration position sensor to the ECM completes the main acceleration position sensor circuit.

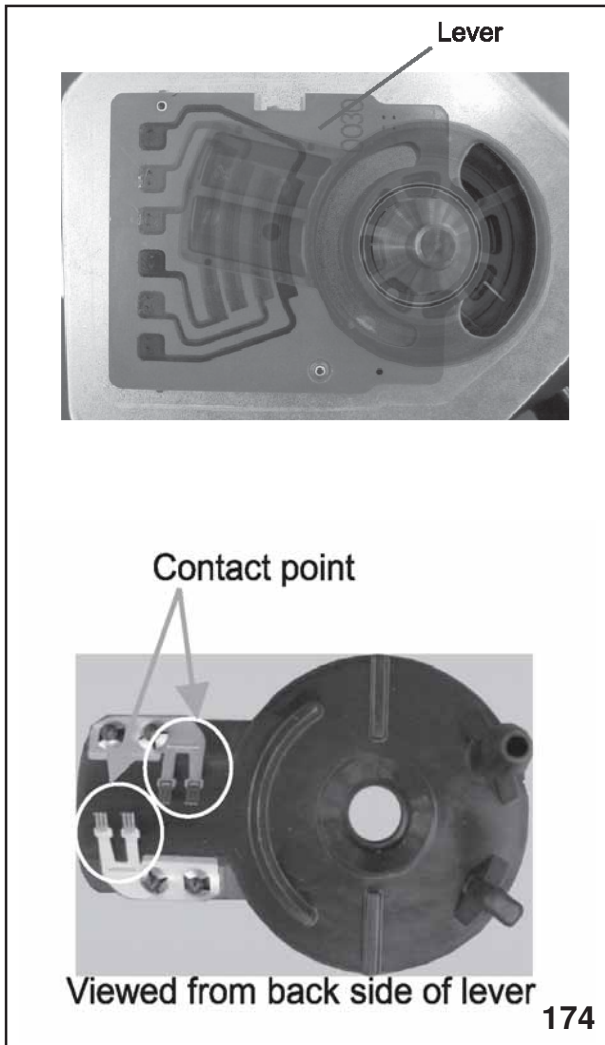
# Fuel Injection and Engine Management (406)

The sub sensor is a completely separate circuit from the main sensor. Five volts is supplied to the Sub sensor feed circuit. The output voltage indicating accelerator position is fed to the ECM on the Sub Sensor Signal Circuit. A ground wire from the acceleration position sensor to the ECM completes the Sub acceleration position sensor circuit.



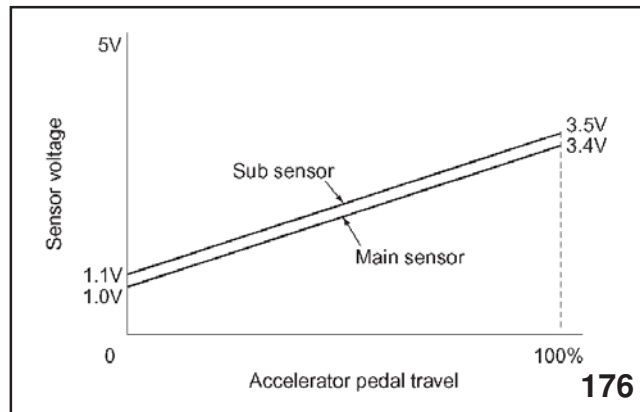
*Contact Points of Lever*

Both the main sensor and the sub sensor vary the voltage in proportion to the accelerator pedal travel. The voltage of the main sensor should be 1.0 volts when the accelerator is fully released (throttle closed) and 3.4 volts when the throttle is fully depressed (wide open throttle). The sub sensor voltage should range from 1.1 volts with the throttle closed to 3.5 volts with the throttle fully depressed. Having two sensors helps the ECM compare the voltages so it can detect problems with the circuit and set DTCs as necessary.



*Contact Lever*

Electrically the sensor has two potentiometers and two wiper arms. The wiper arm inside the sensor is mechanically connected to the accelerator pedal. The wiper arm moves as the accelerator pedal moves. The wiper arm is moving across a resistor and as the accelerator pedal moves, the wiper arm moves on the resistor. This changes the output voltage of the sensor. This voltage indicates the position of the accelerator pedal.

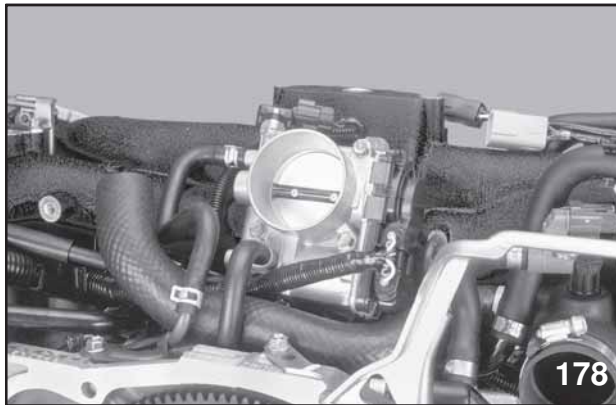


*Accelerator Pedal Travel*

The ECM is looking for this. 1-volt difference to verify the acceleration position sensor is working properly.

## ETC Components

### Throttle Body

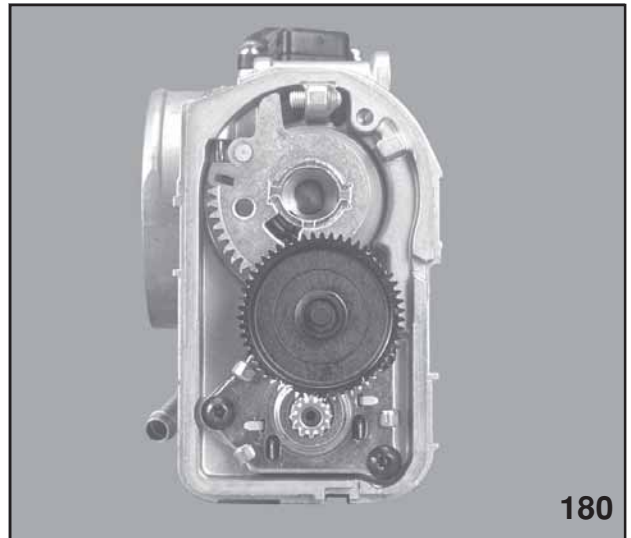


*Throttle Body*

The throttle body is composed of the throttle valve, throttle position sensor, throttle motor, reduction gear, and throttle opener/return springs.

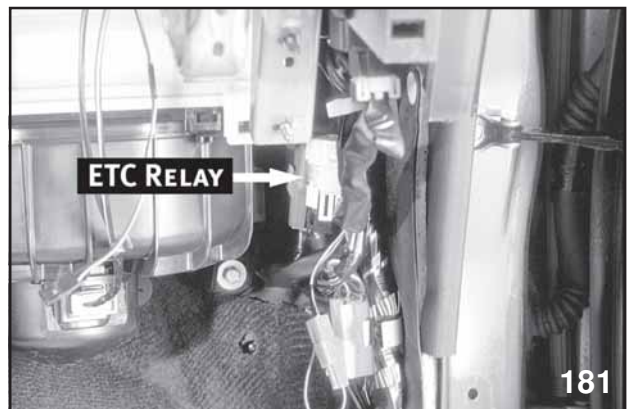


*Reduction and Throttle Shaft Gear*



*Motor, Reduction and Throttle Shaft Gear*

### ETC Relay



*ETC Relay*

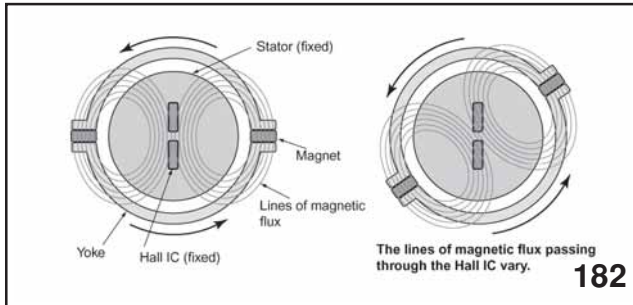
### Throttle Position Sensor

The Throttle Position Sensor provides information to the ECM regarding the position of the throttle valve. The Throttle position Sensor has two build-in Hall Integrated Circuits (a main and sub sensor) each providing a feedback signal to the ECM. The main and sub sensors output voltages at different rates of voltage increase. The Hall effect sensor is mounted in the cover plate. The magnets are imbedded in the gear.

# Fuel Injection and Engine Management (406)

## TPS Hall Effect Throttle Opening Detection Principle

The sensor inside the motor has two magnets integrated into the gear set. The magnets are placed on the outside of the stator. Two Hall Effect Integrated circuits (main and Sub) are placed inside the stator.



*Hall Effect (main and sub) Valve Opening Detection Principle*

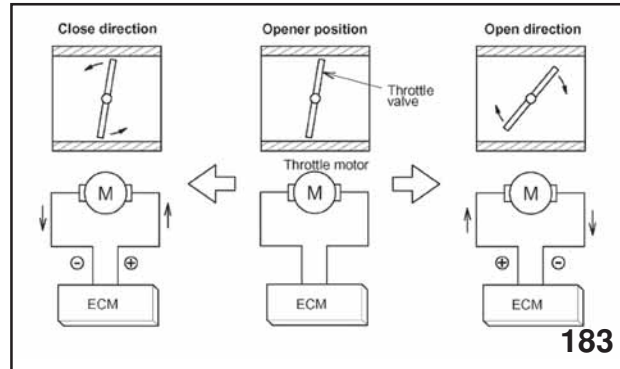
Since the magnet is integrated into the gear, it rotates and changes its output signal as the valve opens and closes.

The Hall IC has the property of changing its output voltage according to changes in the number of lines of magnetic flux that passes over it. Therefore, the voltage output from the sensor changes according to the valve opening.

## Throttle Motor

The throttle motor, which is driven according to the throttle valve opening determined by the ECM, opens and closes the throttle valve via a reduction gear.

The throttle valve opener position (valve is free with no spring force at work) is used as a reference point to control the throttle valve position in the closing direction and opening direction. Accordingly, the throttle motor controls the valve position by changing the direction of current (+, -) in the circuit in the closing direction and opening direction.



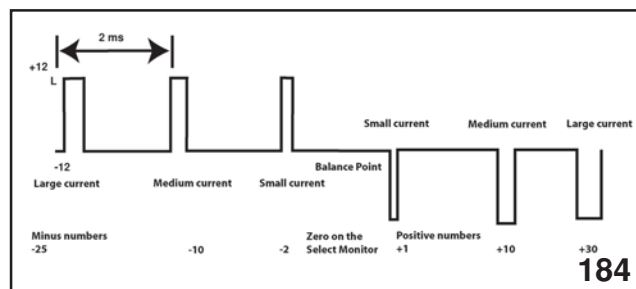
*Throttle Motor Line Art*

The valve opening/closing speed and the valve position are maintained by controlling the duty ratio. The duty ratio that maintains the valve position is determined by balancing the spring force of the return spring or the opener spring.

## ETC Throttle

The ETC throttle body is equipped with two springs. An opener spring and a return spring. The return spring assists with closing the throttle body while the opener spring assists with moving the throttle away from idle. The balance point, the opening of the throttle controlled only by the tension of these two springs is about 1800-2000 PM on a warm engine.

The throttle body is also equipped with a motor that precisely controls the movement of the throttle plate by operating from a signal created in the ECM. This signal is positive or negative dependant on the need to increase throttle opening or decreased throttle opening.



*Throttle Body Duty Ratio Wave Form*

**NOTE: THIS PATTERN IS NOT WHAT WOULD BE SEEN ON A LAB SCOPE, IT EXPLAINS HOW THE CURRENT REVERSES AS THE MOTOR HITS THE BALANCE POINT.**

## Fuel Injector



*Fuel Injector Pattern*



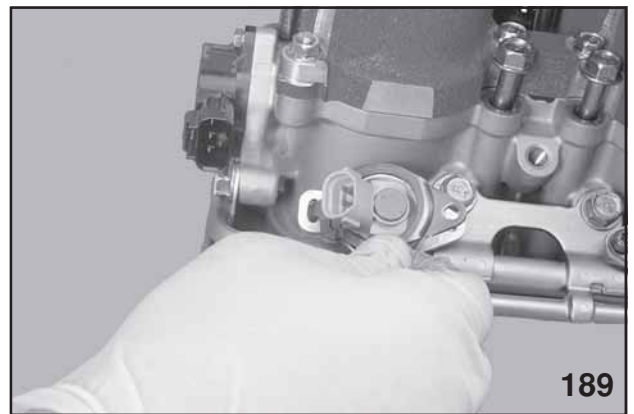
*Fuel Injector Spray Pattern*



*Fuel Injector Rail*

The injectors are classified as side feed type. The multi hole nozzle makes it possible for the injector to produce fine fuel particles which enhances the combustion efficiency and output performance of the engine.

The low profile shape of the injectors provides crash protection and eliminates the need for additional injector guards or covers.

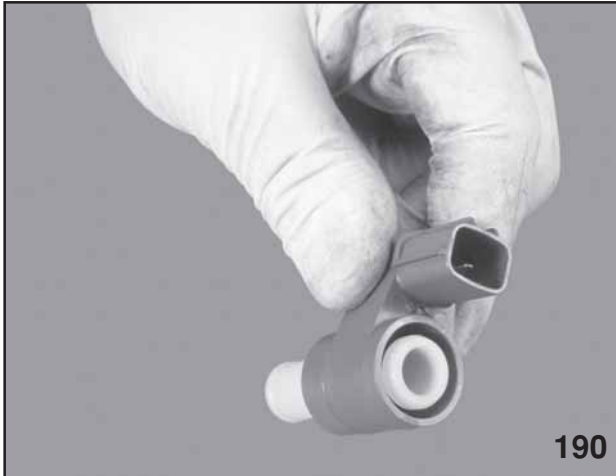


*Injector Removal*

The injectors are secured to the injector rail with a T-25 bolt and notched retaining ring.

Removal of the injector is accomplished by removing the bolt and lifting the retaining ring from the notch in the rail.

**CAUTION: BE CERTAIN TO RELIEVE THE FUEL PRESSURE ACCORDING TO THE APPROPRIATE SUBARU SERVICE MANUAL ON THE STIS WEB SITE BEFORE REMOVING THE INJECTOR.**



*PVC Connector*

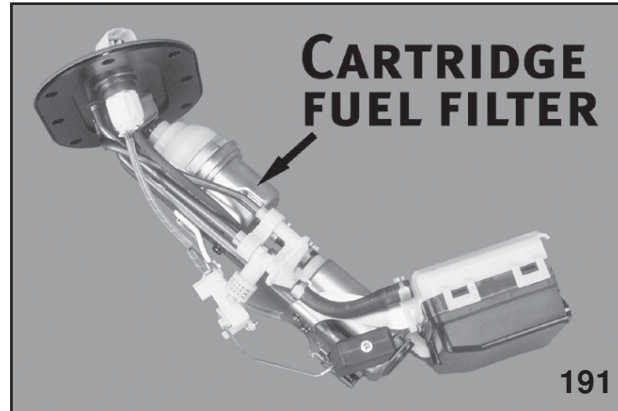
A Positive Crankcase Ventilation system connector is installed on the WRX STi. This connector is used to detect an open hose by simply opening the circuit from the ECM that monitors the connector. The electronic construction of the connector is a shorting loop built inside the connector. When the connector is moved away from its corresponding connector (carrying the PCV hose with it) the ECM detects the opening and triggers the Diagnostic Trouble code.

## Fuel Pump

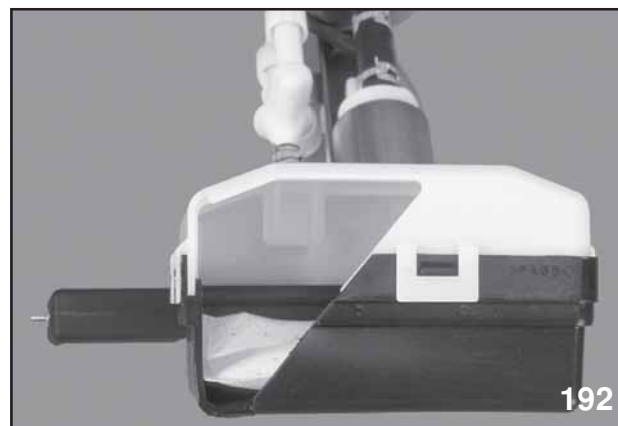
The fuel pump for the WRX STi is equipped with two filters. The mesh filter located at the inlet side of the pump can remove large particles from the fuel before it goes into the pump. The second filter is a cartridge type that filters the smaller particles from the fuel before the fuel is delivered to the injectors. This filter is recommended for replacement every 60,000 miles and according to the maintenance schedule.

Follow: The instructions provided in the appropriate Subaru Service Manual on the STIS web site on pump and filter.

The mesh filter housing is designed to hold enough fuel to prevent aeration on turns during vehicle operation with lower fuel levels.



*Fuel Pump*



*Mesh Filter*



## Intercooler Water Spray



*Intercooler*

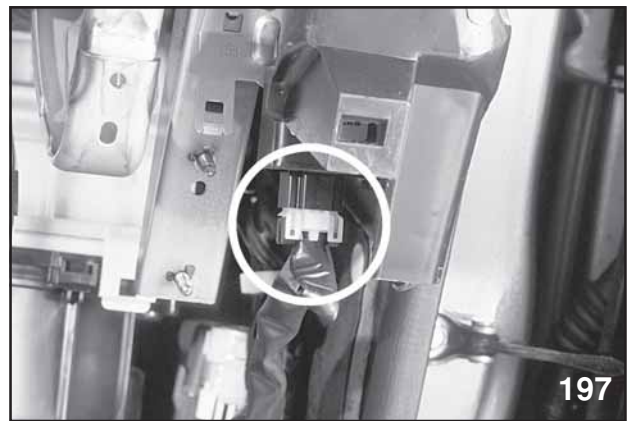


*Hood Scoop*

The intercooler of the WRX STi is 470 mm by 168.5 mm. Air from the hood scoop is directed over and through the intercooler decreasing intake the air temperature. This allows for improved volumetric efficiency and more advanced ignition timing. To further increase efficiency of the intercooler an intercooler water spray has been added to the vehicle. A water spray nozzle is mounted to the bottom of the hood scoop that when activated sprays water in a pattern to cover the full width of the intercooler. This will assist with providing additional cooling of the intake air temperature as the water is pushed through the intercooler cooling fins by the air from the hood scoop.



*I/C Water Spray Control Button*



*Timer*

The I/C water spray button is mounted to the drivers left near the head light leveler control. When activated the button sends a signal to the I/C water spray timer. The timer is located on the A pillar post behind the glove box.



Normal Access to the Water Tank



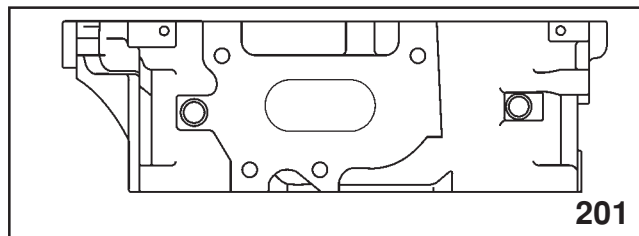
Water Tank Complete

The timer will send a 2 second signal to the I/C water pump. The pump is located in the side of the I/C water tank, located in the trunk. The tank holds about one gallon of water. Do not fill the water tank more than 50% during times of low ambient temperature where freezing conditions are expected or damage to the tank will occur. A warning light on the combination meter will illuminate when the water level in the tank becomes low.

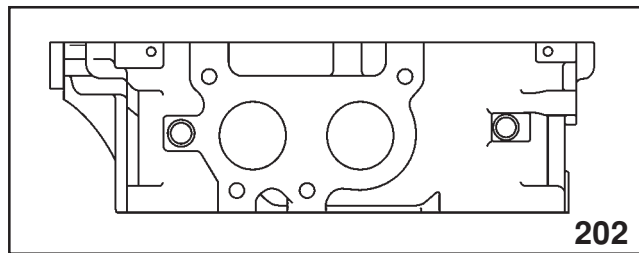
## Partial Zero Emission Vehicle (PZEV)

A Partial Zero Emission Vehicle (PZEV) has been designed for sale in California, Maine, Massachusetts, New York and Vermont. The vehicle is equipped with a 2.5 NA engine with an Emission warranty for 15 years or 150,000 miles.

There are two major engine changes for the PZEV which are the design of the cylinder head and the pistons.

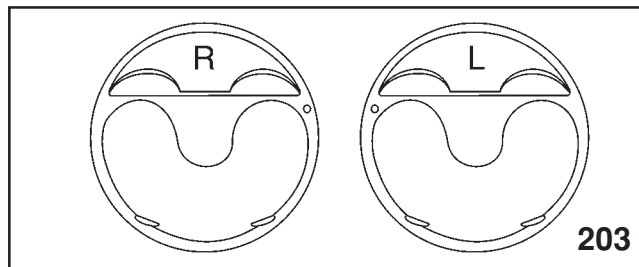


PZEV



Federal

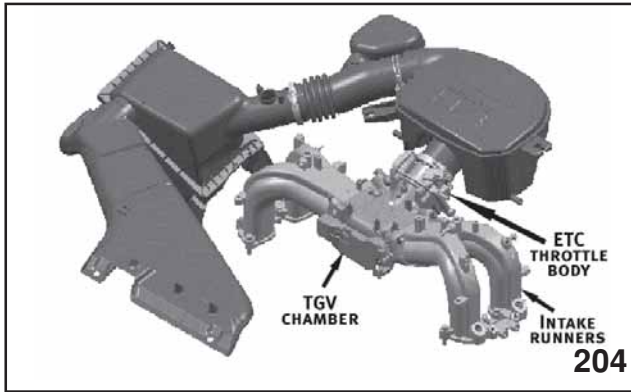
The cylinder head exhaust ports have been unified to a single port to promote faster warming of the catalyst.



Piston Shape

The piston design assists with better mixing of the air/fuel mixture before combustion.

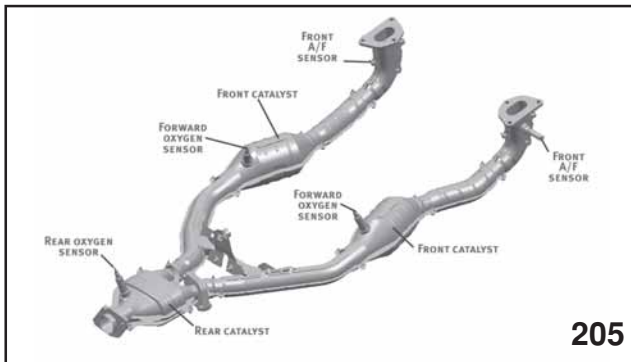
# Fuel Injection and Engine Management (406)



*Intake Manifold*

The three piece intake manifold contains a center TGV chamber with intake runners bolted to each side. The TGV chamber contains all components of the TGV system. The motors and sensors can be serviced separately from the chamber.

The PZEV is equipped with ETC, which incorporates cruise control.



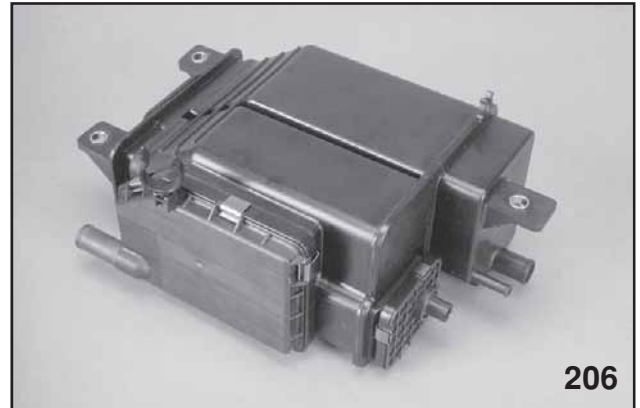
*Exhaust System*

The exhaust system for the PZEV is equipped with an A/F sensors near the exhaust inlet on each side of the engine, two front catalyts, with an oxygen sensor at the rear of each catalyts and the rear catalyts. An oxygen sensor is located at the rear of the rear catalyts.

The front A/F sensors are used to produce main feed back for each side of the engine. Catalyts efficiency (front only) is judged from information from the front A/F and the forward Oxygen sensor for each catalyts.

The rear most Oxygen sensor monitors the total A/F feedback for proper operation.

A new evaporative cannister is installed with a built in drain valve, and filter.



*Canister Complete*



*Drain Valve Separated from Canister  
(NOT SERVICEABLE)*



*Canister Filter*

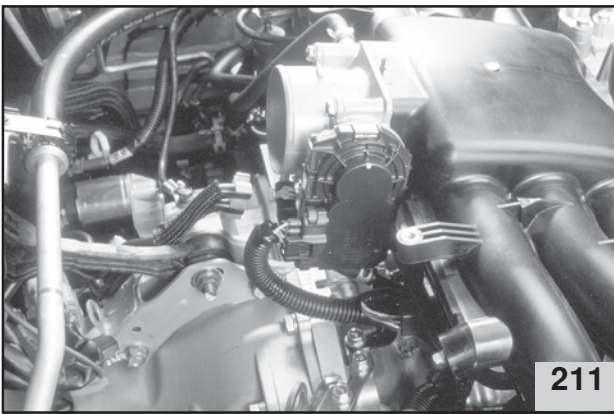
# Fuel Injection and Engine Management (406)

## Legacy H6 Fuel System



Engine Cover

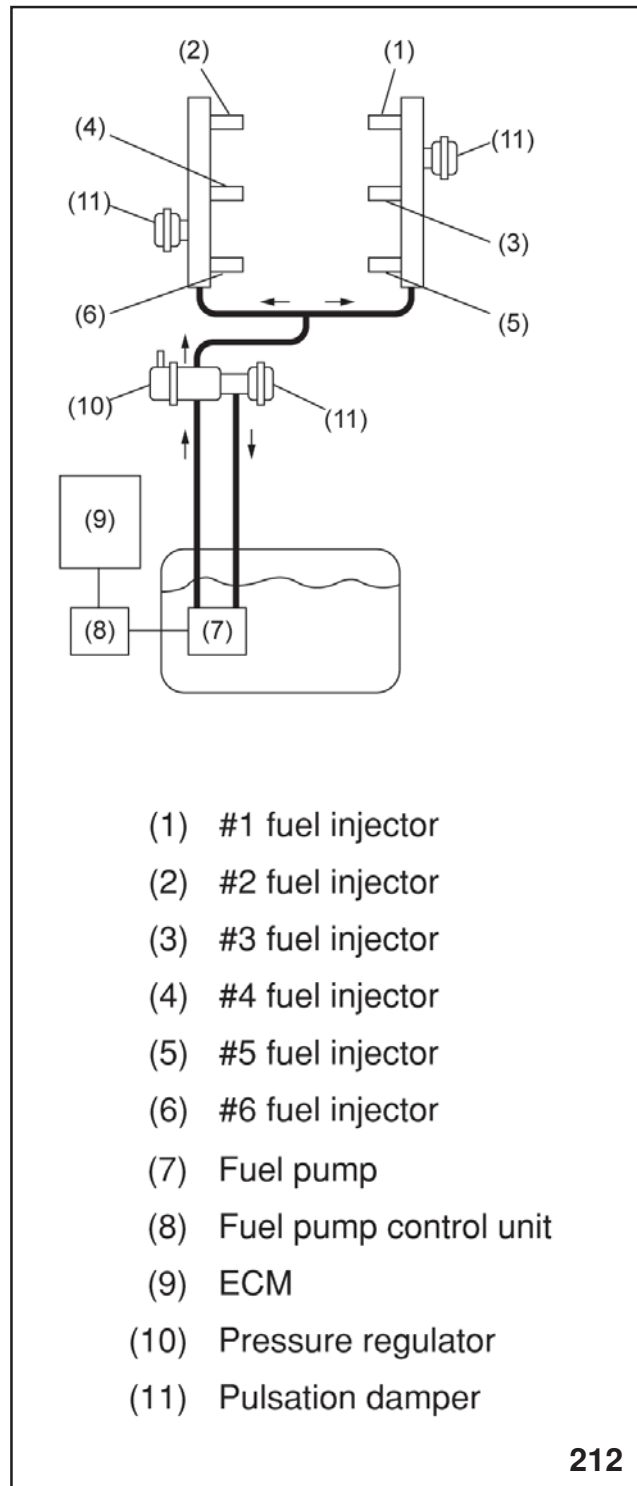
The 3.0 liter engine is equipped with Electronic Throttle control.



Throttle Body

Components include the ETC throttle body with TPS, accelerator sensor and ECM.

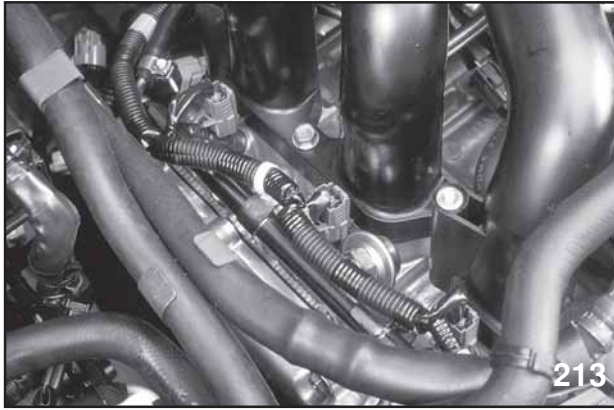
The engine top cover must be removed to gain access to the fuel system components on or near the intake manifold.



Fuel Schematic

The top fed fuel injectors of the 2005 Legacy 3.0 liter engine are mounted directly to the cylinder head and receive fuel through a direct fuel rail.

# Fuel Injection and Engine Management (406)



*Fuel Injectors*

The top fed fuel injectors of the 2005 Legacy 3.0 liter engine are mounted directly to the cylinder head and receive fuel through a direct fuel rail.



*Fuel Damper*

The rail has a built on fuel pulsation damper that is serviceable with rail replacement only.



*Fuel Pressure Regulator*

The fuel pressure regulator which is located near the left front strut tower, delivers regulated fuel to the direct fuel rails and bypasses fuel back to the fuel tank. The regulator has a built on pulsation damper which is serviceable with regulator replacement only.



*Quick Connector*

The fuel delivery and bypass hoses are secured to the fuel lines with quick connectors that are released by special tool 42099AE000. Properly release the fuel pressure before disconnecting any quick connector.



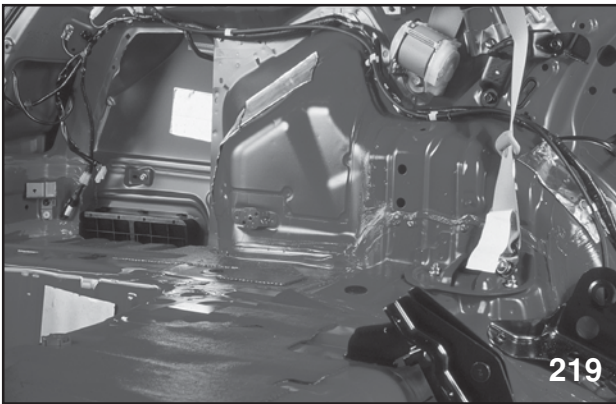
*Tool 42099AE000*

# Fuel Injection and Engine Management (406)



*Fuel Pump Control Unit*

A fuel pump controller is utilized to control the volume output of the fuel pump. 3 different duty ratios are used. (33%, 67% and 100%)



*Left Corner of Vehicle*

The fuel pump controller is located in the left rear of the vehicle.

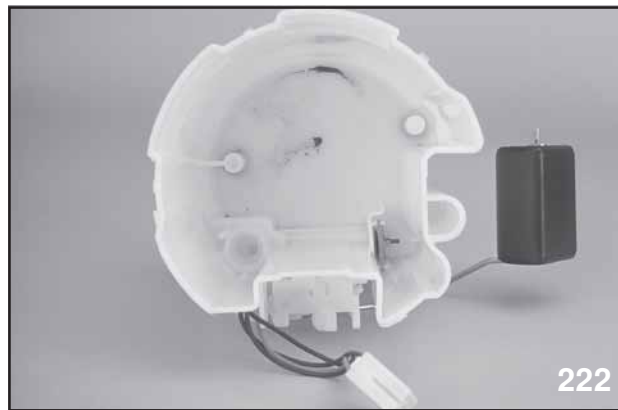


*Fuel Pump, Vertical*



*Fuel Pump, Horizontal*

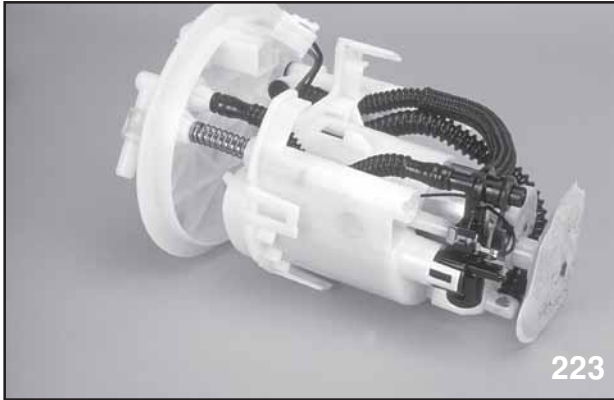
The fuel pump is located in the fuel tank and is supported on the top by the spring loaded access plate mount and on the bottom by 3 rubber pads that rest on the bottom of the tank.



*Main Sending Unit*

The sending unit can be removed by the pump and replaced separately.

# Fuel Injection and Engine Management (406)

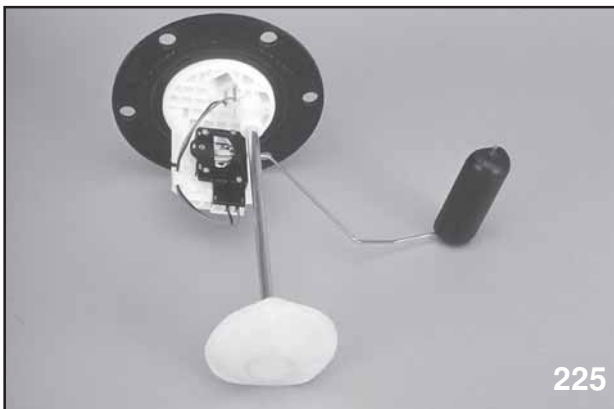


*Pump Assembly*

The fuel pump housing contains the main fuel filter, pick up filter and jet pump. These components are not serviceable separately. (The fuel filters and pump are replaced as a unit)



*Sub Unit, Side View*



*Sub Unit Straight View*

A sub unit is used on the passenger side of the fuel tank.



*Carpet*

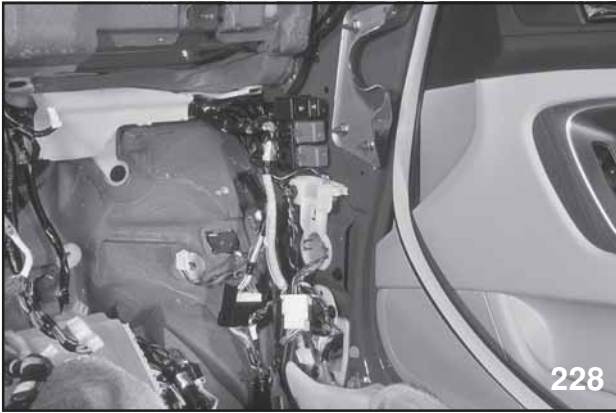
The ECM is accessed from the floor of the passenger seat. The door trim must be removed and the weather seal loosened to remove the carpet locating tabs. Remove the carpet stay tab from the right front corner of the carpet and pull the carpet up slightly.



*ECM*

Remove the 5 bolts that secure the ECM cover plate and remove the ECM cover plate. The inspection mode connectors are located above the ECM.

# Fuel Injection and Engine Management (406)



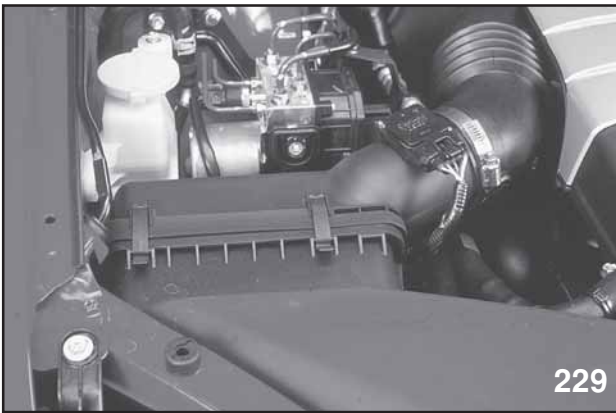
*Relays*

The ignition, fuel pump and ETC relays are located behind and to the right of the glove box.



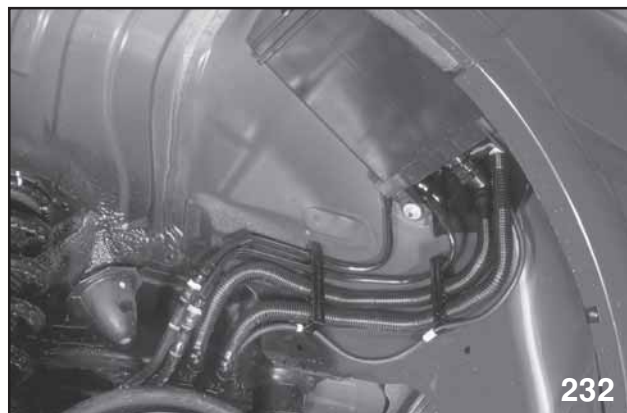
*Canister*

The evaporative canister is located under the left rear inner fender.



*Air Flow Meter*

An air flow meter is mounted in the air induction hose.



*Canister Hoses*

The canister is equipped with the drain valve of the On Board Vapor Recovery (ORVR) and the drain valve filter. All components are replaced as a unit.



*Pressure Sensor*

A pressure sensor is mounted in the front of the resin intake manifold.



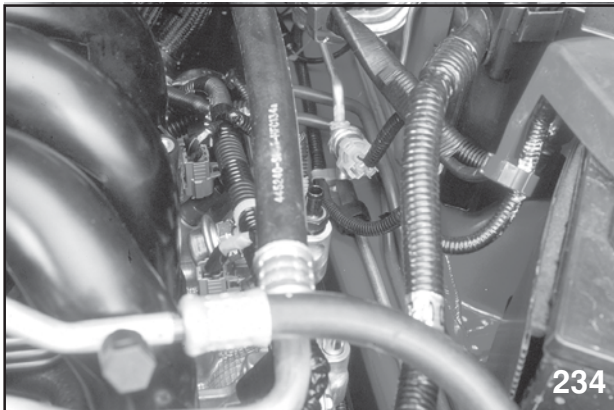


*Vent Tube*

The vent tube for the fuel shut valve is routed through the cargo area under the carpet.

The fuel tank pressure sensor and the fuel tank sensor control valve are located above and to the right of the fuel tank.

The pressure control valve is located to the left of the rear differential.

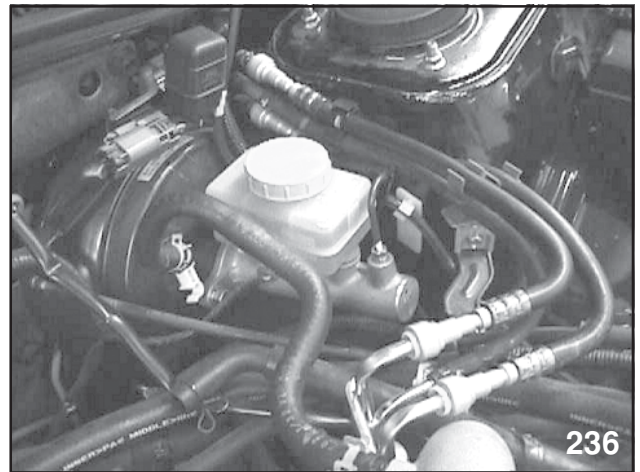


*PCV (Crankcase)*

The positive crankcase ventilation valve is located on the left bank valve cover.

## Quick Connect Fuel Line Service Procedures

In 2004 a new fuel line with a Quick Connector end was introduced on the 6 cylinder Legacy. In 2005 it was added to the Forester and will be used on most models by 2006. This hose must be removed to check fuel pressure since each end of the hose has a quick connector. Once the quick connect fuel hose is removed, the current fuel pressure gauge can be attached to the metal fuel line in place of the fuel line. (Consult the Subaru Service Manual on the STIS web site for the proper procedure of removing fuel pressure).



*Quick Connect Fuel Hose*

# Fuel Injection and Engine Management (406)

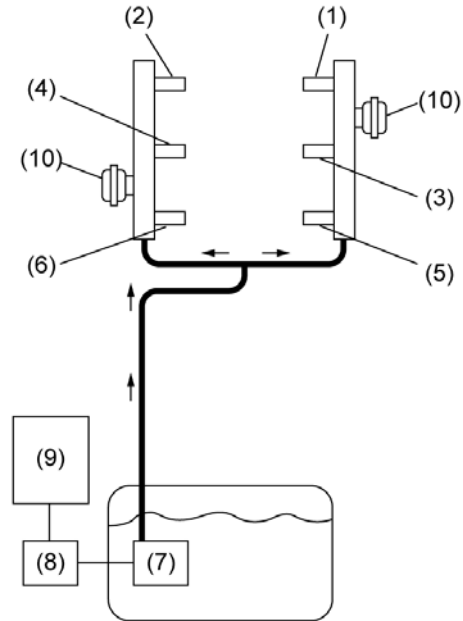
## Fuel Delivery Quick Connector

The quick connector fuel system was originally intended to be a one time use only "Quick Connector". This quick connector must be disconnected when removing the line for parts replacement or fuel pressure checks.

Quick connector service procedure:

1. Separation - Push the internal retainer with a finger in the arrow direction, pull the connector to separate it. After separation, the retainer will remain attached to the pipe.
2. Connecting – Make a visual inspection of the line and the fittings where the line attaches. Check the connecting portion of the pipe for damage to the sealing surface. Clean any foreign particles on the pieces.
3. Align the pipe and the connector; insert the end of the pipe into the connector until an audible click is heard.
4. Confirm connection by pulling the connector backward. Also check that the two parts of the retainer are engaged to the connector.
5. The external clip is the only necessary replacement part if it is damaged.

## Subaru B9 Tribeca Fuel System



- (1) #1 fuel injector
- (2) #2 fuel injector
- (3) #3 fuel injector
- (4) #4 fuel injector
- (5) #5 fuel injector
- (6) #6 fuel injector
- (7) Fuel pump & Pressure regulator
- (8) Fuel pump control unit
- (9) ECM
- (10) Fuel pulsation dampener

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*Fuel Routing System (Artwork)*

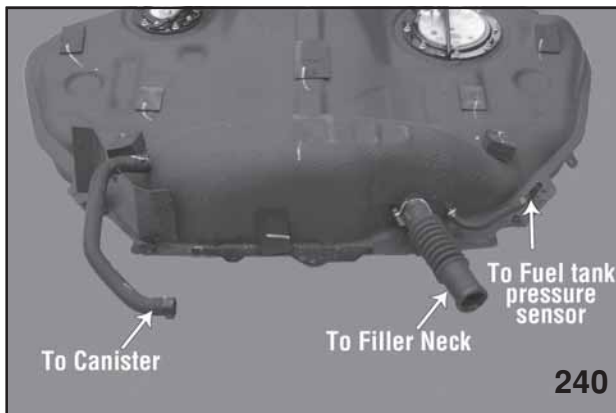
# Fuel Injection and Engine Management (406)

## Evaporative System



*Fuel Tank*

The Evaporative System of the Subaru B9 Tribeca consists of the canister, drain valve, fuel tank vent valve, FCV sub and FCV main with orifice which are built into the tank.



*Fuel Tank Hoses*



*Sub Pump*



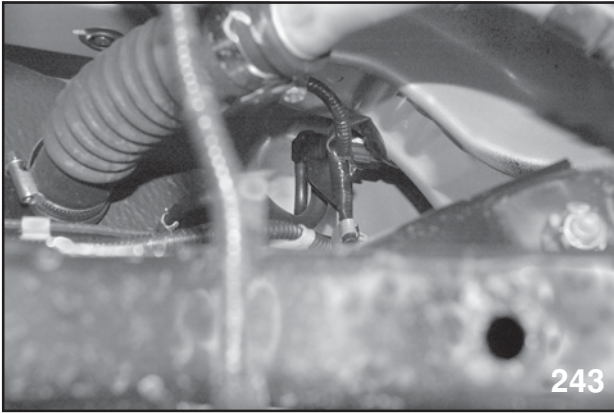
*Main Pump*

During tank refilling the tank pressure increases and is routed to the canister through the vent valve and sub and main FCVs. The multi chambered canister absorbs the fuel vapors and routes the air from the tank to atmosphere through the drain valve. As the liquid in the tank rises the vent valve and sub FCV are closed, leaving only the main FCV open. The FCV incorporates an orifice that is used to throttle the tank evaporation and is not large enough to vent the tank during refilling. At this point the pressure in the tank will begin to increase and turn off the refilling gun.

The drain valve will be closed by the ECM when evaporative system integrity is being checked.

The fuel tank is constructed with an enlarged chamber that serves as an expansion tank and a mounting surface for the FCVs. All components of the FCVs are located inside the tank and are not serviceable.

# Fuel Injection and Engine Management (406)



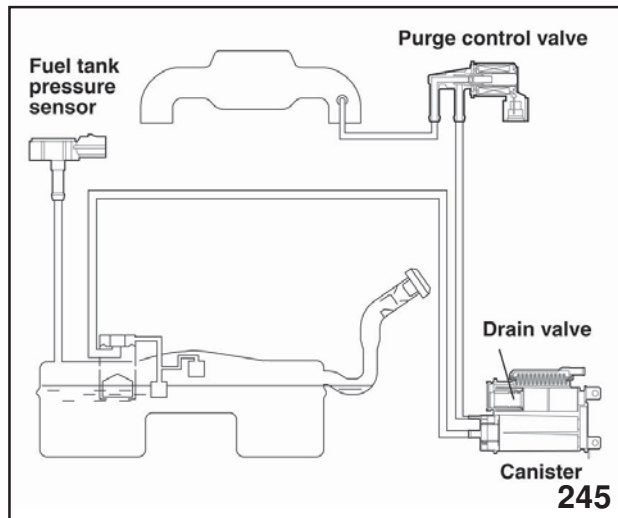
*Pressure Sensor*

The pressure sensor can be accessed from the right rear of the fuel tank and does not require tank removal. (Note: The pressure sensor should be removed from the tank before removing the fuel tank from the vehicle.)

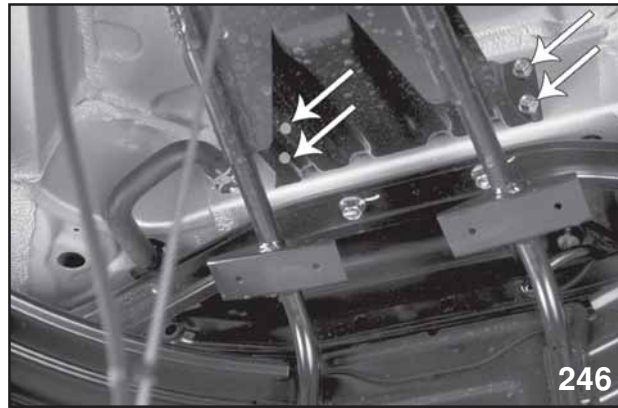


*Canister*

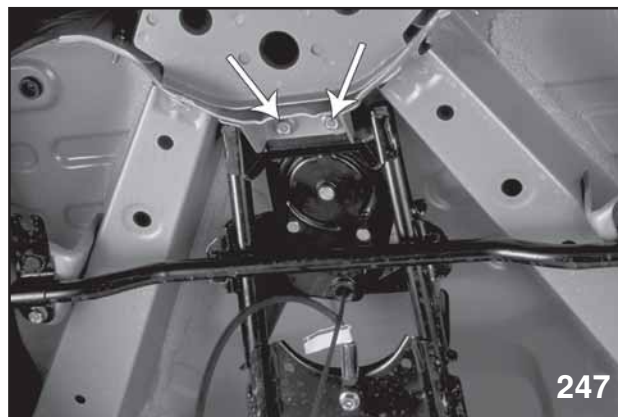
The canister is located above the rear suspension and behind the fuel tank.



*Evaporative System (Artwork)*



*Four (4) Forward Mounting Bolts*



*Two Rear Bolts*

Canister removal is achieved by removing the spare tire and removing the four forward mounting bolts of the spare tire compartment and the two rear bolts of the spare tire compartment.

# Fuel Injection and Engine Management (406)



*Lowered Spare Tire Well*

Lower the spare tire compartment by the amount pictured.



*Three (3) Hoses*

Remove the three hoses and electrical connector from the drain valve.

Next lower the rear suspension slightly and the canister can be removed.

- \* The suspension must be supported while it is not torqued to the vehicle.



*Canister Body (Side View)*

The canister is secured to the vehicle with three nuts. The canister itself is built with rubber inlays inside the mounting holes that assist with canister installation.



*Canister (Bottom View)*

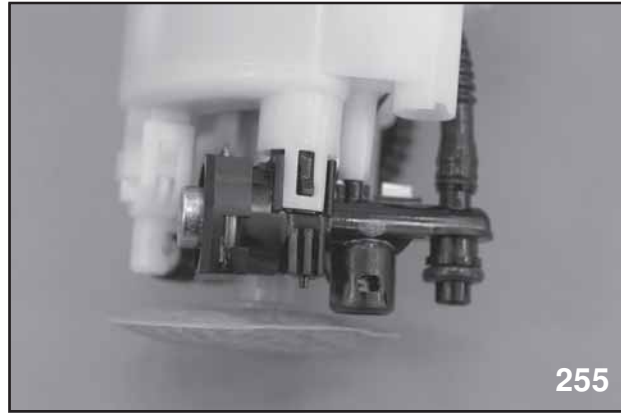
The inlays hold the canister in place while the mounting nuts are being installed.

The drain valve can be removed by releasing the upper latch and twisting the drain valve counter clockwise.

# Fuel Injection and Engine Management (406)



*Canister (End View)*



*Fuel Pressure Regulator*

The fuel pressure regulator is located on the fuel pump assembly and eliminates the fuel return hose from the engine compartment to the fuel tank as used on other Subaru models.



*Drain Valve Separated from Canister  
(NOT SERVICEABLE)*

The drain valve connection on the canister is designed to lock with the shape made onto the drain valve input to the canister.



*Fuel Filter*

The fuel filter is incorporated into the fuel pump and is not serviceable.



*Fuel Pump*

The fuel system of the Subaru B9 Tribeca is designed with a return less fuel delivery system.



*Sub Pump*

# Fuel Injection and Engine Management (406)



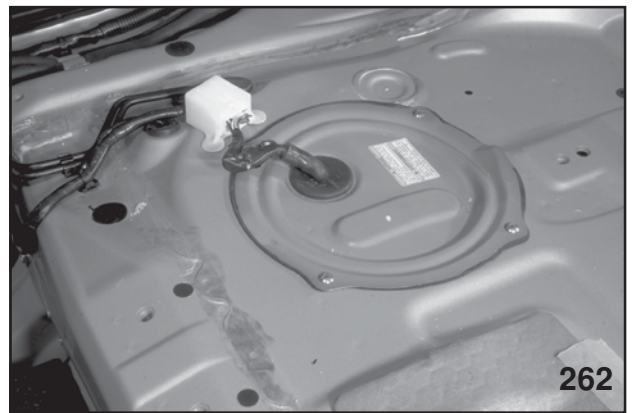
*Main Pump and Sending Unit*



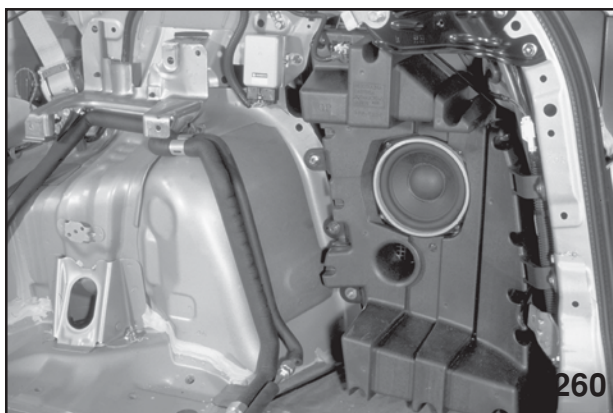
*Sub Pump Access*



*Canister*

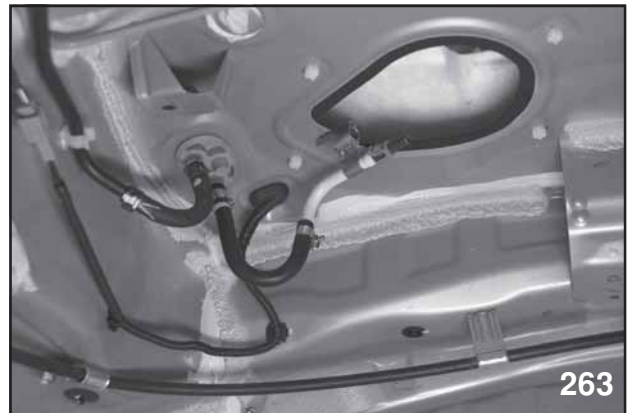


*Main Pump Access*



*Fuel Pump Controller*

The fuel pump is controlled with a controller that is mounted to the right rear of the vehicle behind the interior trim.



*Tank Removed, Sup Pump Access*

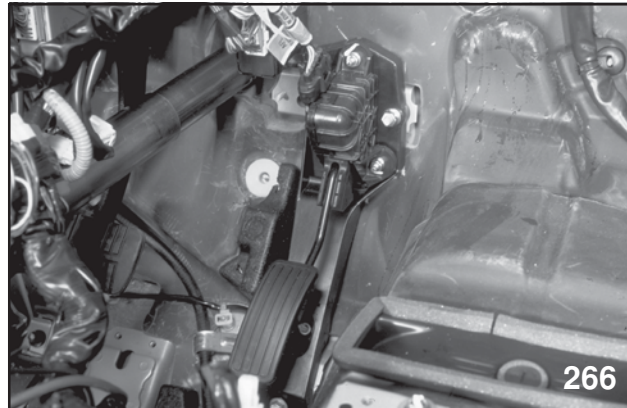


*Tank Removed, Main Pump Access*

The fuel pump and sub pump are accessible from under the second row seat.

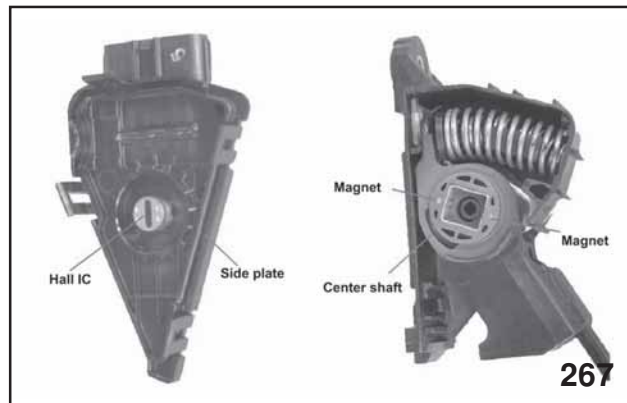
**NOTE: ALWAYS SET THE FUEL LEVEL TO APRX. ½ FULL BEFORE REMOVING THE FUEL PUMP.**

## Accelerator Sensor



*Accelerator Pedal Sensor Apart*

The Accelerator Sensor has changed to a Hall type sensor to enhance the input of the accelerator pedal to the ECM.

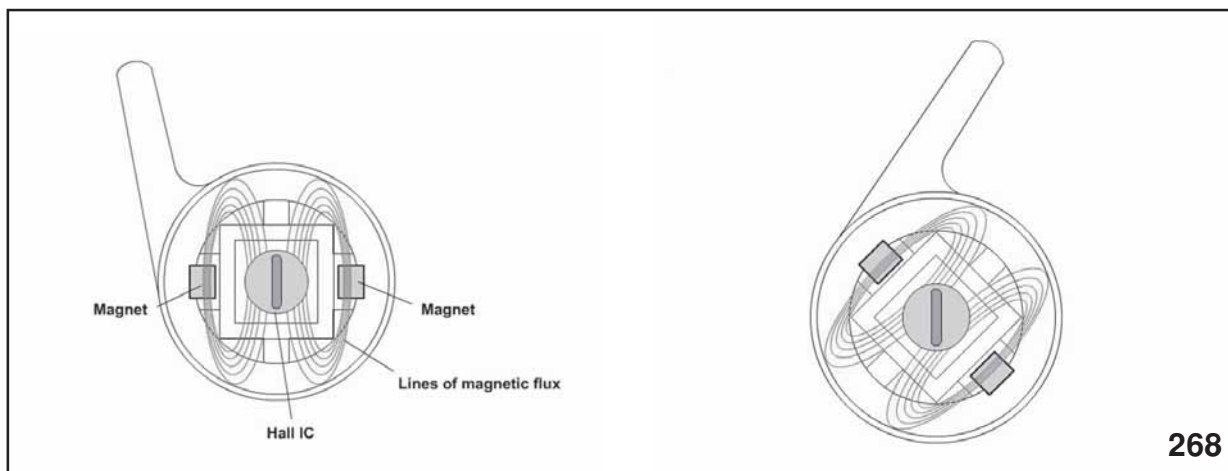


*Accelerator Pedal Sensor Apart*

The Accelerator Pedal Sensor consist of two magnets integrated into a center shaft and a Hall IC (with sensor element) placed on the side plate.

\* *The pedal position sensor is not serviceable and must be replaced as a unit.*





*Sensor (Artwork)*

When the accelerator pedal is operated, two magnets rotate around the Hall IC. The Hall IC has the property of changing its output voltage according to changes in the number of magnetic flux line that pass through the hall sensor element. Therefore, the sensor output voltage changes according to the position of the accelerator pedal.

### **Additional information**

The case of the ECM is plastic.

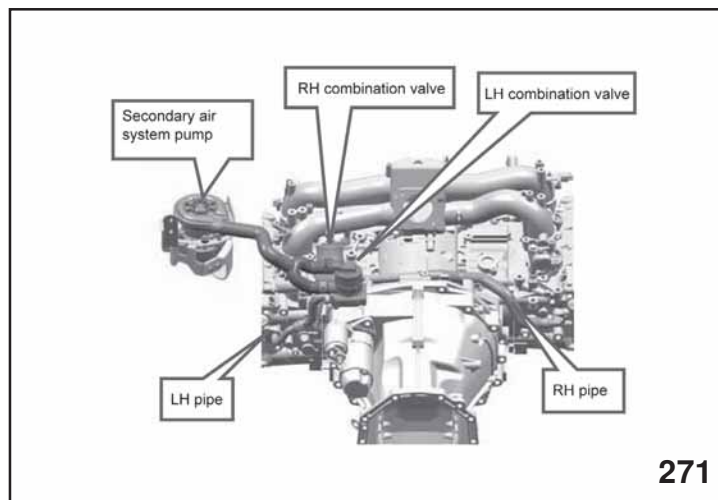
The knock sensor is a two wire type, receiving a ground from the ECM.

## Secondary Air Injection System-2006

### 2.5L Turbo Engine



*Secondary Air System Pump in car*



*Model of Secondary Air Injection System*

*Turbo engines except the STi are equipped with a secondary air injection system, beginning with the 2006 Model Year.*

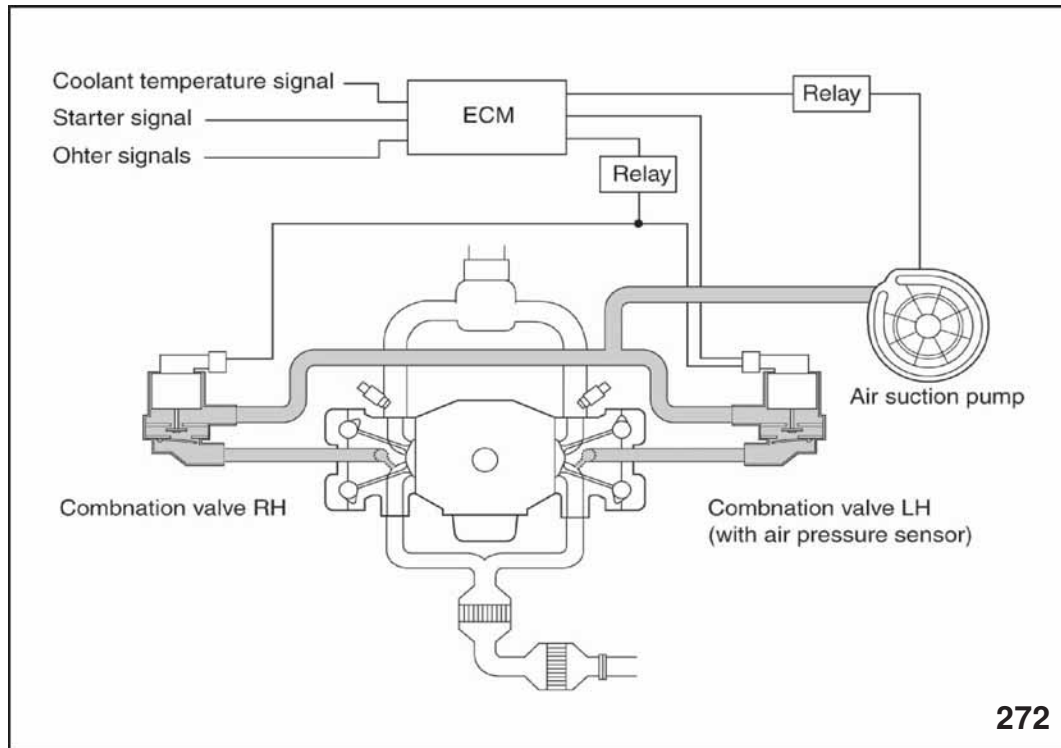
The Secondary Air Injection System reduces harmful exhaust emissions by introducing a supply of fresh air into the exhaust before it reaches the catalytic converter. The fresh air mixing with the hot exhaust causes the unburned emissions to burn and brings the catalytic converter to operating temperature must faster.

The fresh air enters the exhaust from behind a fresh air port located behind each exhaust valve. An electric Secondary Air Pump provides the force necessary to supply the quantity of air needed for mixing with the exhaust. The air from the secondary air pump is divided between the left and right side of the engine. The fresh air is admitted into the exhaust by the action of a reed valve contained in the left and right side combination valves. A metal pipe carries the fresh air to each cylinder head. The pipe must be disconnected from the cylinder head before head removal.

# Fuel Injection and Engine Management (406)

## Secondary Air Pump

The Secondary Air Pump compresses the fresh air which enters the pump from the bottom side through a non-serviceable air filter. The performance of the pump is monitored by a pressure sensor located in the top of the left hand combination valve. This check also monitors the performance of the solenoid valves and their ability to close off the passage to the reed valves.



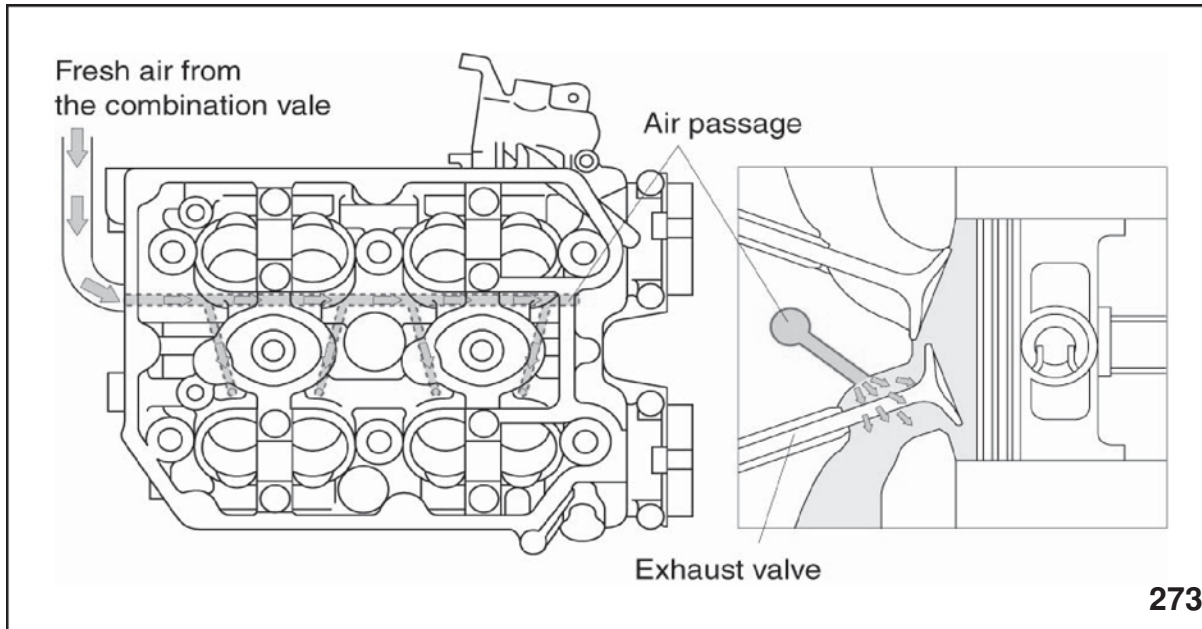
*Combination Valve layout*

## Combination Valve

The Combination valve is composed of a solenoid, air valve and reed valve. The solenoid operates the air valve which allows fresh air from the secondary air pump to flow to the back side of the reed valve. The exhaust pulses of each cylinder control the reed valve. As the exhaust stroke begins the pressure of the exhaust closes the reed valve. As the exhaust pressure reduces, the reed valve opens, as the fresh air pressure is now higher than the exhaust pressure. Fresh air enters the exhaust stream and the ignition of unburned exhaust emissions begins. The reed valve will remain open until the exhaust pressure increases.

# Fuel Injection and Engine Management (406)

## Cylinder Head



*Air Passage Inside Cylinder Head*

Air passages are machined inside the cylinder head as shown below. The air compressed from the combination valve is emitted to the backside of the exhaust valve through the air passages.

### **Control of ECM**

ECM measures engine coolant temperature, starting condition from the starter signal and other signals, and activates air suction pump and combination valve according to the engine coolant temperature.

The ECM will activate the combination valve relays and the pump relay when the engine coolant temperature is below 150 degrees F (70 degrees C)

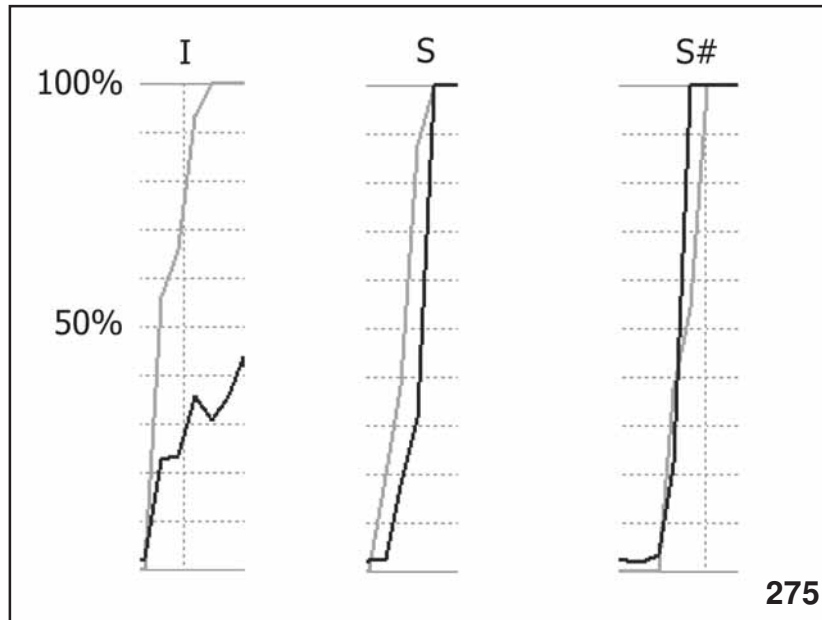
The system will operate for 90 seconds (varies according to the coolant temperature)

# Fuel Injection and Engine Management (406)

## SI - DRIVE (Subaru Intelligent Drive)

SI-DRIVE (Subaru Intelligent Drive) will be standard on all Legacy and Outback turbo models. SI-Drive enables three distinctively different modes of engine power characteristics by regulating the engine control unit (ECM) as well as the transmission control unit (TCU) on automatic transmission models, and by fine-tuning the electronically controlled throttle Torque command control with 3 settings (rotary switch is located in the center console). No other parts are required.

This graph shows the relationship of accelerator pedal movement to throttle response in each of the SI Drive modes. In each case the accelerator pedal is depressed 100%.



*Accelerator Pedal Movement to Throttle*

- I mode: Throttle response provides efficient performance.
- S mode: Throttle response is almost linear.
- S# mode: Throttle response is fast, reaching 100% with approximately 54% of accelerator pedal movement.



*SI-Drive Selector*

# Fuel Injection and Engine Management (406)

## Intelligent Mode

The Intelligent mode provides well-balanced performance with greater fuel efficiency and smooth drive ability.

Power delivery is moderate during acceleration for maximum efficiency.

This is ideal for around-town driving and difficult driving conditions such as slick roads or loose surfaces.

When Intelligent mode is selected in vehicles equipped with a manual transmission, a shift-up indicator will blink to signal the best time to shift gears for maximum fuel efficiency.

## Sport Mode:

The Sport mode provides the engine power desired by those who want to make the driving experience their own personal adventure. The linear acceleration characteristic of this versatile mode is ideal for driving on freeways and suburban streets or for climbing mountain roads.

## Sport Sharp Mode:

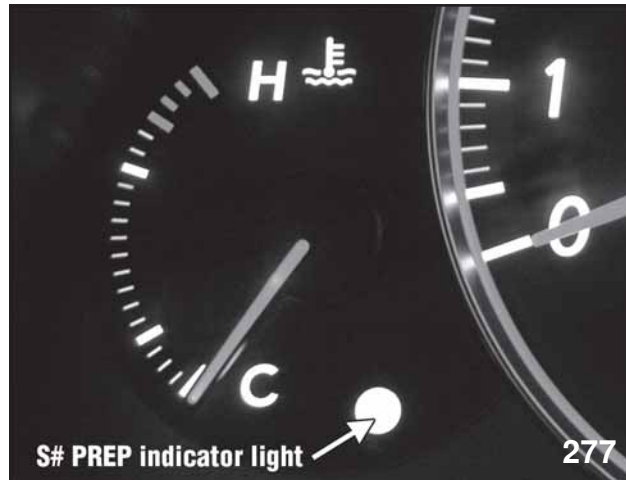
For spirited minded drivers, the Sport Sharp mode offers an exhilarating level of engine performance and control.

The throttle becomes more responsive regardless of engine speed.

Delivering maximum driving enjoyment, this mode is ideal for tackling twisty roads and for merging or overtaking other vehicles on the highway with confidence.

The multi-information display located in the tachometer provides the driver with the ability to monitor both vehicle performance and driving conditions.

In addition to trip computer functions, the current SI-DRIVE mode is exhibited along with an active torque curve display.



*S# PREP Indicator Light*

When this light is illuminated sports sharp mode is not available. This is due to low coolant temperature.

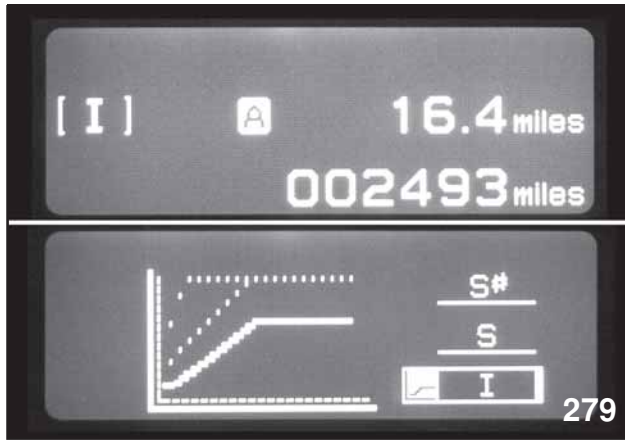


*ECO Gauge*

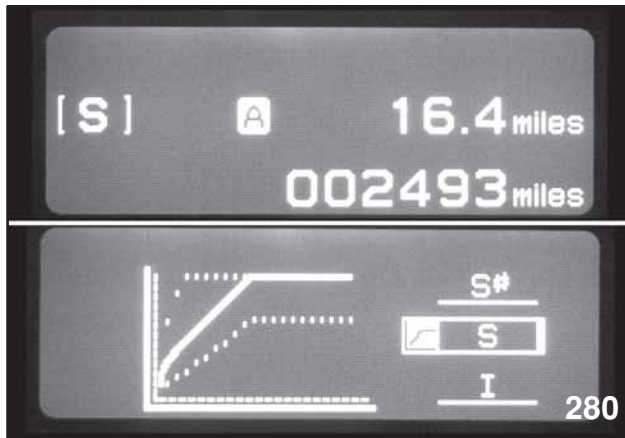
The ECO gauge located in the speedometer challenges the driver to drive more efficiently.

With the easy to read analog gauge, the driver can intuitively improve fuel economy by keeping the needle in the positive zone.

# Fuel Injection and Engine Management (406)



*I-Mode*



*S-Mode*



*S#-Mode*



*Trip Meter Functions*

**NOTE: TRIP METER FUNCTIONS ARE NOW DISPLAYED ON THE ODOMETER AND CONTROLLED BY PRESSING THE TRIP METER STALK.**

**THE CLOCK ON THE TRIP METER IS SET TO 24 HOUR TIME AND CANNOT BE CHANGED.**

# Fuel Injection and Engine Management (406)

## SI Drive Operation Under Special Condition

ENGINE CONDITION	INDICATOR	ECM	TCU
MIL - ON	S	S	S
Coolant Temp $\geq$ 248F Coolant Temp $\leq$ 133F	S#, I	S	S
Reverse Gear	S#, I	S	S

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*SI Drive Logic Chart*

ECM and TCU operation will be fixed to S mode at any of the conditions listed above, even when the customer tries to activate S# and I mode.

Example: ECM will switch mode from I mode to S mode automatically when coolant temp reaches 135° (Degrees Fahrenheit).

### TCU Control

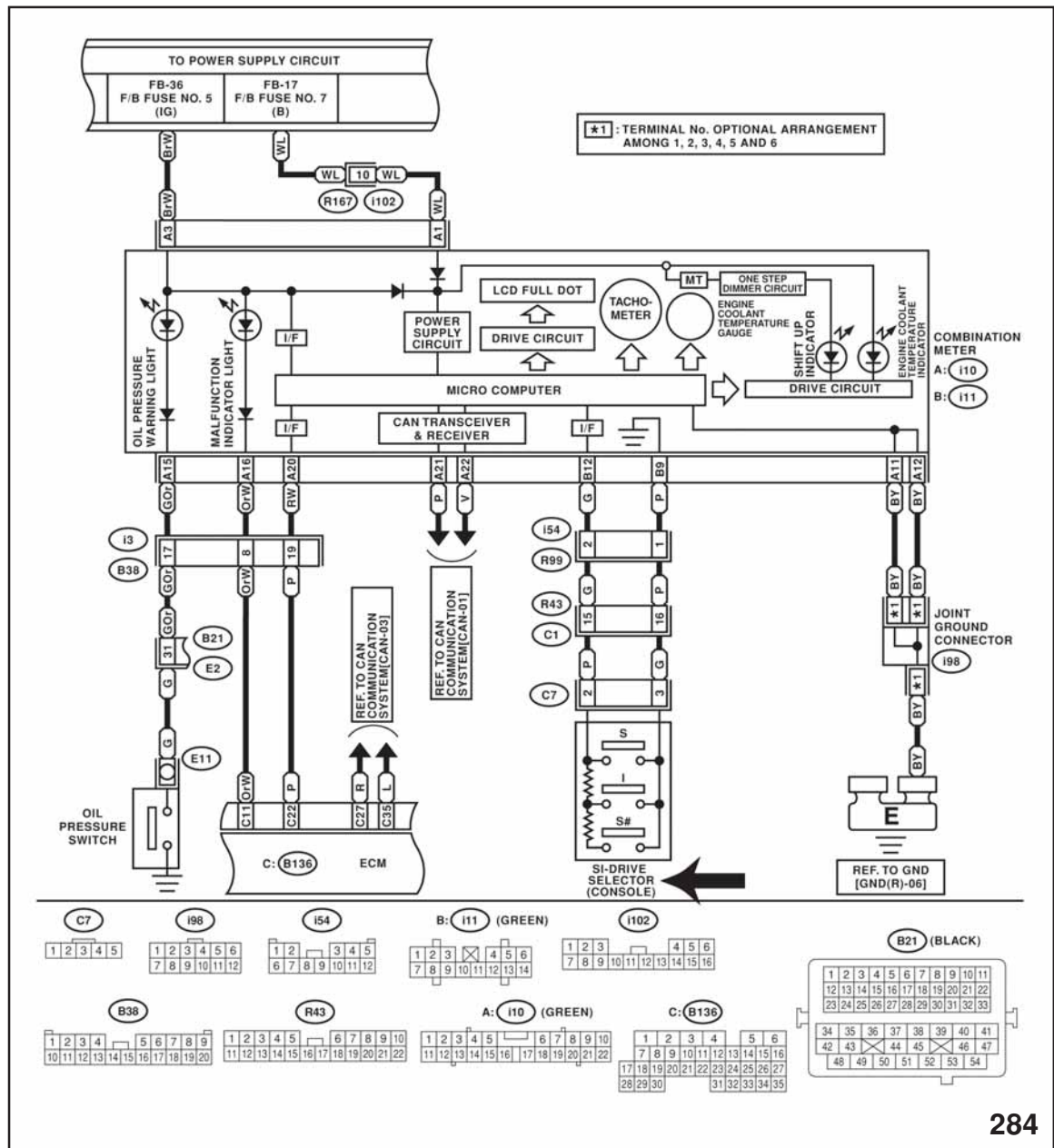
I mode: shift points are earlier than D range with previous model

S mode: almost same as D range with previous model.

S# mode: shift points are later than D range with previous one.

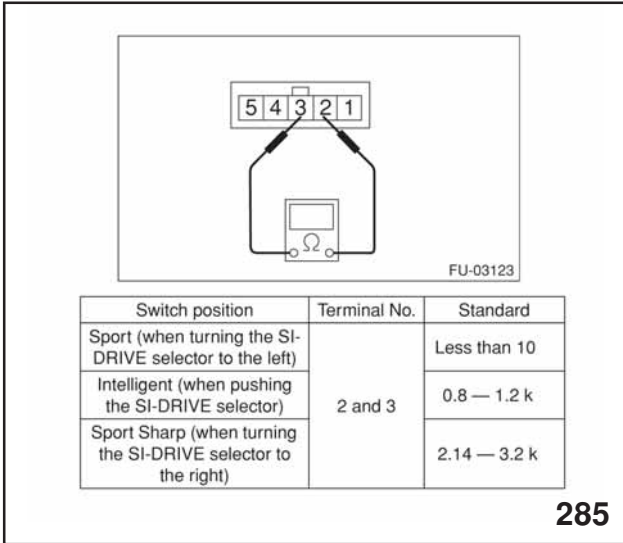


# Fuel Injection and Engine Management (406)



SI Drive Wiring Schematic

The control switch for the SI drive consists of a momentary contact switch that changes a voltage drop to ground.



*SI Drive Switch Terminal Numbers*

This varied ground signal is sent to the combination meter and enters the Low Speed CAN circuit. The signal is then sent to the BIU and then all parts of the High Speed CAN. The ECU controlling the throttle and the TCU controlling the shift points and shifting logic.

**NOTE: THERE ARE NO DTC'S FOR SI DRIVE.**

**THERE IS NO AVAILABLE DATA ON ANY VEHICLE SYSTEM PERTAINING TO SI DRIVE.**

**CHECK SI DRIVE SWITCH AND CORRESPONDING INDICATOR ON THE ODOMETER FOR PROPER OPERATION.**



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# Fuel Injection and Engine Management (406)

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## Tools and Equipment

### Special Tools

Tool Number	Description
ST42099AE000	Special Quick Connect Tool
Universal tool OTC 7660	
42099AE000	Fuel Line Tool

# Fuel Injection and Engine Management (406)

## State I/M Program Advisories Bulletins

<b>No.</b>	<b>Date</b>	<b>Title</b>	<b>Subject</b>
11-50-97	12/05/97	All Subaru Full-Time AWD Models	State Emission Testing
11-51-97	12/05/97	All Subaru Full-Time AWD Models	Diagnostic Service Cautions
11-52-98	05/22/98	All 1999 Model Subaru AWD Models	State Emission Testing
11-49-97R	09/02/98	1996 MY Legacy, Impreza & SVX	OBD Check During State I/M Program
11-53-98	01/05/99	97-98 Legacy, Impreza and Forester Manual Transmission vehicles with 2.5L & 2.2L engines	Hesitation On Acceleration
11-54-99	03/01/99	All 1996-1999MY	On-Board Diagnostic System Diagnostic Link Connector (DLC) Location
11-55-99	03/17/99	All 1996-2000MY	On-Board Diagnostic System Check During State Emission Test
11-56-99	09/08/99	All 2000MY	State Emission Testing
11-57-99	09/29/99	All 2000MY	On-Board Diagnostic System Diagnostic Link Connector (DLC) Location
11-59-00	02/25/00	1999 Legacy, Impreza, Forester	Air Intake Chamber Box Breakage
11-61-00	06/01/00	All Subaru Vehicles	State Emission Test / Fuel Filter or Gas Cap Test
11-62-00	05/08/00	All 2001 Models Subaru Vehicles	On-Board Diagnostic System Check During State Emission Test
11-63-00	11/01/00	1980-1989 MY Subaru Vehicles	Pressure Testing of Fuel Tank system During State Emission Test
11-64-01	02/01/01	All 1996-1999 Legacy Postal Vehicles	On-Board Diagnostic System Diagnostic Link Connector (DLC) Location
11-65-01	02/01/01	All 2002 Model Subaru AWD Vehicles	On-Board Diagnostic System Check During State Emission Test
11-66-01	02/01/01	All 2002 Model Subaru AWD Vehicles	State Emission Testing
11-68-02	03/05/02	All 1996 and Newer Models	On-Board Diagnostic System Check During State Emission Test
11-69-02	11/01/02	All 2003 Models	On-Board Diagnostic System Check During State Emission Test
11-70-02	11/01/02	All 2003 Models	State Emission Testing
11-71-03	09/22/03	All 2004MY Vehicles	State Emission Testing OBD II System Check

# Fuel Injection and Engine Management (406)

## Service Bulletins

<b>No.</b>	<b>Date</b>	<b>Title</b>	<b>Subject</b>
09-23-86	10/09/86	Exhaust System Noise Diagnosis	All 1985 and 1986 vehicles except Hatchback and Brat Models
09-24-87	06/25/87	Front Exhaust Pipe (EPF) and Under Cover Complete Modifications	All 1983 and 1984 Turbocharged vehicles
09-25-88	12/27/88	Exhaust "Y" Pipe Identification, Noise Diagnosis, and rebuild Procedure	1985 and 1986 L and XT series Non-Turbo vehicles
09-26-91	01/09/91	Non-Turbo Single Wall "Y" Pipe Cover Sets (EPF)	"L" series and Non-Turbo Loyale
09-27-90	12/10/90	Catalytic Converter Recycling	All catalyst equipped exhaust pipes
09-28-91	04/30/91	Modified Exhaust Cover Sets	"L" series and Non-Turbo Loyales
09-29-91	05/09/91	Exhaust Pipe Joint Rattle	1987 through 1991 Justy vehicles with flex joint style exhaust pipe
09-30-91	11/08/91	Knocking Noise from the Exhaust Flex Joint	Loyale
09-31-93	01/12/93	Fuel-Cut Control Unit	89MY to 93MY L-Series/Loyale
09-32-93	02/05/93	Exhaust Pipe "EPR" Whistling Noise	All Legacy Models, including Turbo
09-33-95	11/09/95	Fuel Injector Removal	All Legacy, Impreza and SVX Vehicles
09-34-96	09/13/96	Fuel Injector Replacement	Legacy, Impreza and SVX with EGR
09-35-02	01/07/02	2000MY Legacy Vehicles	New Spare Part for Variable Capacity Muffler
09-36-03	04/01/03	2002MY Impreza WRX	Fuel Smell in Cold Weather
09-37-03	07/15/03	2002~2003MY Impreza WRX	New WRX Radiator
09-38-03	02/06/04	200~2004MY Legacy H-4 and H-6 Equipped Vehicles	Fuel Pump Assembly Division of Parts
09-39-04	05/07/04	2005MY Legacy & Outback Vehicles	Engine Coolant System Refilling

# Fuel Injection and Engine Management (406)

## Tech TIPS

<b>Date</b>	<b>Subject</b>
03/95	Legacy and Impreza engines with no injection pulse #1 cylinder
03/95	Impreza air suction valve noise
04/95	2.2 Impreza AWD fuel senders
05/95	Reformulated gasoline's
06/95	1995 Subaru Legacy DTC P0505 - Idle control system malfunction
06/95	1995 Subaru Legacy DTC P0325 - Knock sensor circuit malfunction
06/95	1995 Subaru Legacy DTC P0130 - Front 02 sensor circuit malfunction
07/95	Loyale water pump Leaks
07/95	Rough idle on MPFI vehicles
07/95	94 Impreza ROM sockets
09/95	DTC P0505 idle control system when solenoid measures 5W or less
12/95	Extreme cold weather engine warm up and OBD II
07/96	Loose fuel caps and trouble code P0440
09/96	1997 Legacy warranty claims for loose fuel caps
09/96	Legacy (Non Turbo), SVX, and Impreza ISC valves
10/96	Modified fuel injectors
11/96	P0440 and Legacy fuel caps
11/96	Blue vs. Gray connectors during diagnosis
11/96	Extreme cold weather engine warm-up and OBDII
03/97	DTC P1500 radiator fan relay one circuit
03/97	1997 Subaru Impreza Outback Sport
04/97	Understanding P0440
05/97	DTC P0507-Idle control system RPM higher than expected
07/97	Code P0500
07/97	Additional information regarding code P0440
08/97	OBD II cylinder misfire codes
09/97	Cooling fan operation
10/97	More P0440 information
01/98	Exhaust smell during cold start
01/98 & 05/98	Model Year 1998 changes in P0440 Evap operation
05/98	DTC P0440 Revisited
11/98	P0440 TIP
11/98	DTC P1507
03/99	1999 Legacy excessive crank time
03/99	Vehicle won't take fuel
05/99	DTC P0705 diagnostics
08/99	Freeze frame data

# Fuel Injection and Engine Management (406)

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## Tech TIPS

<b>Date</b>	<b>Subject</b>
09/99	Evaporative system diagnosis
09/99	Vehicles that won't take fuel
10/99	Fuel system quick connector
11/99	OBD readiness codes
11/99	P0440 1998/1999 Forester
01/00	Don't touch that screw
05/00	Sulfur smell from the exhaust
11/00	WXV-79 engine control module service program
11/00	Use of genuine air cleaner element
01-02/02	H6 Extended crank time
09-10/02	Forester fuel line noise
08/03	WRX STi Driveability
09/03	2004MY Legacy fuel filter replacement
11/03	H6 Driveability
12/04	Fuel Line Tool
03/05	Gas Mileage
04/06	Subaru B9 Tribeca Fuel Line Tool
06/05	Fuel Hose Retainer Clips



