SUBARU®

Confidence in Motion

Technician Reference Booklet

Fuel Injection Systems

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MSA5P0161C

September 2015

This Technical Reference Booklet (TRB) is designed to be used in a classroom environment or as a guide for self study.

The TRB is not intended to be used as a supplement or substitute for the Subaru Service Manual. Always consult the appropriate Subaru Service Manual when performing any diagnostics, maintenance or repair to any Subaru vehicle.

The date on the front cover indicates the month and year this book was last revised.

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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.

The fuel injection system is a collection of many systems that are designed to control and maintain the operation of the engine that both meets the driver's demands and provides the best output of emissions. During this course we will be discussing these systems and their construction, operation and diagnosis.

Analyzing and diagnosing fuel injection requires a balance between understanding the mechanical aspects of the engine and components. The electrical data being received by the ECM, analyzed and then outputs to control components.

SUBARU MODELS

Air Induction System

Over the last 30 years Subaru's Air Induction System has evolved to what we now use on all models, the Electronic Throttle Control System (ETC). ETC consists of a spring loaded gas pedal with a two sensor assembly , the spring loaded throttle body with an electric motor and two sensor assembly, a mass air flow meter, a pressure sensor, intake manifold, air filter, duct work and related relays and wiring.

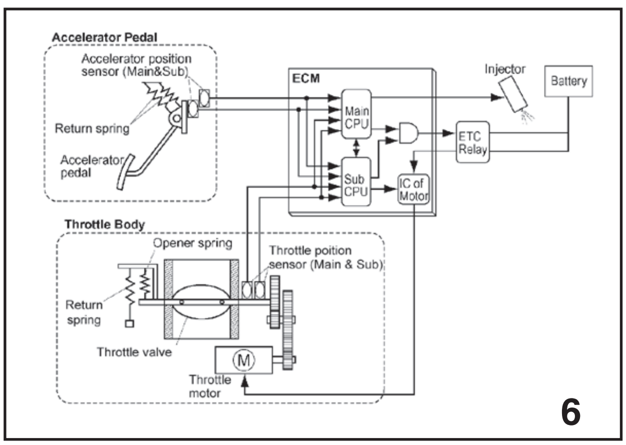
ETC Control

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.

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.

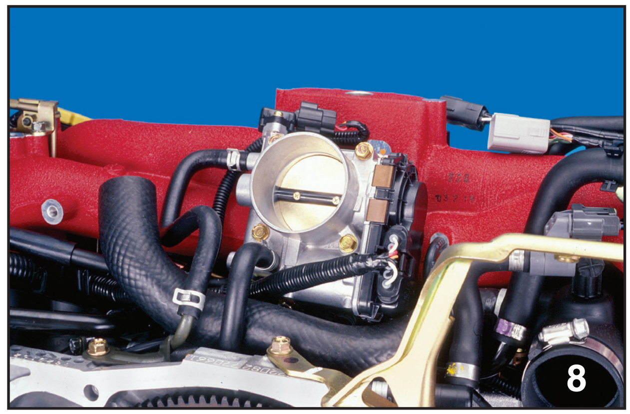


ETC SYSTEM LAYOUT

ETC Components

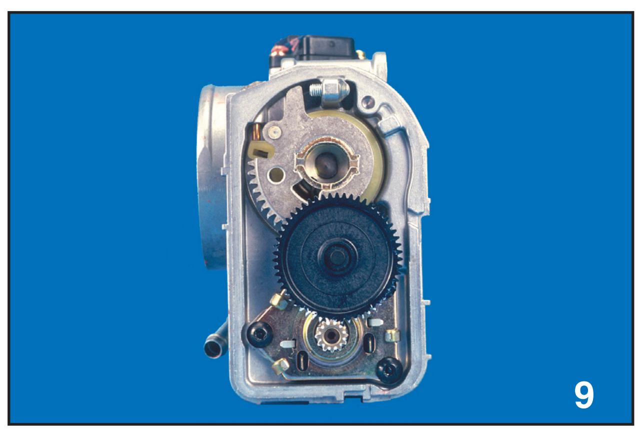
Throttle Body

The throttle body is responsible for taking the demands from the driver and delivering them to the engine to produce the desired power and vehicle response. The throttle body also controls idle speeds that differ based on engine coolant temperature and accessory load. Additionally cruise control operation and torque reduction are controlled by the 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.

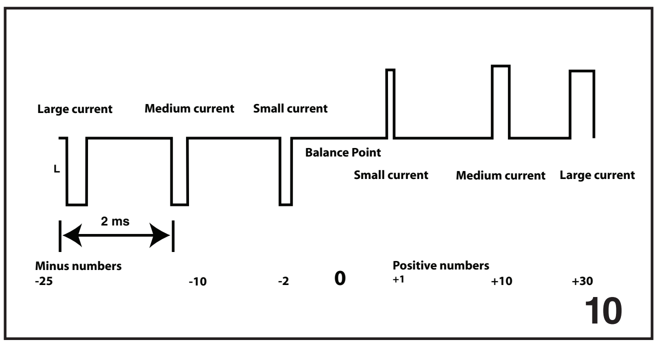


MOTOR, REDUCTION AND THROTTLE SHAFT GEAR

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 RPM 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.



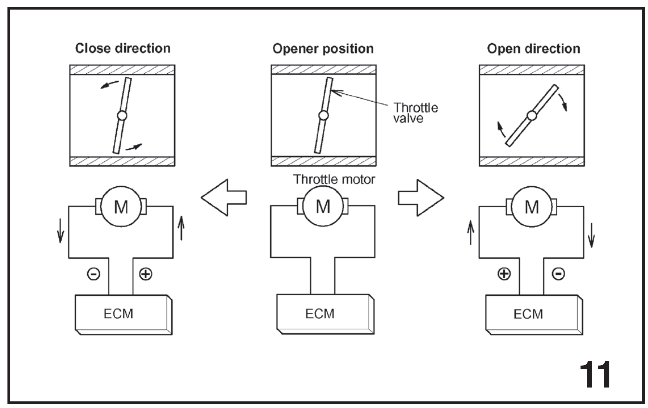
THROTTLE BODY DUTY RATIO WAVE FORM

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.**

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

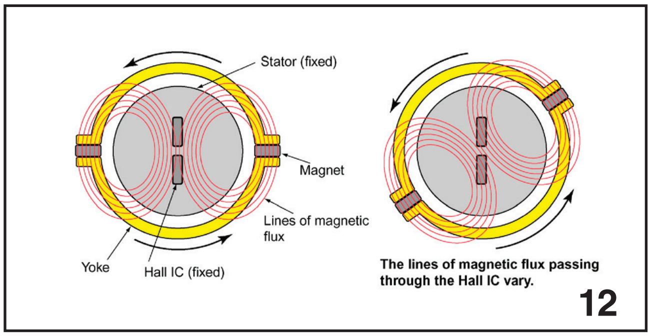
The valve opening/closing speed and the valve position are maintained by controlling the duty ratio. The duty ratio that maintains the valve position is determined by balancing the spring force of the return spring or the opener spring.

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.

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.



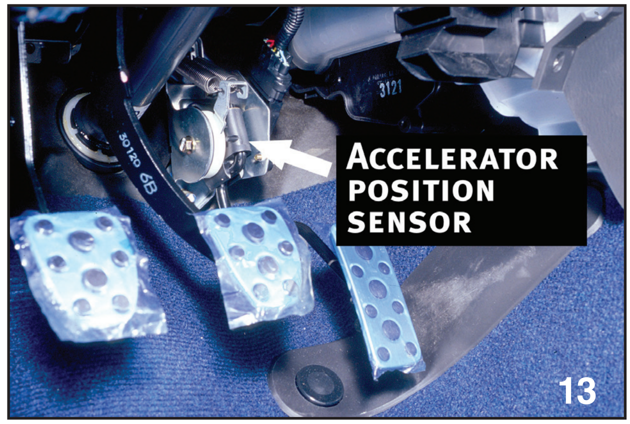
HALL EFFECT (MAIN AND SUB) VALVE OPENING DETECTION PRINCIPLE

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.

Acceleration Position Sensor

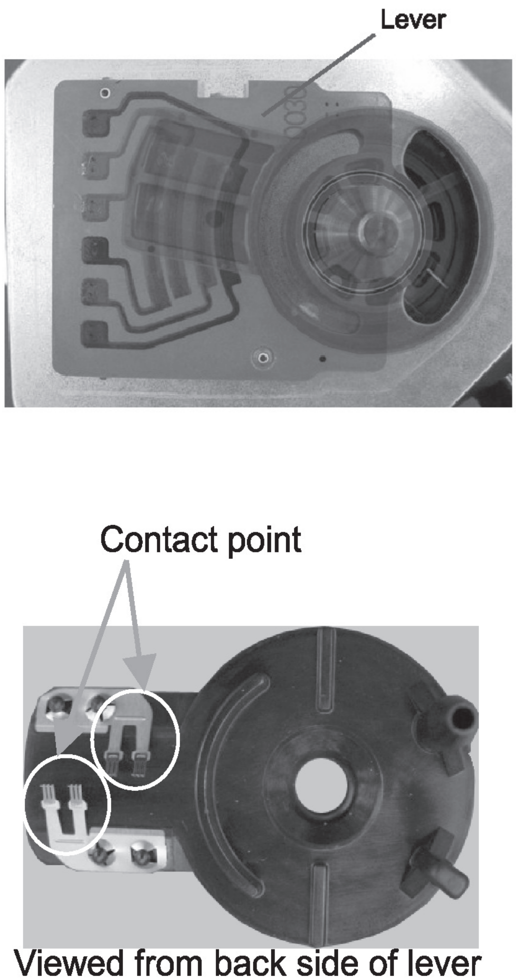
The Acceleration Position Sensor is mounted on the accelerator pedal inside the passenger compartment. It provides information on the movement of the accelerator pedal on two separate circuits that can provide detailed information on the position of the accelerator pedal.



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.

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.



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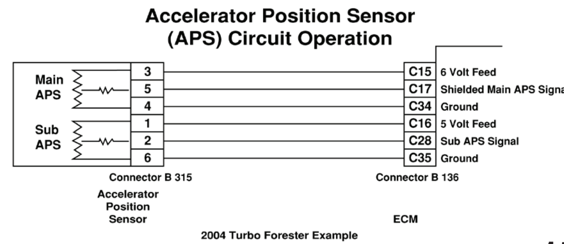
CONTACT LEVER

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.



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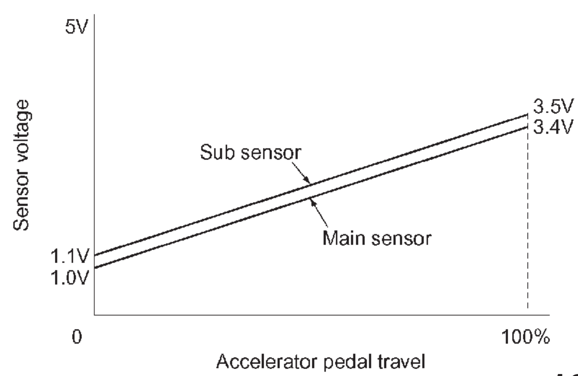
CONTACT POINTS OF LEVER (SCHEMATIC)

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.



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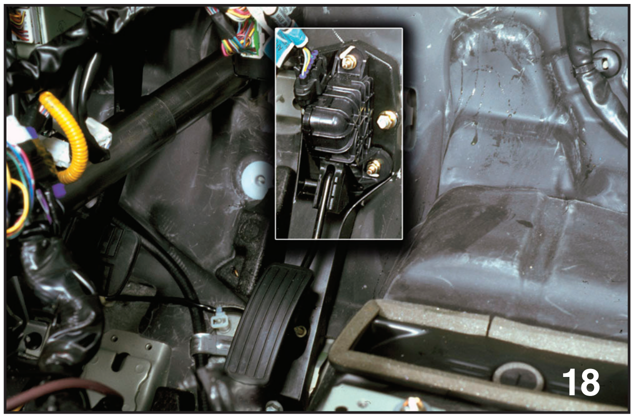
ACCELERATOR PEDAL TRAVEL

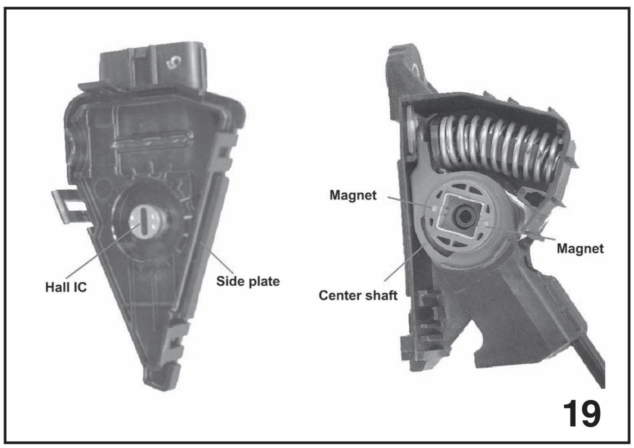
The ECM is looking for this. **.1** volt difference to verify the acceleration position sensor is working properly.

Accelerator Sensor



ACCELERATOR PEDAL SENSOR

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

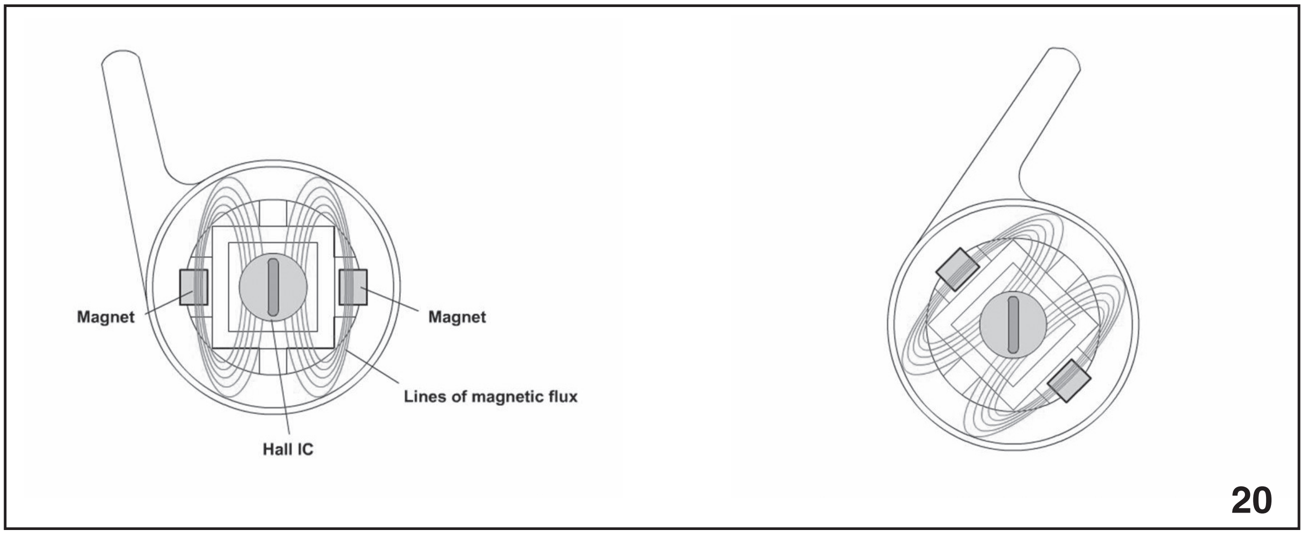


ACCELERATOR PEDAL SENSOR APART

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.

NOTES:

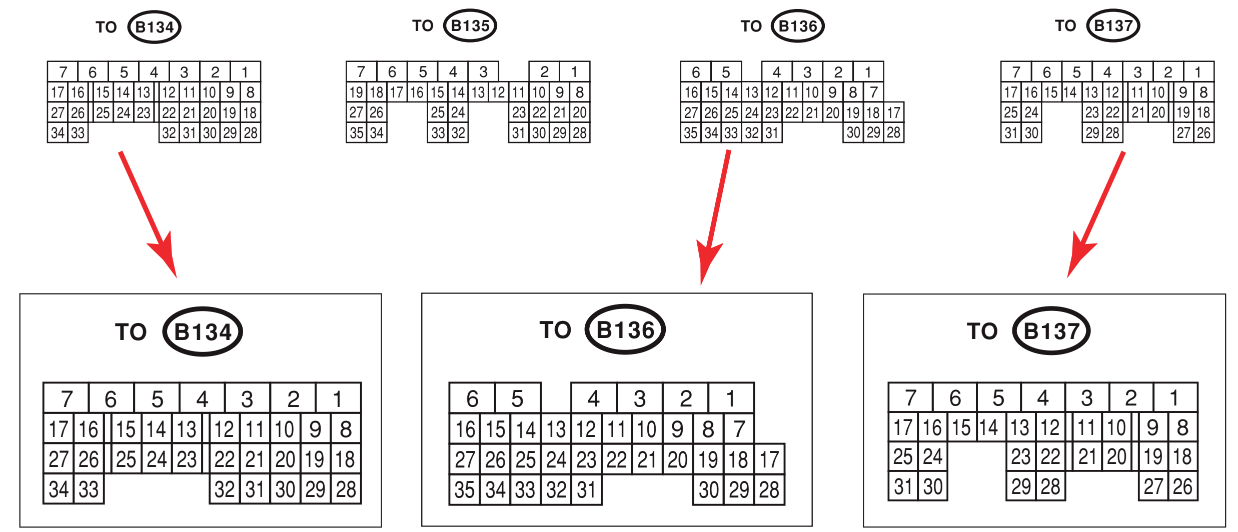


SENSOR (ARTWORK)

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.

Checking the Engine Control Module (ECM) I/O Signal chart shows the inputs and outputs of the entire fuel injection system. The values of each wire into and out of the ECM are shown or described. The systems or components are usually grouped together which allows a quick check of the values needed during the understanding of operation or diagnosis.

Electric Throttle Control (ECM) I/O Signal



Contents		Connector No.	Terminal No.	Signal (V) Ignition SW ON (engine OFF)	Signal (V) Engine On (idling)	Note
Electric throttle control	Main	B134	18	0.64 – 0.72 Fully opened: 3.96	0.64 – 0.72 (After engine is warmed-up)	Fully closed: 0.6 fully opened: 3.96
	Sub	B134	28	1.51 – 1.58 Fully opened: 4.17	1.51 – 1.58 (After engine is warmed-up)	Fully closed: 1.48 Fully opened: 4.17
	Power supply	B134	19	5	5	–
	GND (sensor)	B134	29	0	0	–
Electronic throttle control motor (+)		B137	5	Duty waveform	Duty waveform	Drive frequency: 500 Hz
Electronic throttle control motor (-)		B137	4	Duty waveform	Duty waveform	Drive frequency: 500 Hz
Electronic throttle control motor power supply		B136	1	10 – 13	12 – 14	–
Electronic throttle control motor relay		B136	21	ON: 0 OFF: 10 – 13	ON: 0 OFF: 10 – 13	When ignition switch is turned to ON: ON

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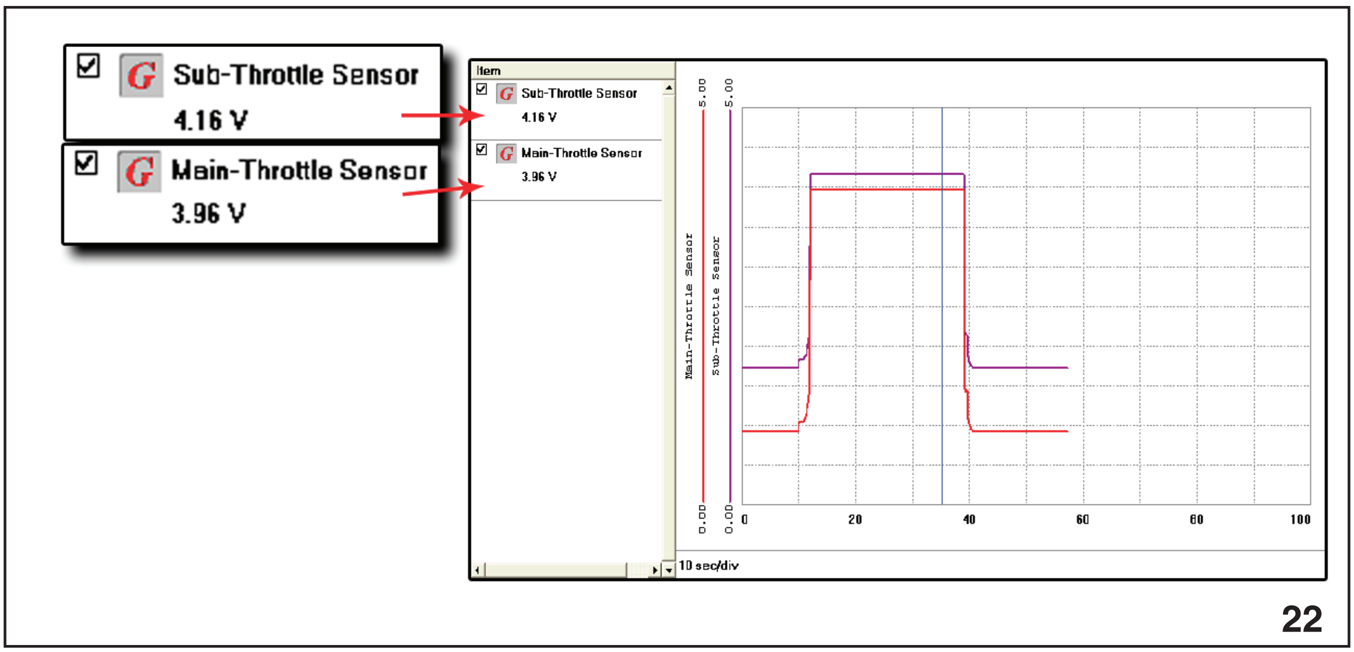
ELECTRIC THROTTLE CONTROL

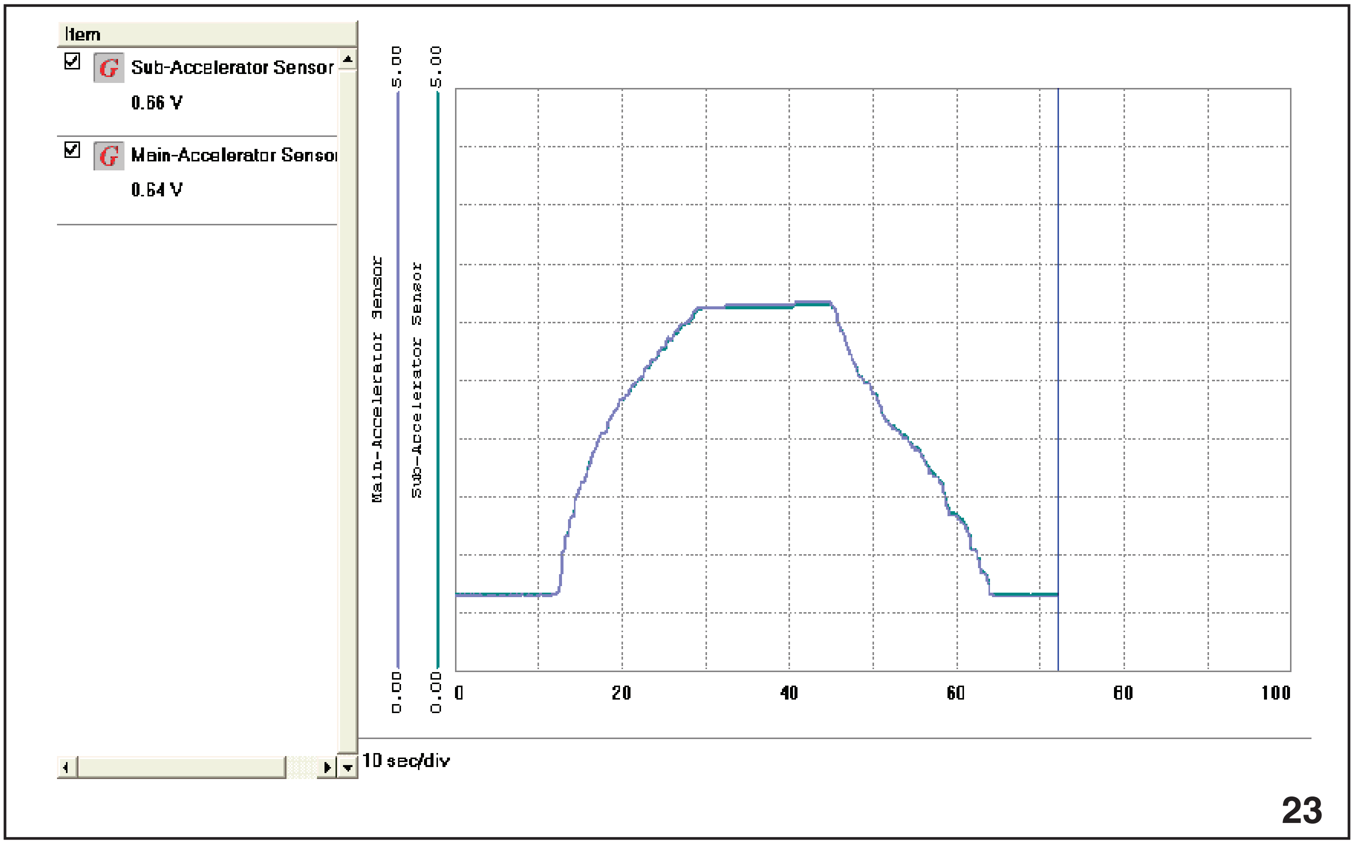
For the ETC the described values for the Throttle Position Sensor are: Main fully closed 0.6 and fully open 3.96. Take into account that the ECM will adjust the throttle body for a cold engine slightly higher than a warm engine so the closed or idle value may be higher than 0.6.
The Sub sensor fully closed 1.48 and fully open 4.17. The difference between the Main and the Sub at idle or closed throttle is .88 volts and fully open is .21 volts. So the distance between the two signals as seen on a graph will become closer together gradually as the throttle is moved from fully closed to fully open.

The movement of the throttle position from fully closed to fully open may not be linear as compared to the movement of the accelerator pedal, especially on vehicles equipped with SI Drive. This will make it difficult to graph the values of the Main and Sub throttle position sensors to observe for a constant and gradual increase in voltages from fully closed to fully open.

The best way to observe these signals is to use the graph function on SMIII. Slowly press the gas pedal (key on engine off) from fully closed to fully open and allowing the slow an gradual return to fully closed. Hold the data and review the values of the two sensors. Compare the differences at fully closed and fully open. Compare the graphs as they slowly increase and decrease. As long as the differences remain constant and smooth and within the parameters written down on the I/O chart, the sensors are working correctly. This procedure can also be used for the Main and Sub sensors of the Accelerator pedal.



SMIII GRAPH SHOWING THROTTLE SENSOR DIFFERENCES



SMIII GRAPH SHOWING ACCELERATOR SENSOR DIFFERENCES

Diagnostic Procedure with Diagnostic Trouble Code (DTC)

ENGINE (DIAGNOSTICS)

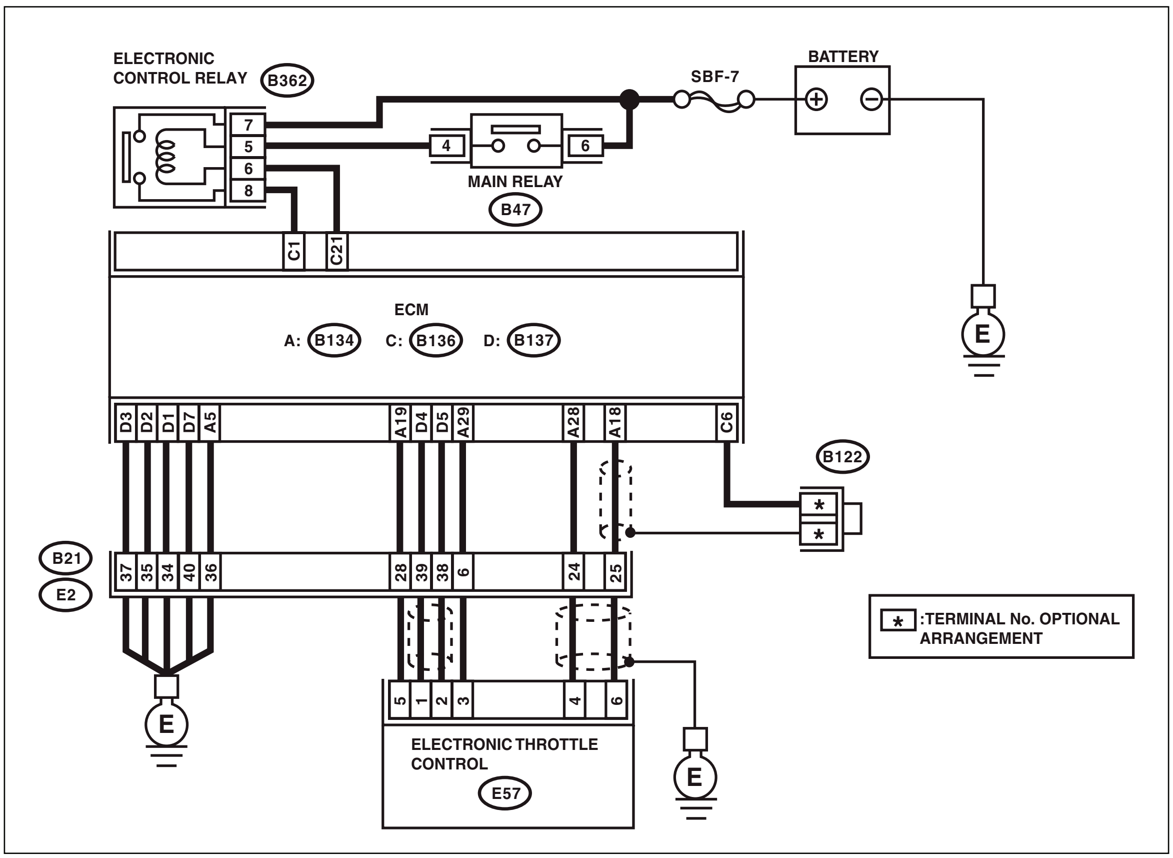
DY:DTC P2135 THROTTLE/PEDAL POSITION SENSOR/SWITCH "A"/"B" VOLTAGE CORRELATION

DTC DETECTING CONDITION

- Immediately at fault recognition
- GENERAL DESCRIPTION <Ref. to GD(H4DOTC)-271, DTC P2135 THROTTLE/PEDAL POSITION SENSOR/SWITCH "A"/ "B" VOLTAGE CORRELATION, Diagnostic Trouble Code (DTC) Detecting Criteria.>

TROUBLE SYMPTOM:

- Improper idling
- Poor driving performance



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"A" THROTTLE POSITION SENSOR / "B" SUB SENSOR

Diagnostic trouble codes (DTC) are listed in the service manual along with the diagnosis needed to find and repair the condition. OBDII regulations mandate that the DTCs be labeled by a given number as well as an A and or B assignment. Any references to A for the Throttle Position sensor are describing the Main sensor while the B is the labeling assigned to the Sub sensor.

Diagnostic Trouble Code (DTC) Detecting Criteria

GENERAL DESCRIPTION

DIAGNOSTIC METHOD

Abnormality Judgment

- If the duration of time while the following conditions are met is longer than the time indicated, judge as NG.

Judgment Value

Malfunction criteria	Threshold value
Signal difference between two sensors	> Value from Map

Map

Throttle position sensor 1 opening angle (°) = d	0 ≤ d < 2.125°	2.125° ≤ d < 4.25°	4.25° ≤ d < 9°	9° < d ≤ 31.625°	31.625° < d
Sensor output difference (°)	5.15°	6.15°	8.28°	10.4°	12.4°

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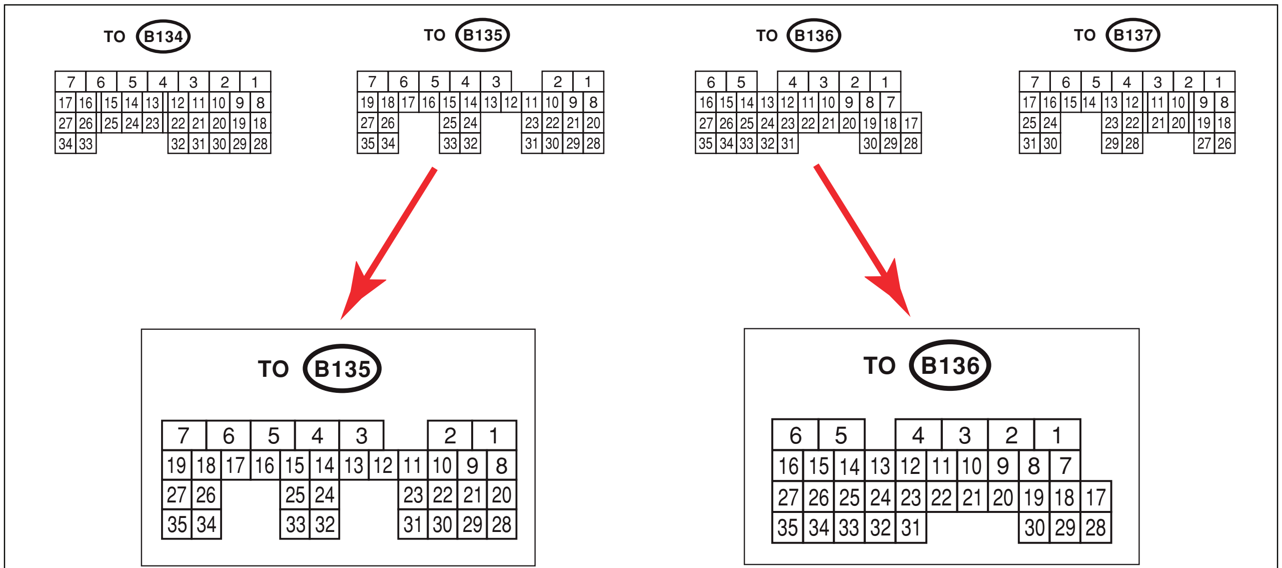
DTC DETECTING CRITERIA

The following article explains how to analyze the OBDII judgement criteria vs the SMIII data displayed.

The criteria needed to set a code can be found in the general description chapter of the engine diagnostics. However, the information provided for some codes can be confusing or provides information that cannot be used.

For example the criteria for DTC P2135 Throttle /Pedal Position Sensor/Switch A/B Voltage Correlation indicates that the difference between the Main and Sub sensor with the throttle open more than 0 degrees but less than 2.125 degrees can have no more difference than 5.15 degrees. The biggest challenge here is that the SSMIII does not display throttle opening angle or the value of the Main and Sub throttle sensors in degrees.

Accelerator Pedal Position Sensor (ECM) I/O Signal



Contents		Connector No.	Terminal No.	Signal (V)		Note
				Ignition SW ON (engine OFF)	Engine On (idling)	
Accelerator pedal position sensor	Main sensor signal	B135	23	Fullyclosed: 1 Fully opened: 3.3	Fully closed: 1 Fully opened: 3.3	–
	Main power supply	B135	21	5	5	–
	GND (main sensor	B135	29	0	0	–
	Shield	B1	6	0	0	–
	Sub sensor signal	B135	31	Fully closed: 1 Fully opened: 3.3	Fully closed: 1 Fully opened: 3.3	–
	Sub power supply	B135	22	5	5	–
	GND (sub sensor)	B135	30	0	0	–

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ACCELERATOR PEDAL POSITION SENSOR CHART

The accelerator sensors described on the I/O chart chosen indicates that the Main and Sub sensors both are at 1 volt with the throttle fully closed and 3.3 volts fully open. These two values should be equal during the opening and closing of the throttle. If there is a big enough deviation between the two a DTC will be set and the ETC will go into failsafe. This also applies to the main and sub throttle sensors.

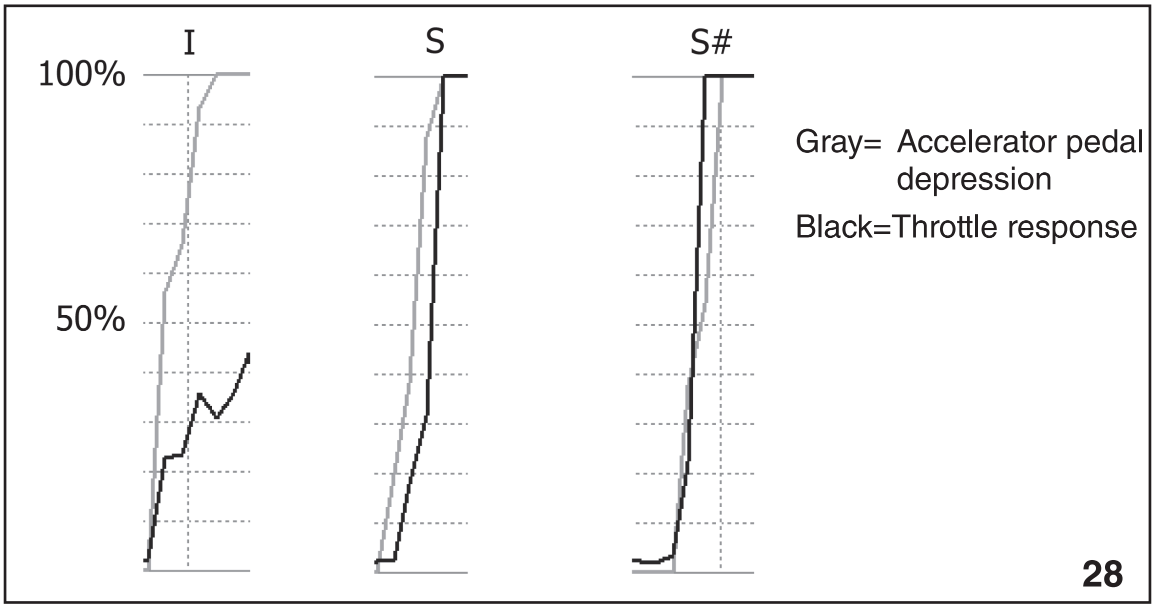
Failsafe throttle opening is about 6.3 degrees of opening or the position of where the two springs are balanced.

DTCs regarding the Accelerator sensors are labeled D and or E. D is the main sensor and E is the Sub sensor.

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 (TCM) 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%.

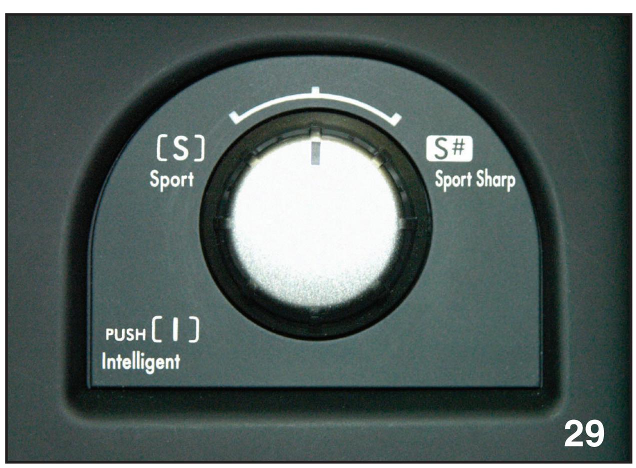


ACCELERATOR PEDAL MOVEMENT TO THROTTLE

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

Intelligent Mode

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

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.

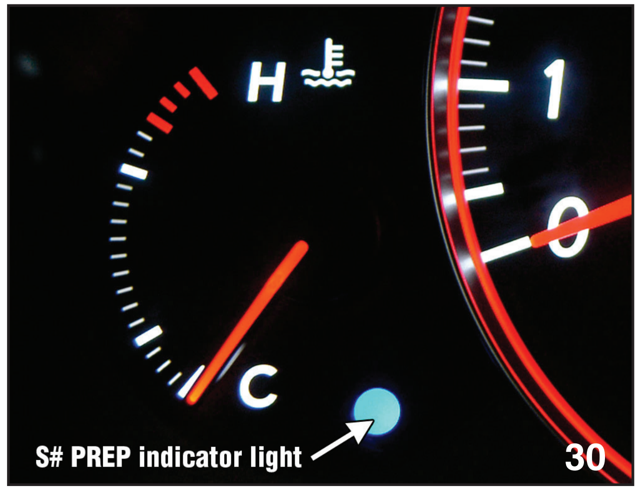
Sport Sharp Mode:

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.



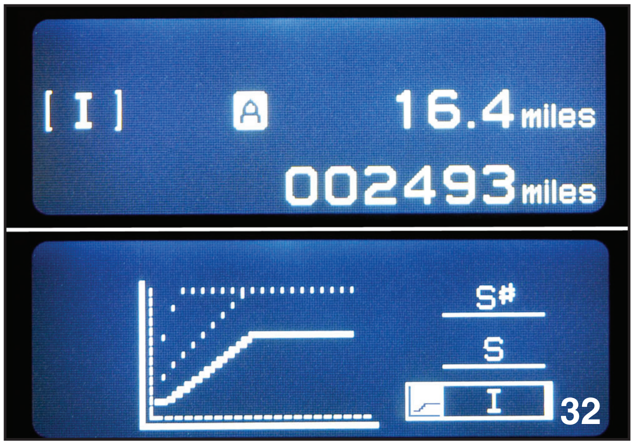
S# PREP INDICATOR LIGHT

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

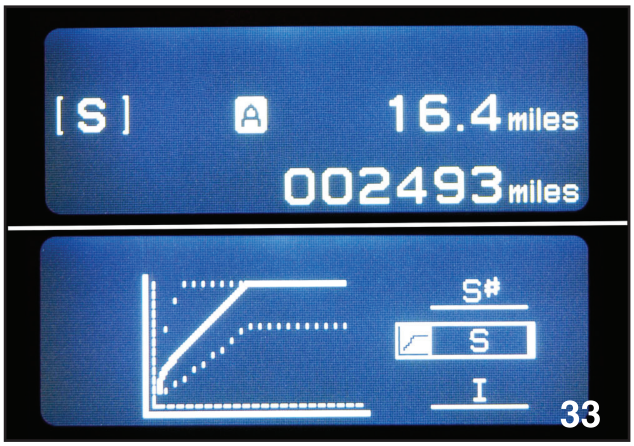
ECO GAUGE

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

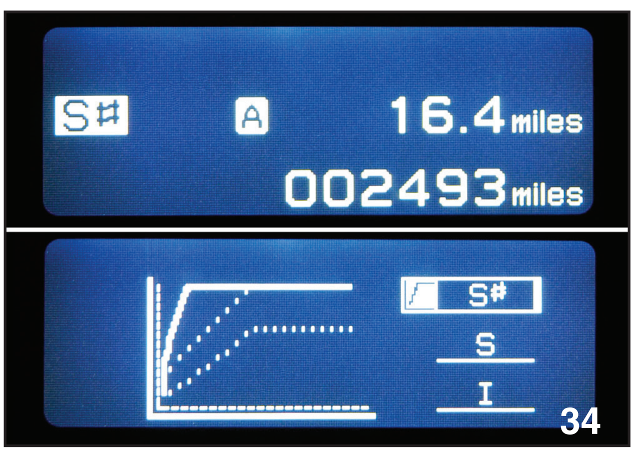
With the easy to read analog gauge, the driver can intuitively improve fuel economy by keeping the needle in the positive zone.



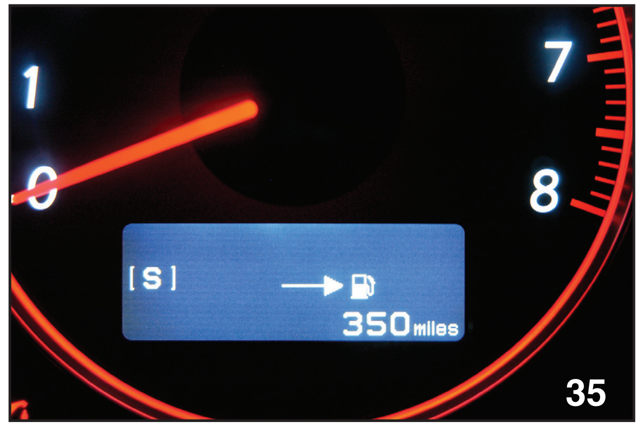
I-MODE



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.

SI Drive Operation Under Special Condition

ENGINE CONDITION	INDICATOR	ECM	TCM
MIL - ON	S	S	S
Coolant Temp > 248°F Coolant Temp < 133°F	S#, I	S	S
Reverse Gear	S#, I	S	S

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SI DRIVE LOGIC CHART

ECM and TCM 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.

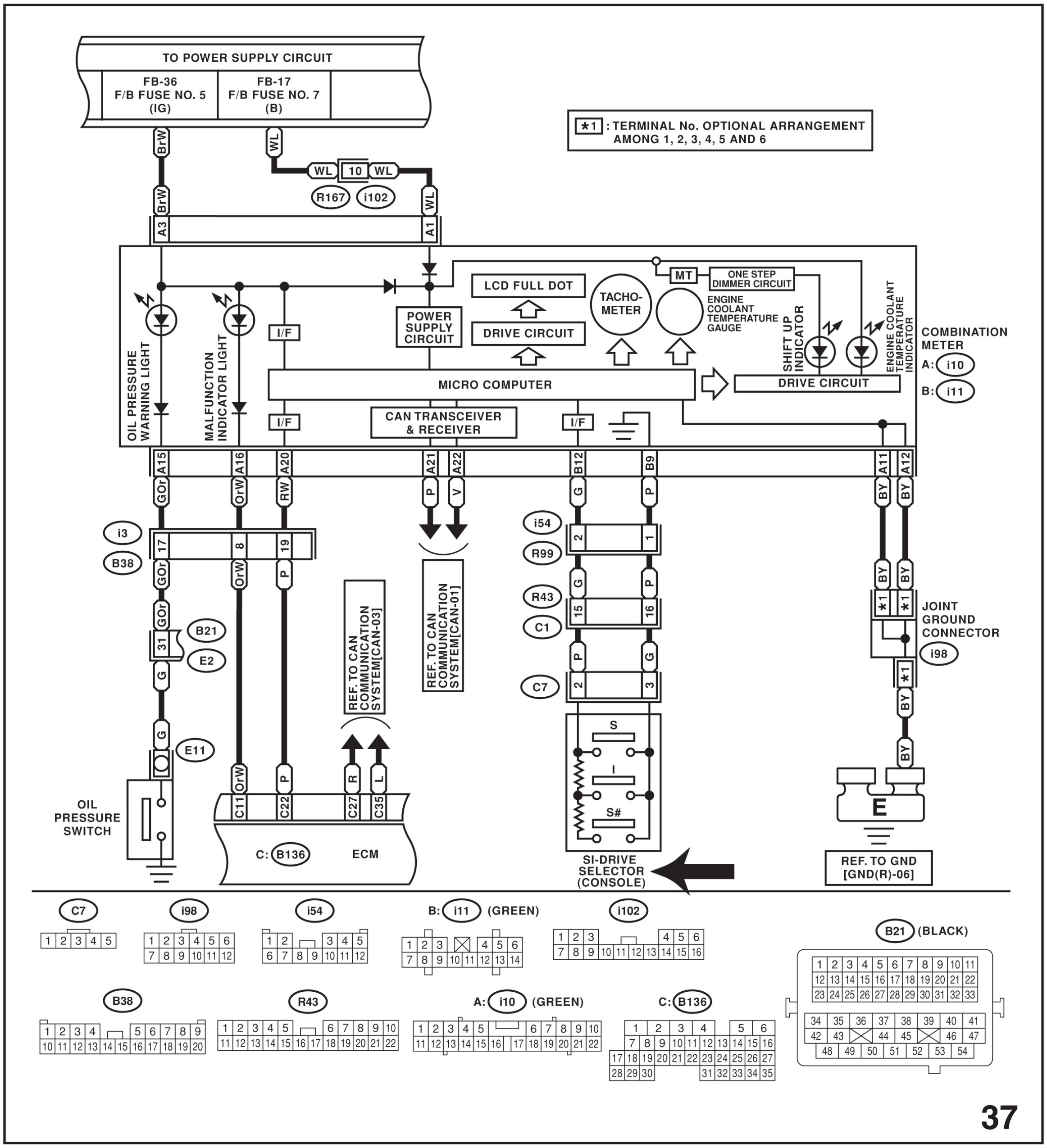
Example: ECM will switch mode from I mode to S mode automatically when coolant temp reaches 135° (Degrees Fahrenheit).

TCM Control

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

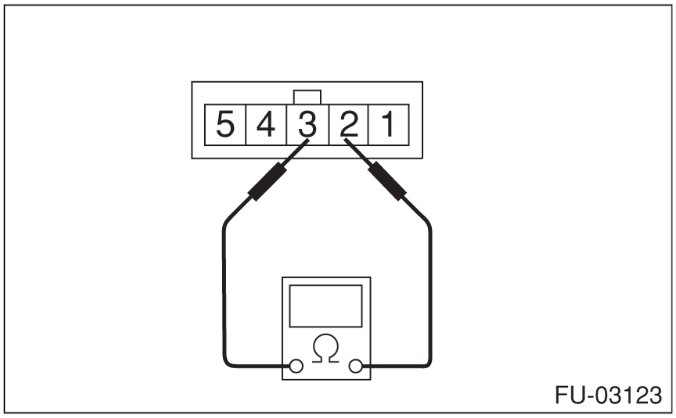
S mode: almost same as D range with previous model.

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



SI DRIVE WIRING SCHEMATIC

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



Switch position	Terminal No.	Standard
Sport (when turning the SI-DRIVE selector to the left)		Less than 10
Intelligent (when pushing the SI-DRIVE selector)	2 and 3	0.8 — 1.2 k
Sport Sharp (when turning the SI-DRIVE selector to the right)		2.14 — 3.2 k

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SI DRIVE SWITCH TERMINAL NUMBERS

This varied resistance on the 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 ECM controls the throttle and the TCM controls the shift points and shift logic.

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

Check SI Drive switch and corresponding indicator on the odometer for proper operation.

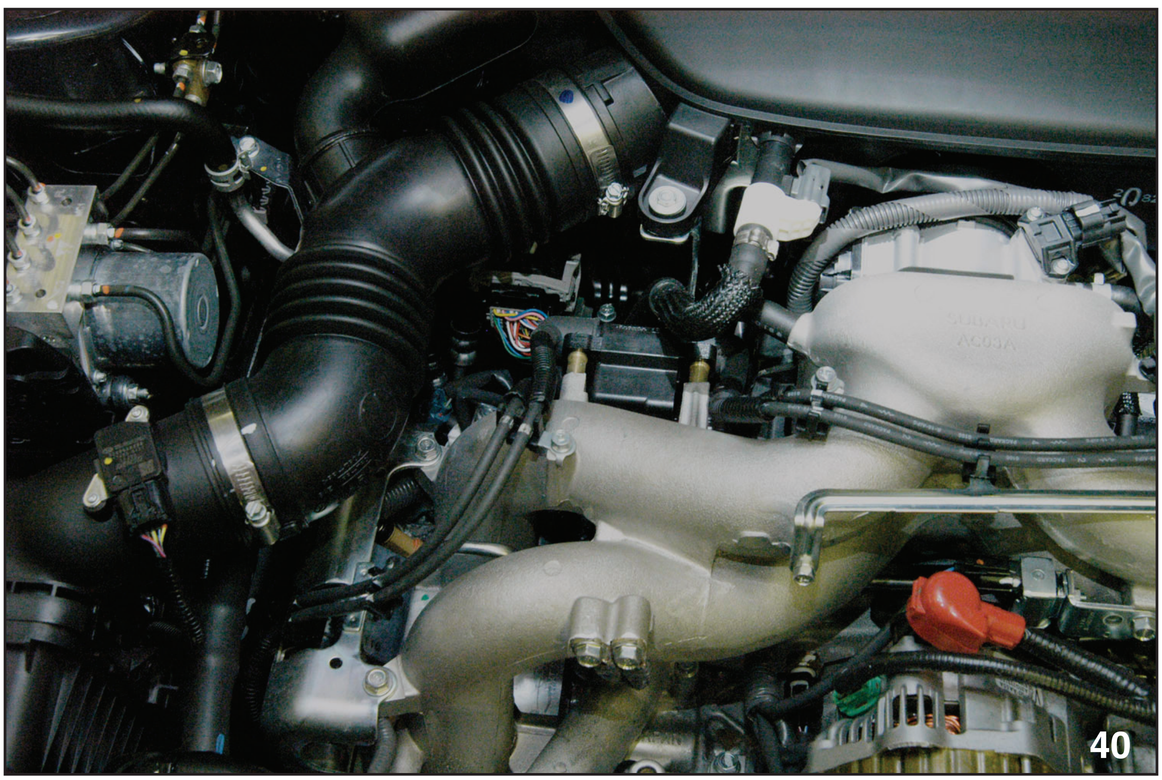
Air Flow Meter and Pressure Sensor

Once the air has entered the induction system it must be measured. Over the years Subaru has used two different systems either together or separate. The decision to use one or both systems mainly depends on the government regulations set forth for a given year and model type. These two methods are the air flow meter and the manifold pressure sensor.

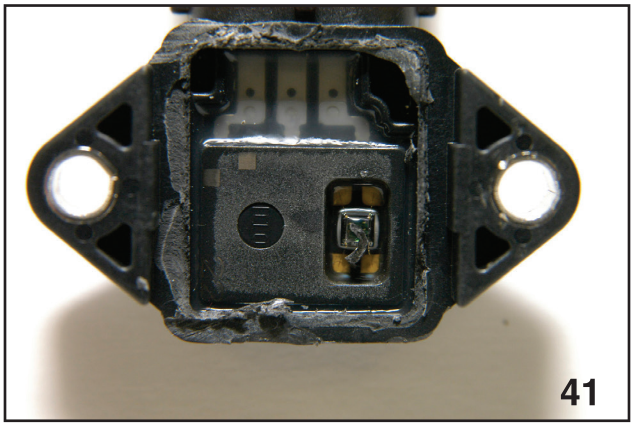
In either case the goal of the air measurement was to provide the ECM with the information necessary to match the amount of air coming into the engine with the correct amount of fuel. This provides a stoichiometric burn of the air fuel mixture and provided the correct engine speed and power for any given vehicle condition or driver demand.

The two sensors have changed many times since their introduction but the results have stayed the same. The characteristics of the airflow meter show that it provides a very sensitive and very accurate measurement of the inducted air as long as the volume remained at a somewhat constant level, such as cruising. Conversely manifold pressure sensors show their best results during changes from one level of operation to another, such as going from cruising to wide open throttle.

Using both sensors ensures that all operations and conditions of the vehicle are monitored to the most possible accurate means available.

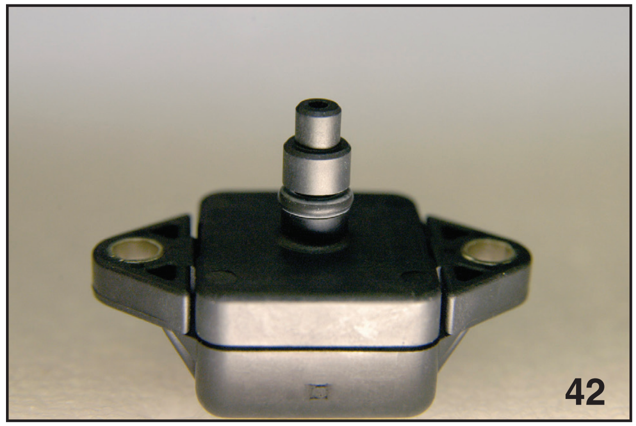


AIR FLOW METER AND PRESSURE SENSOR



41

INSIDE NEWER PRESSURE SENSOR



42

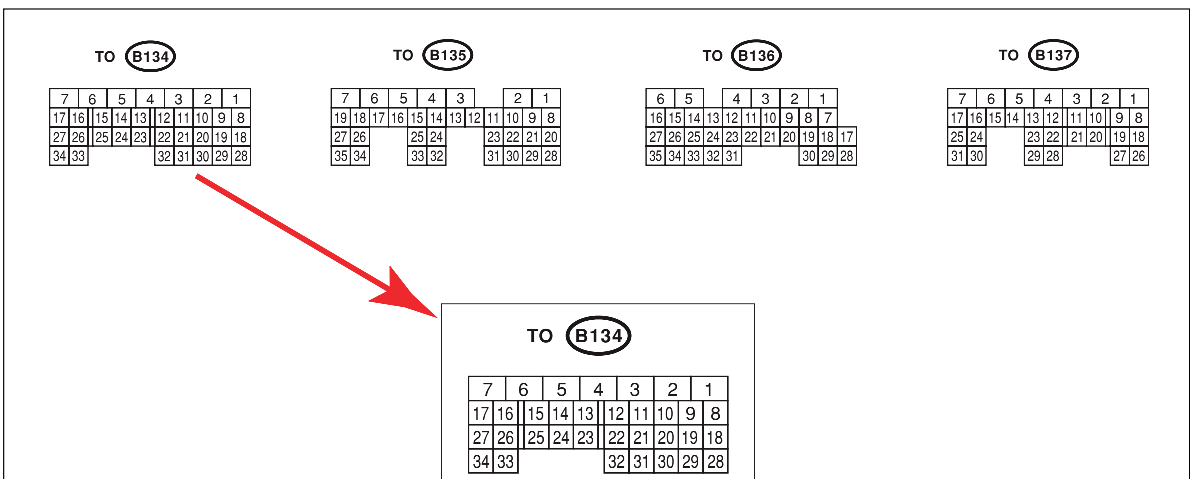
NEWER PRESSURE SENSOR

Newer pressure sensors work by using a very small piece of a quartz crystalline structure that changes its electrical characteristics based on the amount of air pressure placed against it.

The quartz structure provides an input to an integrated circuit which in turn creates the signal that represents manifold pressure.

The integrated circuit is placed inside an airtight housing and is sealed to the intake manifold or throttle body with an O-ring and two bolts or screws to hold it in position. The tip of the air tight housing is placed so that it can sample the intake manifold pressure.

Manifold Absolute Pressure Sensor (ECM) I/O Signal



Contents		Connector No.	Terminal No.	Signal (V) Ignition SW ON (engine OFF)	Signal (V) Engine On (idling)	Note
Manifold absolute pressure sensor	Signal	B134	6	1.7 – 2.4	1.1 – 1.6	–
	Power Supply	B134	19	5	5	
	GND (sensor)	B134	29	0	0	

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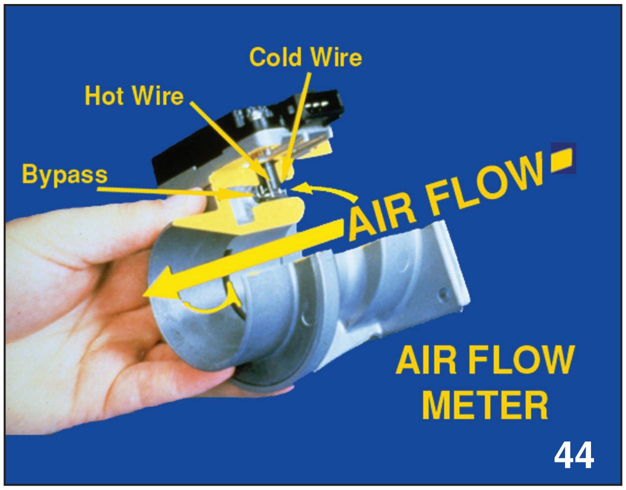
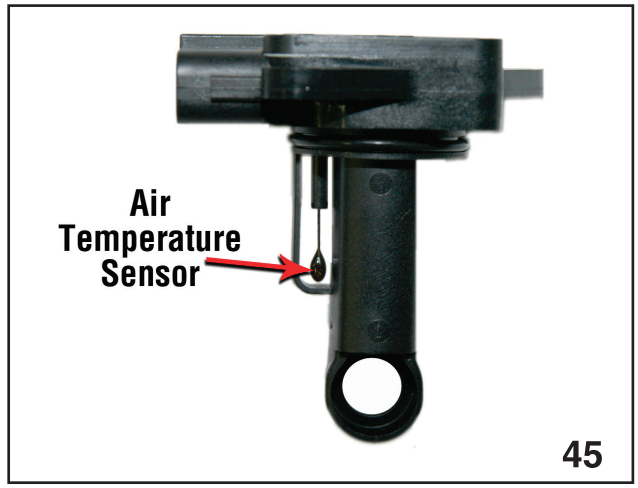
MANIFOLD ABSOLUTE PRESSURE SENSOR - (ECM) I/O SIGNAL CHART

Air Flow Meter

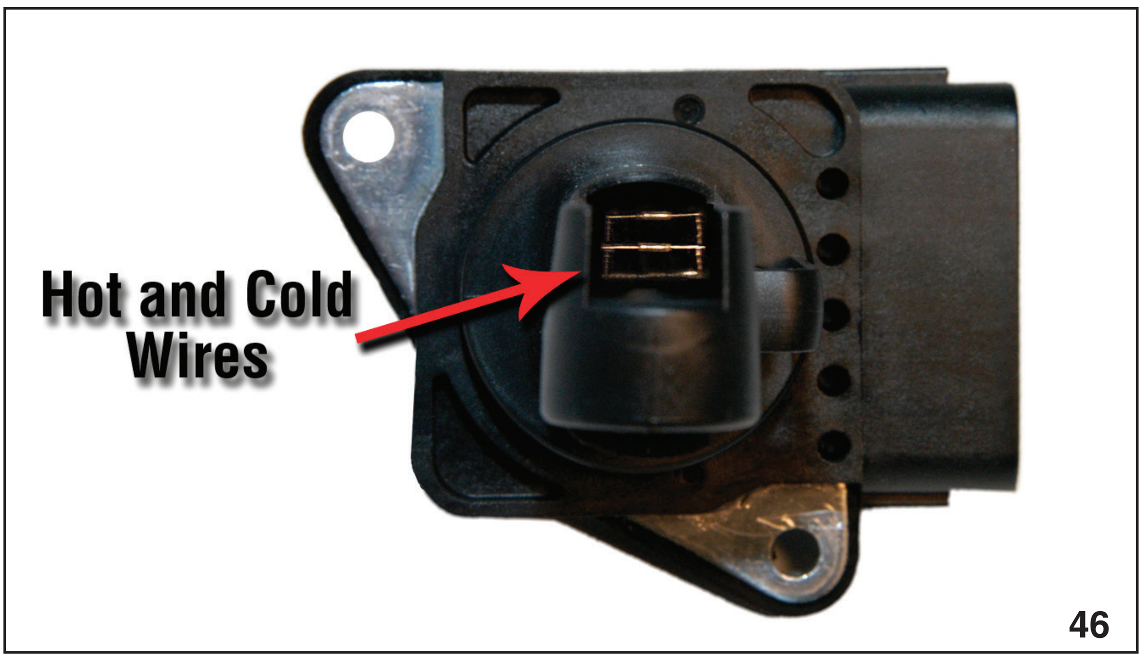


EARLY AIR FLOW METER



NEWER 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 the hot wire which is exposed to the incoming air flow.

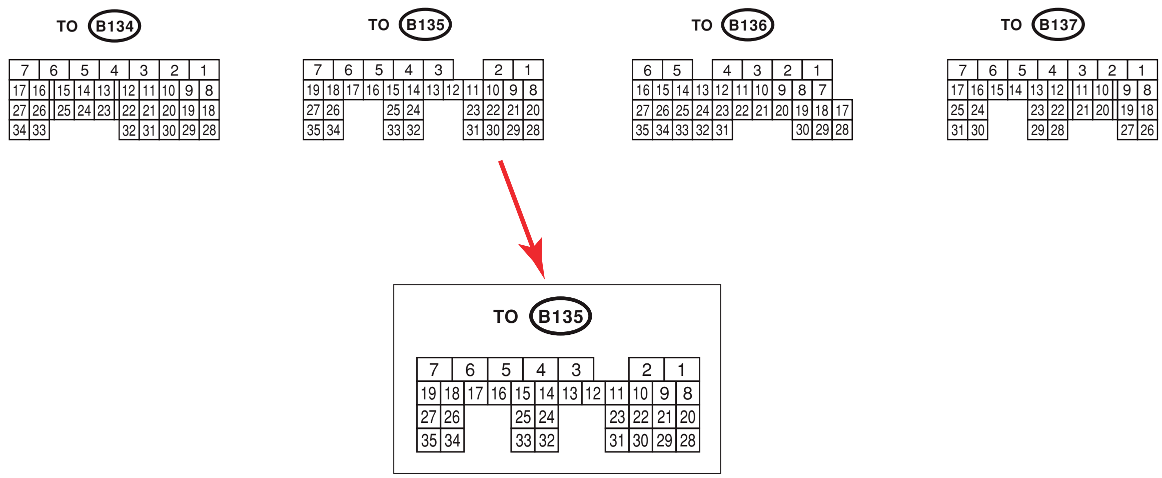


BOTTOM VIEW OF NEWER AIR FLOW METER

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.

Air Flow Sensor-Intake Air Temperature Sensor Signal (ECM) I/O Signal



Contents		Connector No.	Terminal No.	Signal (V) Ignition SW ON (engine OFF)	Signal (V) Engine On (idling)	Note
Air flow sesnor	Signal	B135	26	–	0.3 – 4.5	–
	Shield	B135	35	0	0	–
	GND	B135	34	0	0	–
Intake air temperature sensor signal		B135	18	0.3 – 4.6	0.3 – 4.6	–

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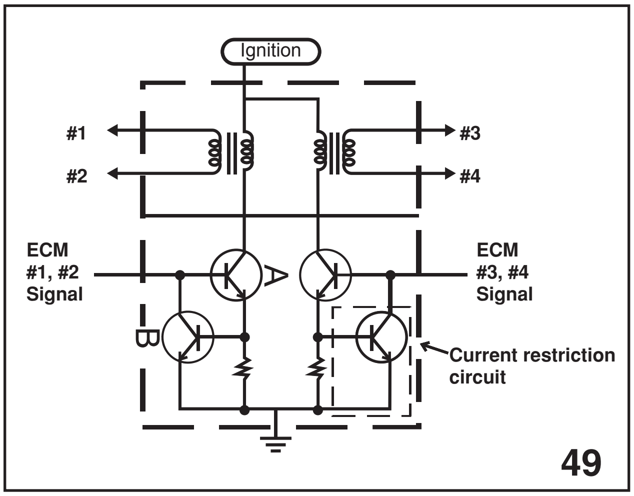
AIR FLOW SENSOR-INTAKE AIR TEMPERATURE SENSOR SIGNAL

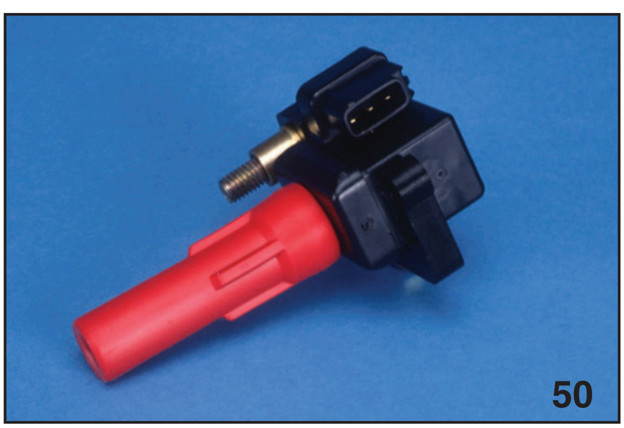
Ignition System

Current Subaru models are equipped with either a waste spark ignition system or a coil over plug ignition system. Naturally aspirated 4 cylinder models utilize the waste spark ignition system while the 6 cylinder and turbo charged engine models use the coil over plug ignition system.

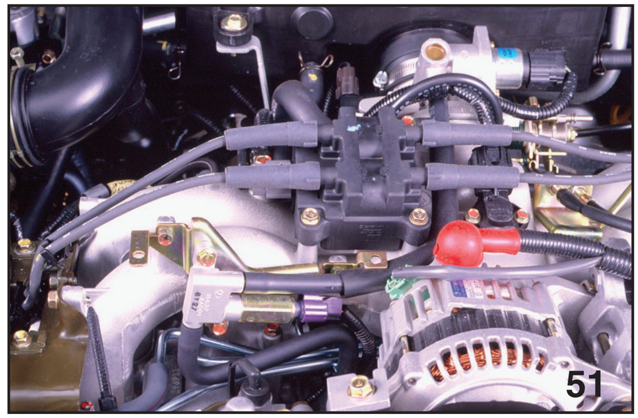


IGNITION COIL CONSTRUCTION

The coil of the waste spark ignition system creates a condition where one end of the secondary circuit is very negative and other end is very positive. This potential difference is delivered through the spark plug wire to the spark plug. A spark results that carries the potential difference to the cylinder block to the base of the companion cylinder spark plug. The potential difference travels across the gap of the spark plug as a spark and travels to the opposite end of the secondary circuit that created it.

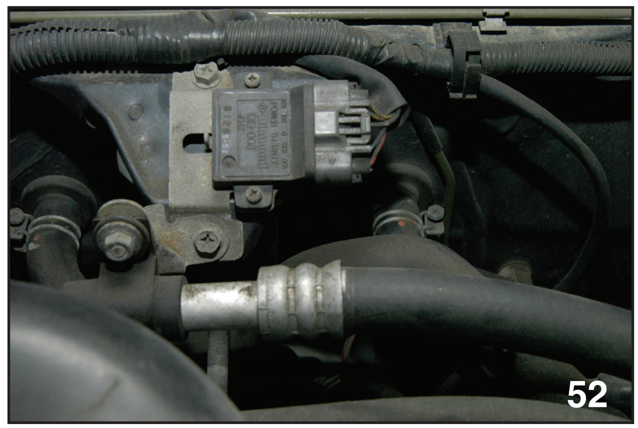


WASTE SPARK COIL

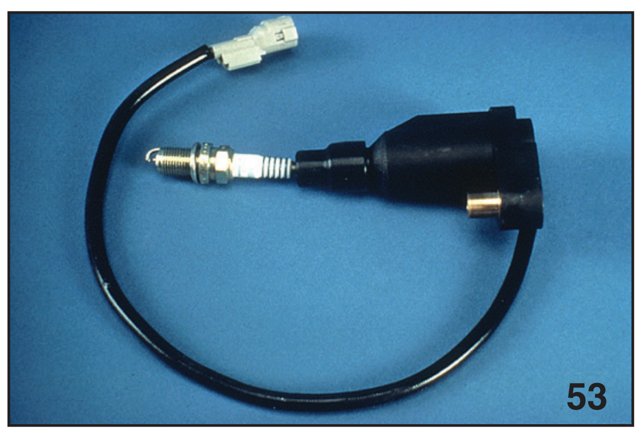


IGNITION COIL COMPLETE

Both systems currently incorporate the igniter in the coil assembly. Older Subaru models depended on a remotely mounted igniter.



REMOTE MOUNTED IGNITOR

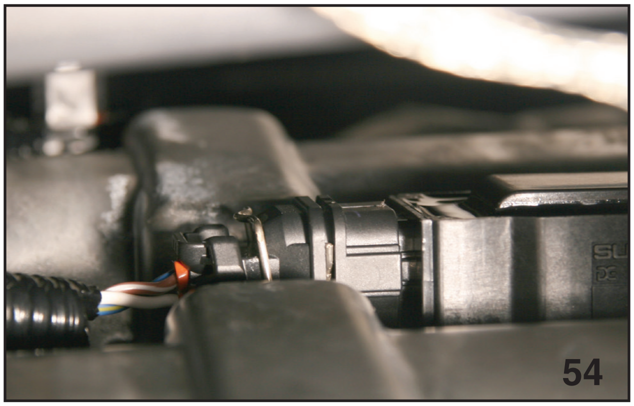


SVX IGNITION COIL AND SPARK PLUG

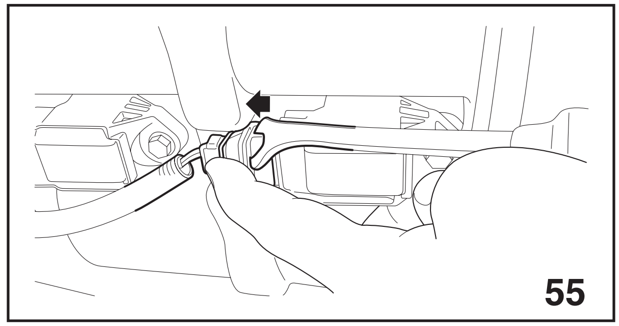
In either case the function of the igniter was the same, controlling the current and timing of the ignition coil.

2015 WRX and WRX STI

The connector of the ignition coil has been changed to a spring-lock type.

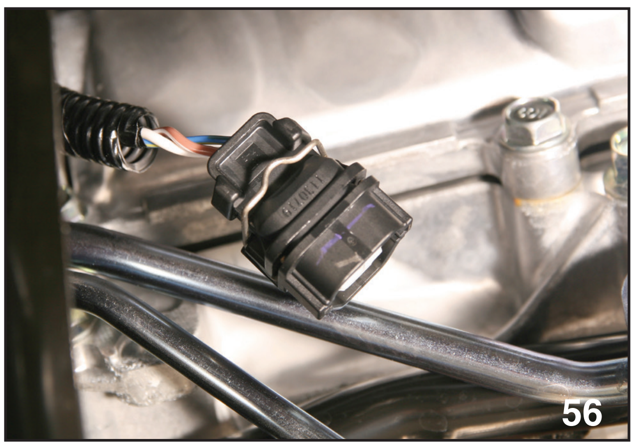


IGNITION COIL CONNECTOR CONNECTED

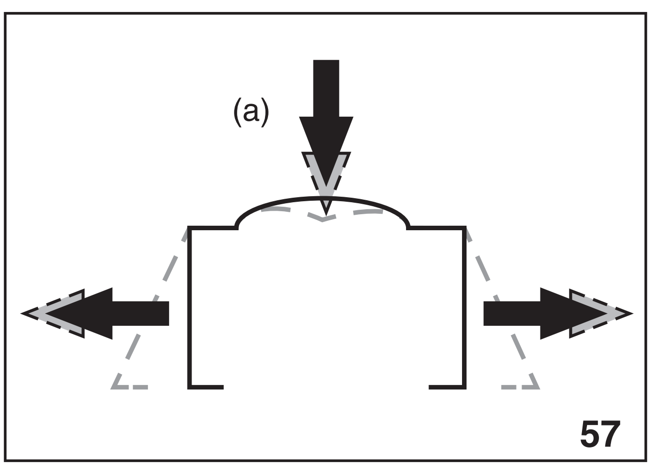


IGNITION COIL CONNECTOR ARTWORK

While pressing the spring shown in the figure, slide the connector in the direction of the arrow.

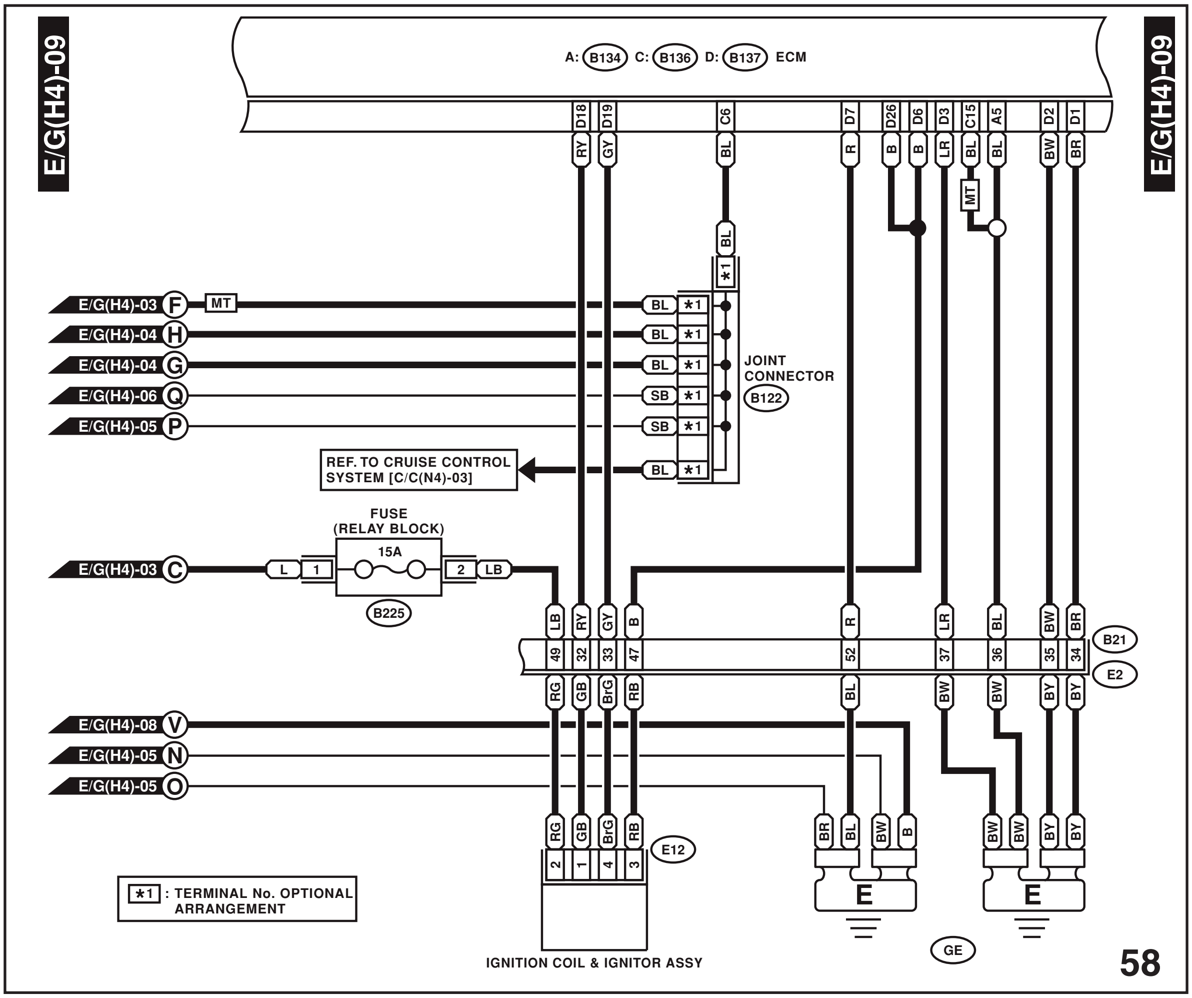


IGNITION COIL CONNECTOR DISCONNECTED

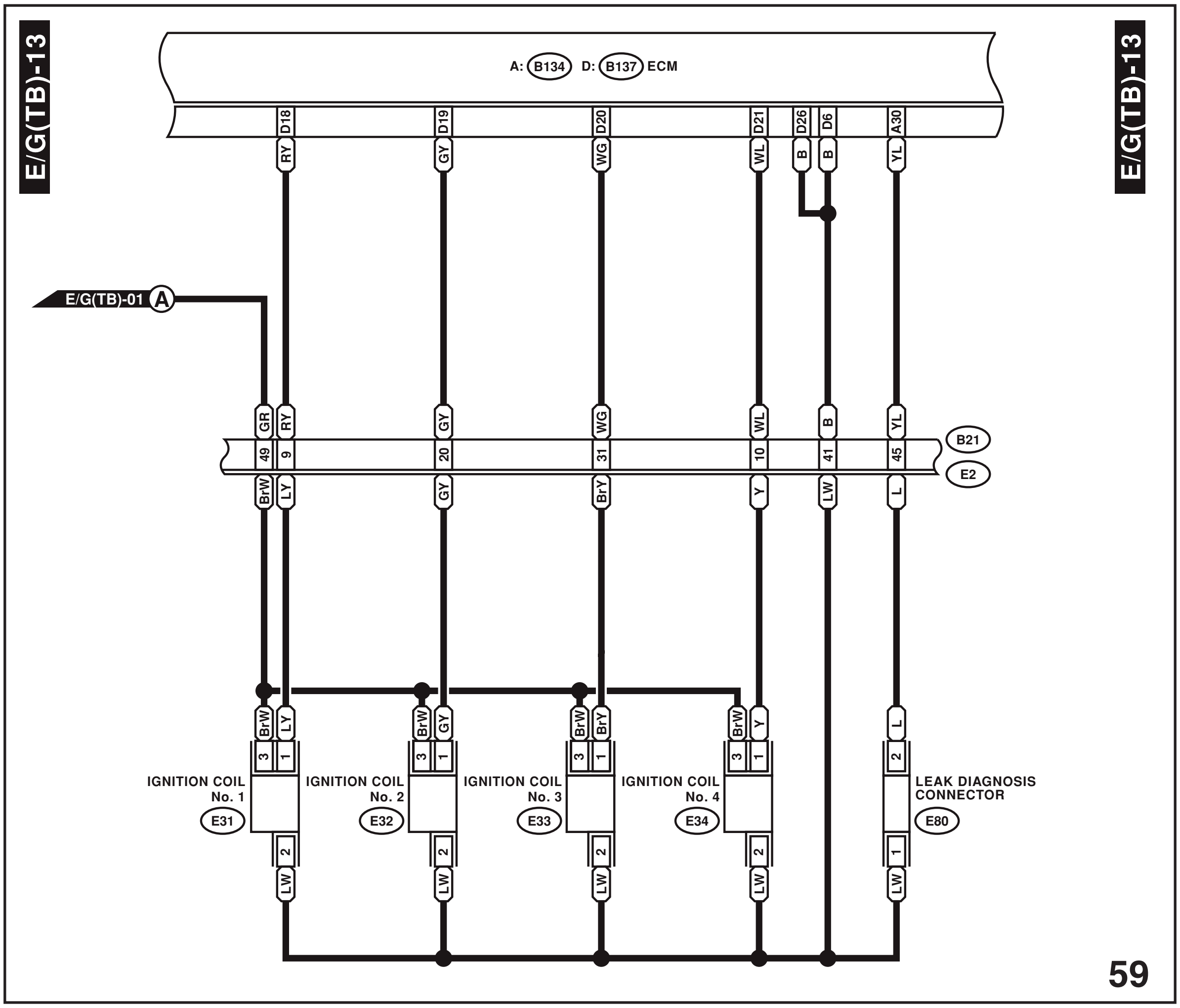


SPRING-LOCK OUTWARD

Pressing at point "a" pushes the locking tab of the spring-lock outward and unlocks the connector. Do not remove the spring-lock from the connector.

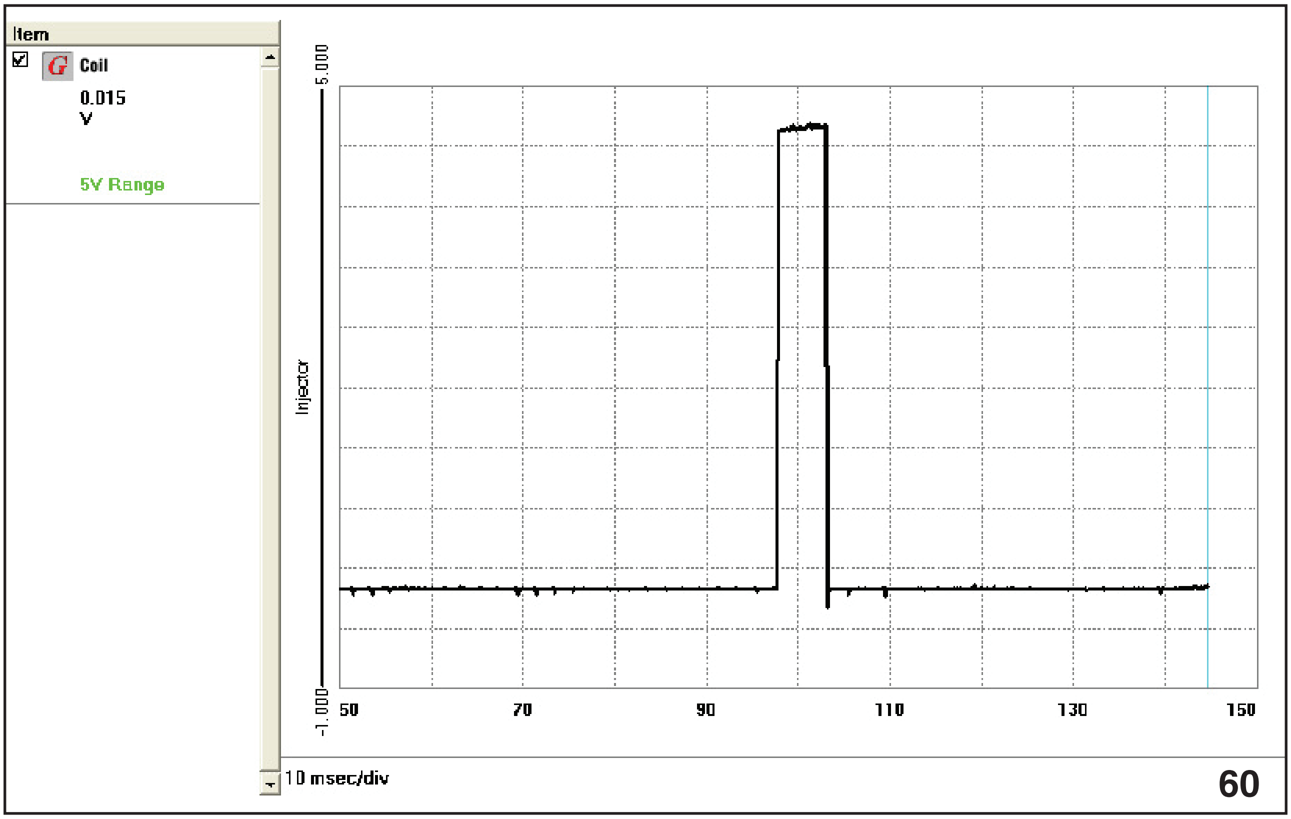


WIRING SCHEMATIC (WASTE SPARK)



IGNITION WIRING SCHEMATIC (COIL OVER PLUG)

A signal from the ECM is sent to the igniter. Waste spark systems have two wires from the ECM carrying the controlling signals to the igniter and the coil over plug systems have 4 or 6.



ECM TO COIL SIGNAL

Note: **A 12-volt (5-volt after mid 2008) square wave signal is sent to the coil from the ECM to control the igniter.**

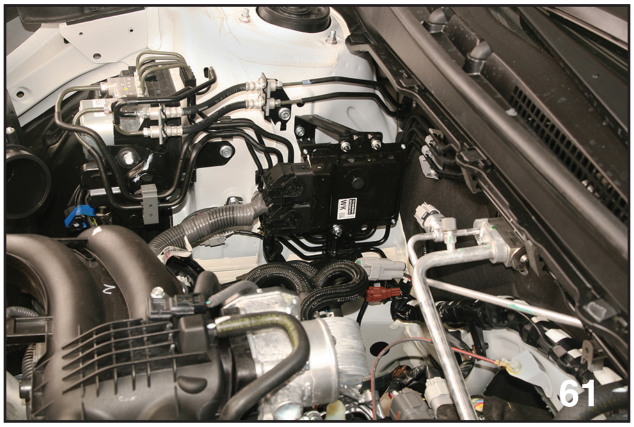
The signal from the ECM to the igniter is a 12 volt square wave. The exact shape and length of the signal is altered by the ECM. This will tell the igniter how much current the primary winding of the coil should receive and when to collapse the primary circuit. This of course charges the secondary windings of the coil and fires the spark plug(s).

The waste spark ignition system works by taking advantage of the engine design by using one coil (two are required for the 4 cylinder engine) to fire the spark plugs of the two companion cylinders. One cylinder will be on compression and the other will be on the exhaust stroke. Firing the cylinder on compression stroke creates power and firing the cylinder on exhaust stroke helps to burn any unburned hydrocarbons left over from combustion.

Note: **Waste spark has been eliminated on 2010 models and replaced with a coil over plug type ignition system.**

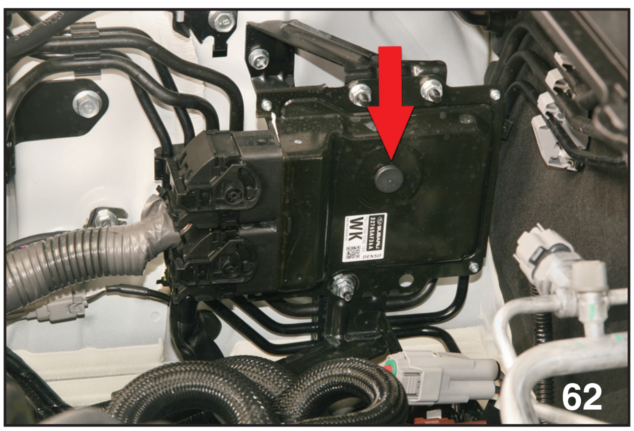
Service & Diagnostics

For FB 2.5 and EZ 3.6 models the Engine Control Module is located in the engine compartment along the passenger side inner body panel.



ECM LOCATION

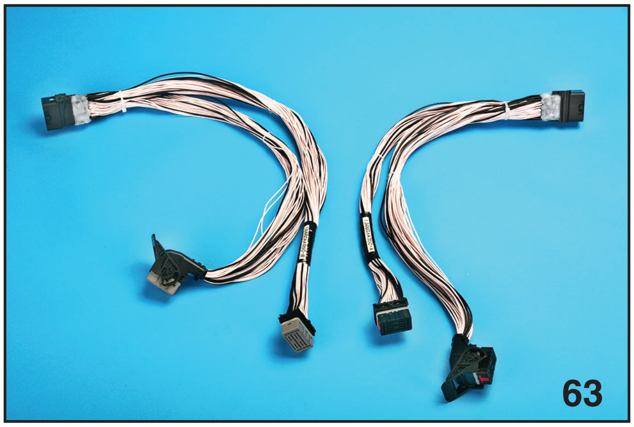
The small black rubber button, indicated by the arrow, allows the ECM to sample atmospheric pressure. Never Press this button as this may damage the waterproofing characteristics of the vent.



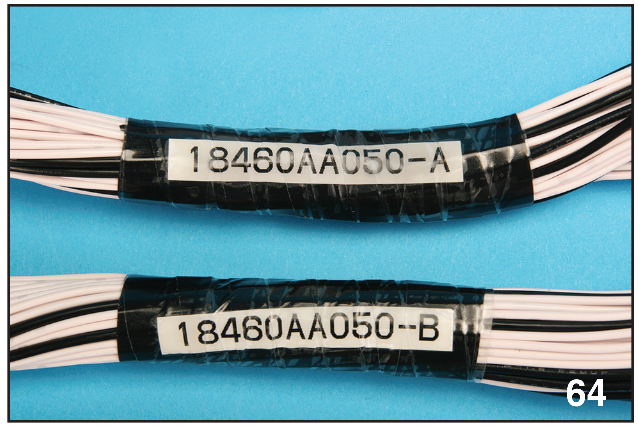
ECM ATMOSPHERIC VENT

SST Check Boards

Engine diagnostics are now performed using new SSTs 18460AA050-A and 18460AA050-B.

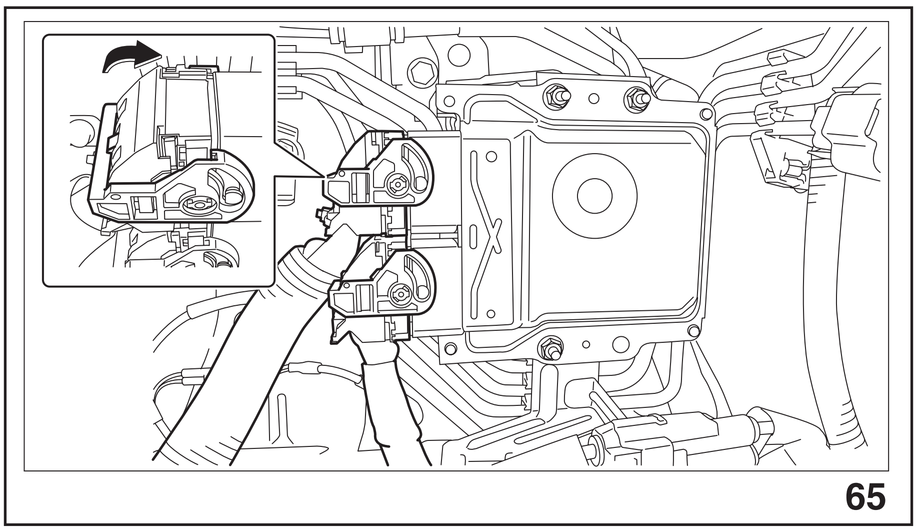


CHECK BOARD HARNESS

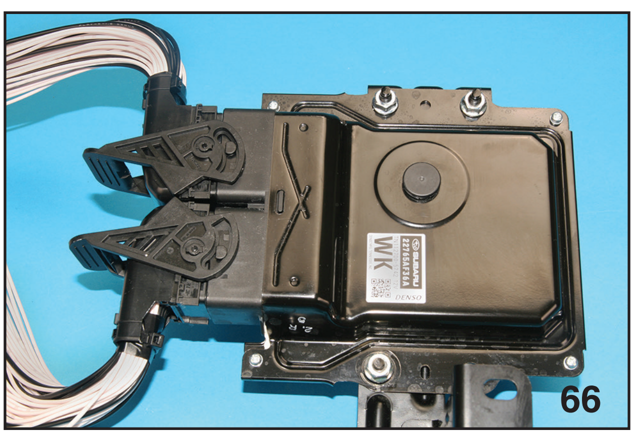


SST IDENTIFICATION

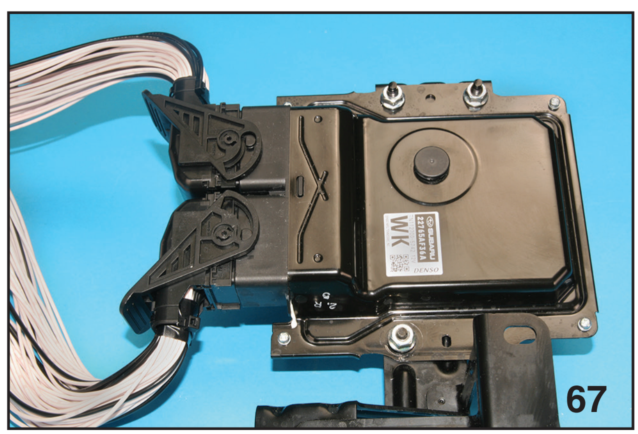
Ensure the hinge locks are fully seated before beginning diagnostics.



CHECK BOARD HARNESS INSTALLATION

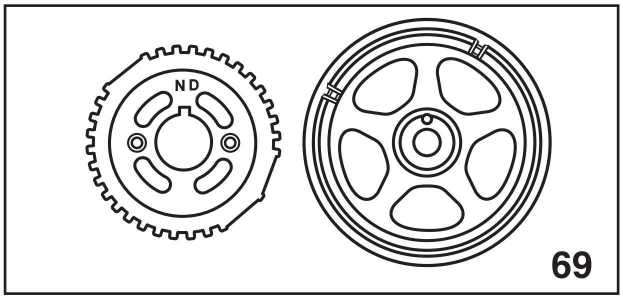


CHECK BOARD HARNESS UNLOCKED

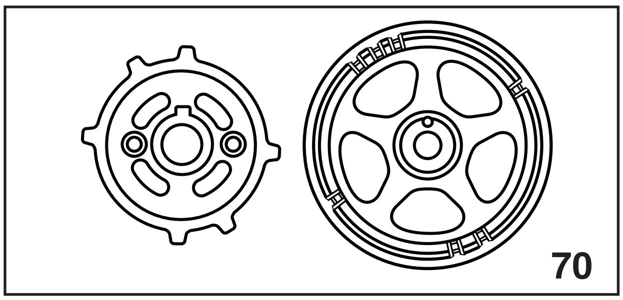


CHECK BOARD HARNESS LOCKED

Crankshaft and Camshaft Sensors

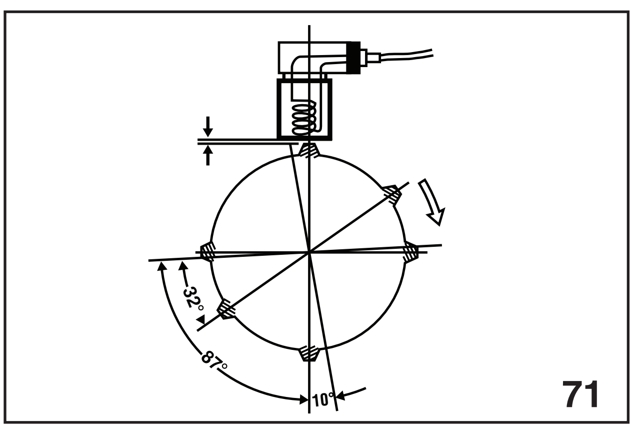


CRANK AND CAM 1



CRANK AND CAM 2

Controlling the ignition and the fuel injection system requires the ECM to know the crankshaft and Camshaft positions. This will ensure that a spark or an injection of fuel is delivered to the correct cylinder at the correct time.

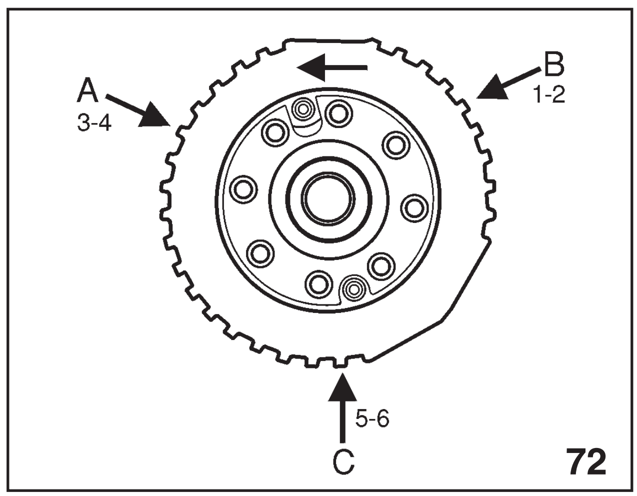


CRANK ANGLE SENSOR RELUCTOR CONSTRUCTION

Throughout the years the shapes and designs of the sensors and the reluctors used to sense the crank and Camshafts positions have changed in appearance and location.

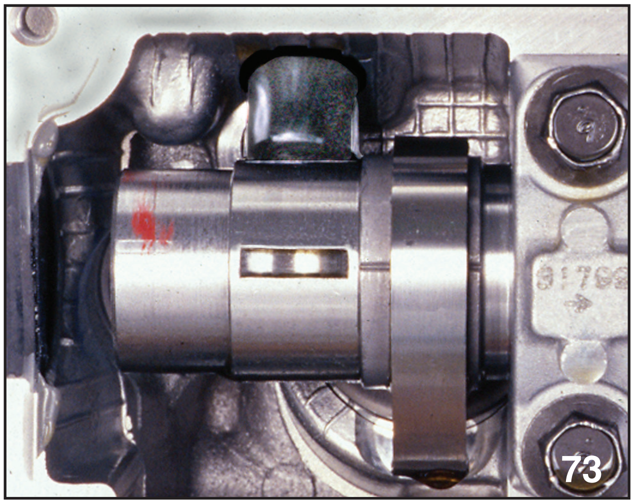
For the crankshaft, an induction type sensor has always been used. As the reluctor on the end of the crankshaft rotates, its teeth alters a small magnetic field in the sensor. The result is an A/C sine wave that takes on the shape of the reluctor teeth.

This signal must reach the ECM without any change. Any interference, short to ground, or malformality to the signal will incorrectly inform the ECM of the crankshafts position. Chipped reluctor teeth, worn crankshaft bearings or improper air gap between the reluctor and the sensor can all cause an incorrect signal to be generated.

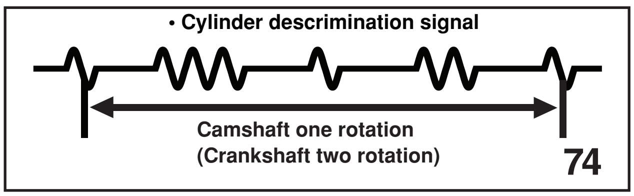


CRANKSHAFT RELUCTOR

4 Cylinder models will always have the crankshaft sensor located at the front side of the engine. 6 cylinder models in the past used the same location but this was changed with the introduction of the 3.0 liter engine. This newer engine design has the crankshaft sensor and the reluctor on the rear of the crankshaft.



HALL EFFECT CAMSHAFT SENSOR



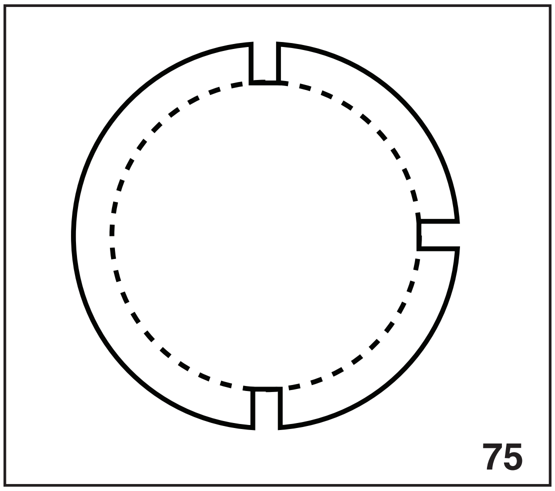
INDUCTIVE CAMSHAFT SENSOR SIGNAL

Camshaft sensors and reluctors have been both inductive and Hall effect type. The inductive sensor functions the same as the crankshaft sensor. The Hall effect sensor needs a power source to function. Inductive type generates it's own power. As the reluctor of the Camshaft rotates under the sensor a magnetic field is altered and the integrated circuit inside the sensor outputs a square wave that is sent to the ECM. An engine with Dual Active Valve Control System is equipped with 4 of these sensors.

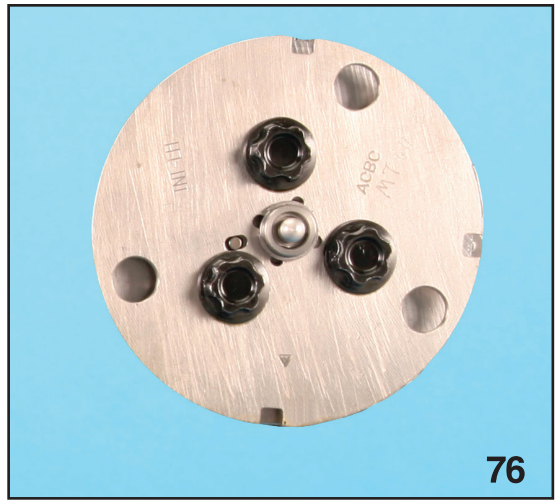
NOTES:

Previous Camshaft Sensor Design

The original FA Camshaft Sensor provided a zero volt output circumference of the sensor plate rotated just below the tip of the Camshaft Sensor.

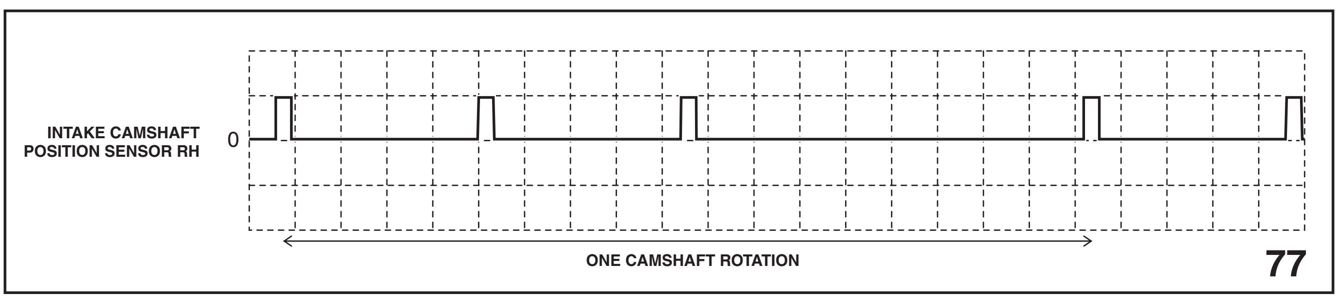


SENSOR PLATE ARTWORK



SENSOR PLATE

As the tooth of the sensor plate aligned with the Camshaft Sensor, the absence of metal triggered the Hall affect of the Camshaft Sensor resulting in a 5 volt output.

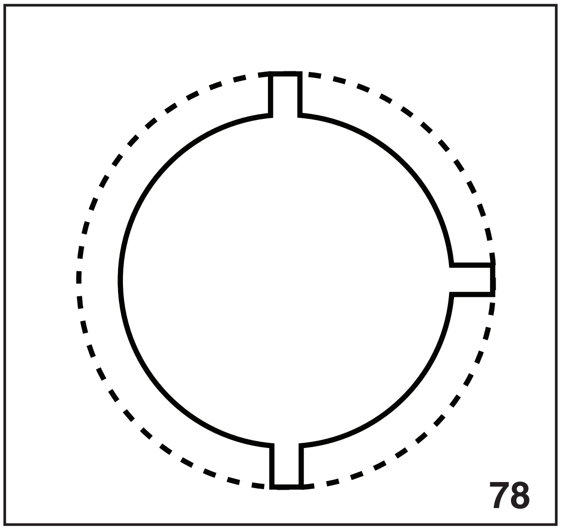


2014 FORESTER I/O

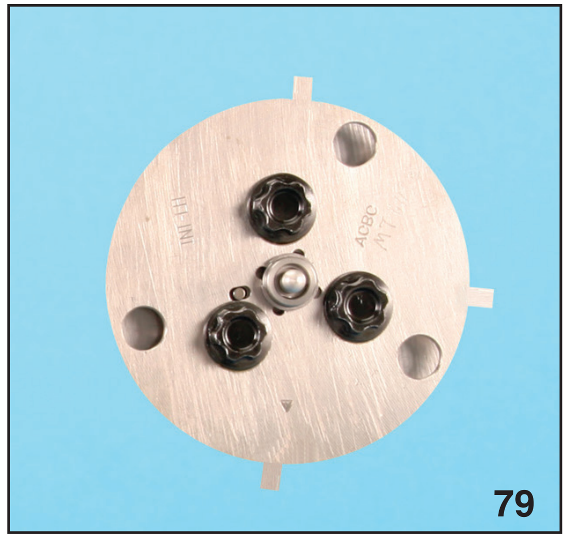
As the void of the tooth passed by the camshaft Sensor the voltage output from the camshaft Sensor returned to zero.

2015 WRX and WRX STI Camshaft Sensor Design

The new design of the camshaft sensor plate or reluctor has a smaller outer circumference so that a large air gap exists betwween the sensor plate and the tip of the Camshaft Sensor.

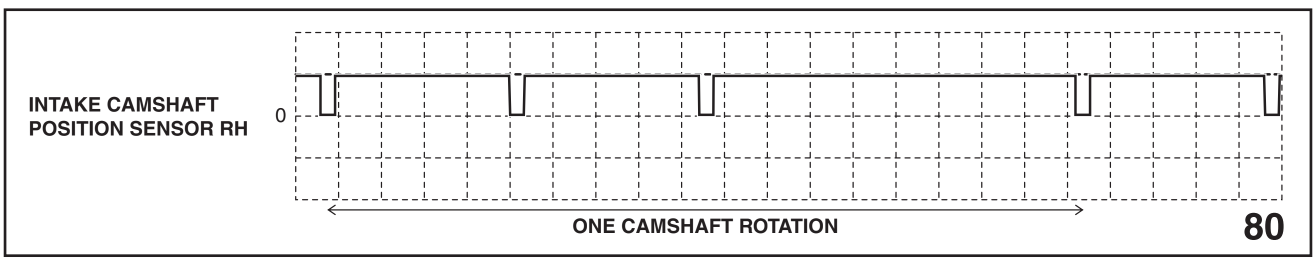


15MY SENSOR PLATE ARTWORK



15MY SENSOR PLATE

Anytime the air gap is large the output voltage of the Camshaft Sensor is 5 volts.

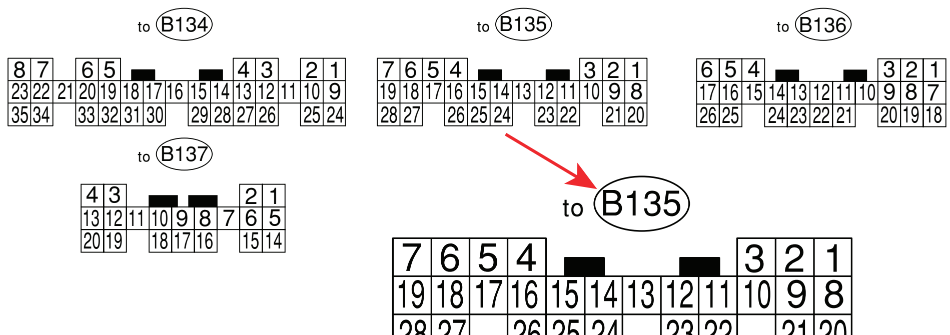


2015 WRX AND WRX STI I/O

As the taller tooth of the sensor plate aligns with the Camshaft Sensor the voltage output becomes zero.

The 5 volt value returns as the tooth rotates passed the Camshaft Sensor.

This enhancement will be phased into future FA and FB engine designs.



Inductive Camshaft position Sensor

Content		Connector No.	Terminal No.	Signal (V) Ignition SW ON (Engine OFF)	Signal (V) Engine ON (Idling)	Note
Crank-shaft position sensor	Signal (+)	B135	7	0	-7—+7	Sensor output waveform
	Signal (-)	B135	17	0	0	—
	Shield	B135	28	0	0	—
Camshaft position sensor	Signal (+)	B135	6	0	-7—+7	Sensor output waveform
	Signal (-)	B135	18	0	0	—
	Shield	B135	20	0	0	—

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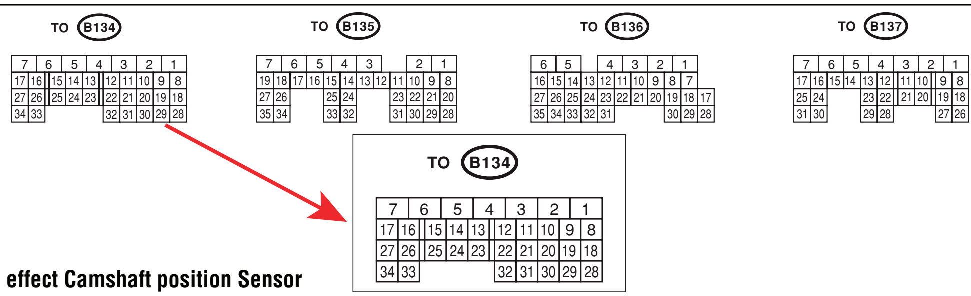
INDUCTIVE CAMSHAFT POSITION SENSOR



Hall effect Camshaft position Sensor

Contents		Connector No.	Terminal No.	Signal (V) Ignition SW ON (engine OFF)	Signal (V) Engine On (idling)	Note
Crankshaft position sensor	Signal (+)	B134	13	0	-7—+7	Waveform
	Signal (+)	B134	14	0	0	—
	Signal (+)	B134	24	0	0	—
Intake camshaft position sensor (LH)		B134	21	0 or 5	0 or 5	Waveform
Intake camshaft position sensor (RH)		B134	11	0 or 5	0 or 5	Waveform
Intake camshaft position sensor ground		B134	22	0	0	—

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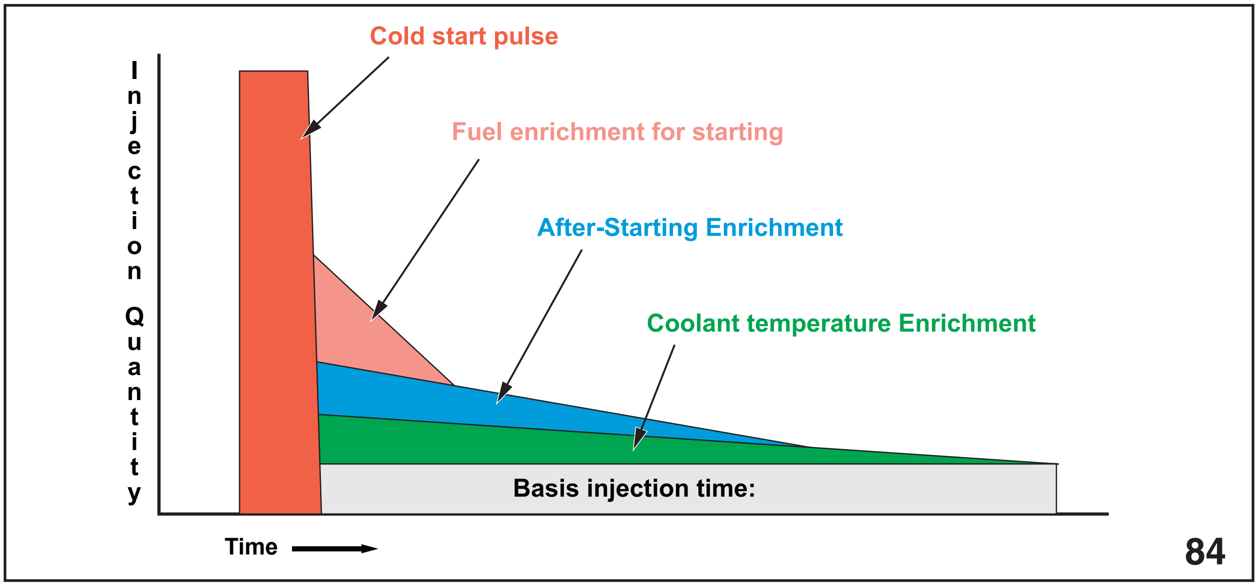
HALL EFFECT CAMSHAFT POSITION SENSOR

NOTES:

Injection Logic



INJECTION LOGIC GRAPH

Starting Enrichment Mode

When starting the engine, the injection quantity is increased to ensure an adequate quantity of vaporized fuel. This is due to the fuel vaporization rate being low (when the engine is cold and the air flow speed is low).

Cold Start Pulse

The cold start pulse determines the injection time from the coolant temperature sensor.
The following controls are performed to prevent the spark plugs from fouling and causing poor starting.

Note: In case of long cranking, the injection quantity is gradually decreased.

Note: The cold start pulse is decreased when depressing the throttle pedal.

Fuel Enrichment for Starting

During the starting of the engine the fuel is injected behind the intake valve which is cold. Due to the low temperature of the intake valve the fuel entering the cylinder is not easily vaporized. To compensate for this and to ensure that an adequate amount of vaporized fuel is in the cylinder, additional fuel is injected.

After Engine Start Enrichment

After starting the engine the air and fuel vapors will begin to move around in the intake manifold due to the inertia of the air. As this occurs with a cold intake manifold the fuel will cling to the intake manifold and create a lean condition at the cylinders. To compensate for this additional fuel is injected.

The injection quantity is increased immediately after the engine starts, and for a set period of time which is determined according to the coolant temperature.

Coolant Temperature Enrichment

The quantity of increment is set according to the engine coolant temperature while the engine is warming up and until it is warmed up.

Acceleration Enrichment Control

During high load and wide open throttle operation, maximum engine power can be obtained before full throttle.

- The ECM monitors the Mass Air Flow reading and injects additional fuel.
- The full throttle enrichment is applied when the throttle valve opening exceeds a predetermined angle.
- The amount of fuel must be increased to compensate for power and to maintain the A/F ratio.

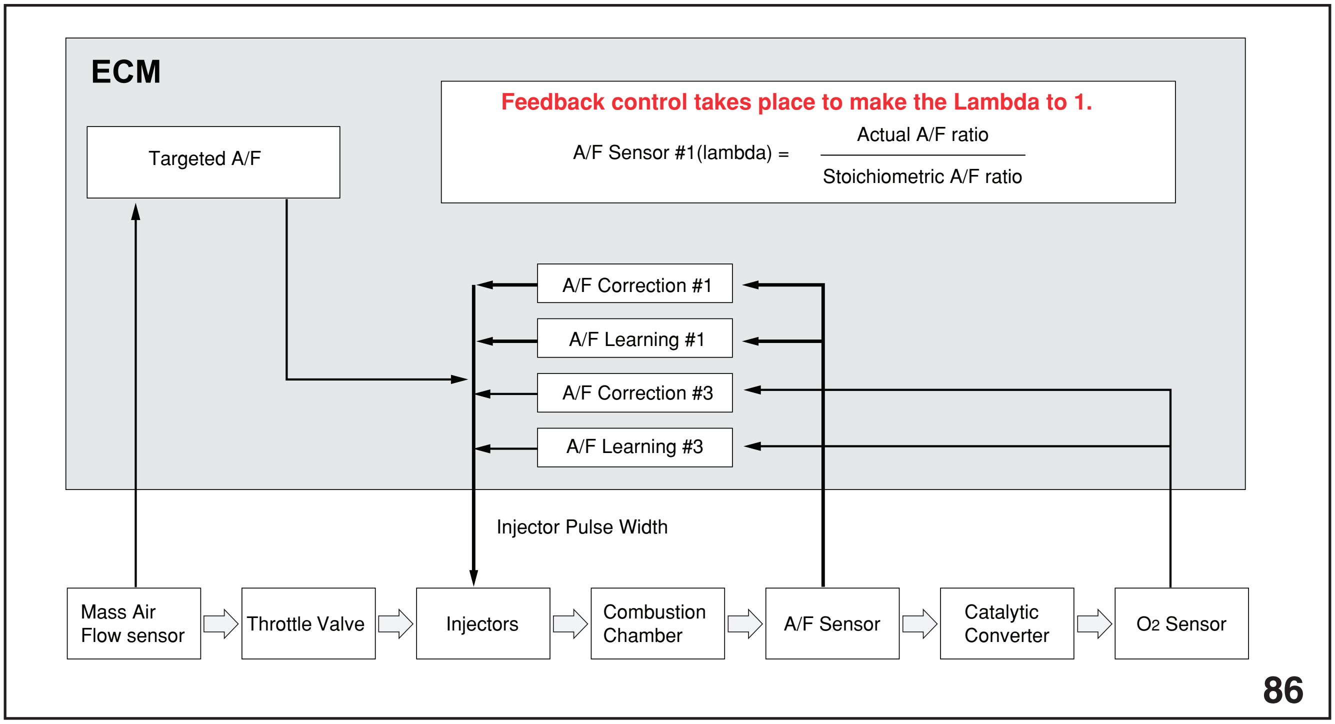
Fuel Cut Control

This control cuts off fuel to the engine when it is decelerating or under conditions such as high engine speeds. The injection pulse will be set to 0.

The ECM stops injection of fuel when the following conditions are met:

- Ignition switch is OFF.
- Engine speed is the set value (according to A/C ON, coolant temperature, and so on or higher when the throttle valve is fully closed)
- Engine speed is the set value or higher regardless of vehicle speed.
- Engine speed is the set value or higher for a set period of time while vehicle speed is zero.
- Torque control signal is input from the TCM, ABSCM or VDCCM.

Closed Loop Control



A/F SENSOR #1 VALUE (LAMBDA VALUE)

A/F Sensor #1 value (LAMBDA value)

The value of the A/F Sensor #1 (and/or #2) indicates how far the actual air/fuel ratio deviates from Stoichiometric ratio.

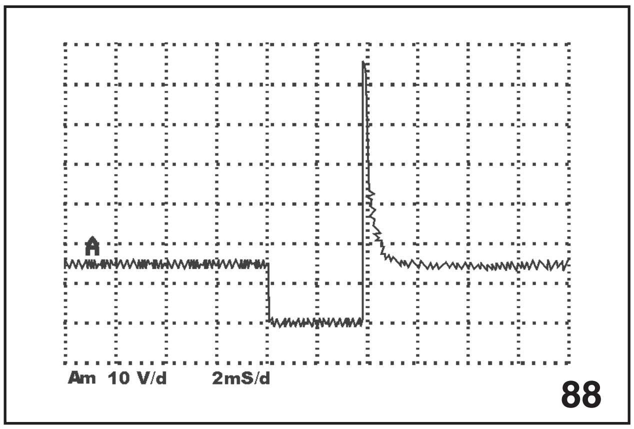
Select Monitor Injector Pulse Width Diagnosis

It is important for a technician to know what normal injector pulse width is for the particular area where the customer drives. The basic IPW comes from the MAF input and the engine operating variables listed below, and modified further based on feedback from the air/fuel and oxygen sensors.

- Engine Coolant Temperature
- Intake Air Temperature
- Engine RPM
- Throttle Position
- System Voltage

Fuel Injectors

Fuel is delivered to a cylinder by a fuel injector which is pulsed in milliseconds (ms) by the ECM. A fuel injector is an electromechanical part that can deliver precise amounts of fuel into the intake during the different operating conditions. The ECM calculates the duration (on time) for each injector based on inputs that set the base injector duration which are then modified based on the feedback from the air/fuel sensor.



INJECTOR PATTERN 2.5L 1998 FORESTER

Injectors receive battery power when the key is turned on. The ECM grounds the injector and current should flow through the injector solenoid. This creates an electromagnetic force that overcomes the injector's internal spring pressure. The injector pintle is pulled off the seat, and pressurized fuel sprays from the nozzle into the intake manifold where it mixes with air and is drawn into a cylinder. Subaru uses several different designs for injector nozzle tips to provide the most efficient fuel atomization for power and performance. Subaru uses a galley or side feed type of fuel injector that delivers fuel to the intake manifold.

Fuel injector sequence is determined by the camshaft sensor (CMP) input, and the initial injector duration is determined by the crankshaft position (CKP) sensor.

If an injector is not being activated by the ECM use the Select Monitor to verify the ECM has an RPM input from the CKP sensor.

Injector Duration

The time the injector circuit is grounded is referred to as injection duration. The pre-OBDII Select Monitor may display injection duration as "TIM" (Time of Injection Duration). OBDII Data shows the Duration as Injector Pulse Width (IPW).

Fuel injectors

2009 FORESTER ENGINE

Fuel injectors can fail in many ways. Some failures will affect a pressure drop or volume flow across the injector delivery pintle. Use an injector balance tool during a fuel pressure test to verify that all injectors are within 2.5-psi pressure drop of each other. An injector having a higher or lower pressure drop will indicate a problem. It is possible that an injector will work better after a cleaning procedure, but if the injector does not deliver the same pressure drop as the other known good injectors, it must be replaced.

Alcohol fuels can build up sediment on the tip of the injector that can break up the spray pattern. This can cause driveability problems such as hard to start (hot or cold), rough idle, misfire, surge, hesitation, and stalling. It is a good idea to clean injectors as a regular service in areas where oxygenated or reformulated fuels are required.

Fuel injector Circuit Testing

There are 3 primary basic electrical tests: resistance, voltage, and current. An injector balance test or a flow test could help identify some injector faults. A Lab Scope could provide valuable information about how the injector is operating.

Testing for Resistance

Resistance testing is a basic test; however it has the following problems:

Resistance ranges are so broad to cover so many different operating conditions that an injector can have a partial short and still be with the resistance range value.

Opens and shorts can occur, but they are not common.

Even with a hard failure, it is often difficult to access all injectors.

Many faults only show up when current is flowing, Resistance measurements are non-loaded measurement and often will not identify the problem.

Even if resistance values are within specification, the injector can still not function mechanically.

Testing for Voltage

Voltage testing helps find injector circuit faults. Voltage testing verifies open circuit voltage and ground circuit voltage drops. Although many problems can be found by testing dynamic resistance with voltage drop testing, the better way to test the circuit is with a lab scope.

Current Testing

A Low-Amps probe can be used to monitor the actual current flow through an injector or group of injectors. Monitoring current also shows information about the resistance of the injector and can show if there is extra resistance, low feed voltage, an unwanted voltage drop in the ground and other electrical faults. Some mechanical features can also be verified using the current waveform.

Injector Noid Light Testing

A Noid light is helpful to determine if there is an injector control circuit fault. This is a special injector test light that will not light if the driver is not sufficient. The Noid light is placed into the injector harness connector in place of the injector and should blink every time the ECM grounds the control circuit. If the light flashes brightly as the engine is cranked, the power, ground, and control circuits can be considered to be good. If the Noid light does not illuminate then the ECM driver, the security system, the CKP sensor, the system has lost power, or the Noid light is at fault. If the Noid light is on all the time then the injector control circuit is shorted to ground or the ECM driver is shorted and defective. If the Noid light is blinking dimly then check for low voltage, a poor ECM ground, or high resistance in the circuit.

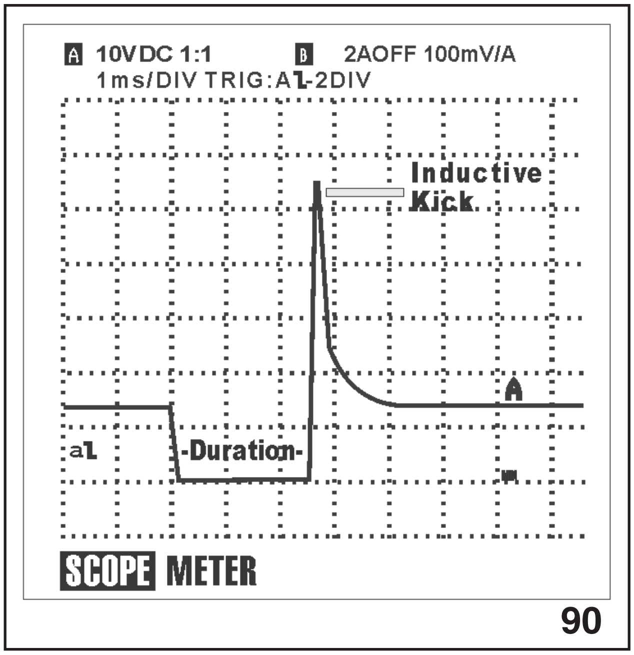
Noid Light Issues

While the Noid light can be a helpful to determine the condition of the injector control circuits and components, it can lead to misdiagnosis in some cases. Injector mechanical operation can change based on current flow. Since current flow is a function of total circuit resistance, if the Noid light does not have similar resistance as a known good injector, then the current flow will not be the same when testing with the Noid light as it would be in normal operation. It is possible that a lower resistance Noid light is not capable of providing proper current for injector operation. Also, a higher resistance Noid may be dim or not operate in a circuit that is capable of providing proper current for injector operation.

A Lab Scope is the most effective tool for verifying or condemning electrical and mechanical attributes of the fuel injectors and control circuits.

Lab Scope Testing

Voltage testing is a reliable test that is made more useful when using a Lab Scope. A scope is the most effective test to find most injector faults. Voltage testing verifies open circuit voltage, ground, field strength (via the inductive kick), and driver performance. Additionally, the actual mechanical operation of the injector can be verified through the voltage waveform.



SCOPE METER INDUCTIVE KICK

Any problems that can be found by testing resistance will also show up in a voltage drop test, but testing with a lab scope gives a picture of what is happening to the voltage over time in actual operation.

These waveform examples were obtained by back probing the control circuit of an injector at the injector harness connector. The injectors share a power source and are ground-controlled, so the control circuit will show battery voltage being pulled low to cause injector operation. Each injector will have 1 wire colored the same for all injectors, and one wire that is uniquely colored (except for older bank or group-fired injectors). The control circuit is always the common colored wire.

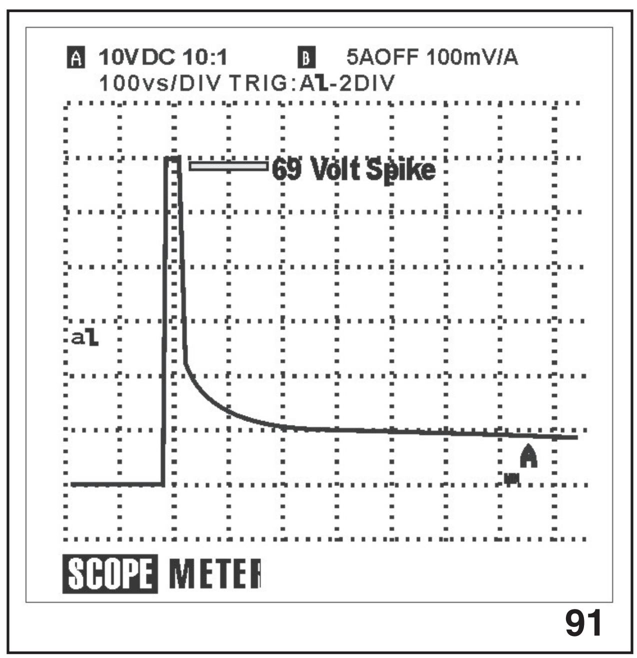
Lab Scope Injector Diagnosis

This waveform shows a typical injector lab scope pattern. The power to the injector is pulled to ground by the ECM. This creates the electromagnetic field that opens the injector pintle.

The time the injector voltage is pulled to ground is called injector duration or ('on-time'). The lab scope shows the voltage is pulled to ground as represented by the time the signal is low (2.6 ms at hot idle in the example). The amount of fuel released during injection is proportional to the amount of time the injector is open.

Inductive Kick

When the ECM removes the ground from the injector control circuit the electromagnetic coil field collapses. The collapsing field crosses the coil windings and induces a voltage. This higher voltage is called an inductive kick or voltage spike. The presence of the proper voltage spike verifies that the coil electromagnetic field was built and collapsed. It can be assumed that the coil resistance is correct and that the windings are not shorted if the value is in a normal range. The presence of an inductive spike does not verify that the injector is mechanically functional.



SCOPE METER 69 VOLT SPIKE

Select Monitor Fuel System Troubleshooting

Scan Tool Data: Fuel Pump Command

One of the data PIDs on the Engine Control Data Stream informs the technician about the ECM command to the fuel pump. The Fuel Pump data does not tell the technician if the fuel pump is operating. It indicates what the ECM has intended to do. In a no start condition, the PID for the fuel pump can indicate whether or not the ECM is commanding the fuel pump to come on. If there is a no start and the fuel pump is not commanded on then the ECM data must be check to determine if all of the enable conditions are met for operating the fuel pump. The technician must check to verify there is a CKP (engine speed, RPM) signal and must verify that the BIU is not showing any security codes. If there is a problem with the security system or with the immobilizer system they must be repaired first.

Scan Tool Data: Injector Pulse Width (IPW)

The Injector PID values will be displayed in milliseconds (ms). The normal injector duration at a Hot Idle is about 2-4 ms.

The Service Manual may list some values for the Injector Pulse Width, however, the individual climate, geography, and driving patterns of the customer and the technician can greatly affect the value seen during a test drive. Each technician must develop a driving test cycle and memorize the normal PID values for that terrain and traffic conditions. IPW values can fall over such a wide range based on how aggressive the acceleration and how difficult the geography. If a technician does not know what “normal” is for his area then some out of range IPW commands can not be identified. IPW therefore, is an important PID to watch, but would not be used by itself to identify a fuel control correct or incorrect condition. However, it is useful data to help find fuel control related problems.

An IPW value of 0.0 ms would indicate that the ECM was commanding the injector to shut off. This would be a normal condition during deceleration, but if the throttle was steady, then it could indicate that the CKP (engine RPM) sensor could have an intermittent signal drop out. The ECM has a “clear flood” mode if the IPW were to go to zero and the CKP was not dropping the signal, then look for a throttle position sensor intermittently dropping out. A sudden drop in the TPS voltage would be interpreted by the ECM as a decel condition and would result in a momentary command to shut off fuel.

If the IPW is higher than normal this would indicate a command to increase fuel into the cylinder. Look for anything that would tell the ECM to give a rich mixture. High resistance in the Engine Coolant Temperature (ECT) sensor or circuit would indicate the engine was colder than it is. The ECM would command too much fuel and dying, stalling, and/or poor gas mileage could result. Fuel Correction (Fuel Trim) should also show the command. For example, if the IPW appeared to be normal, but the Fuel Correction was at the -20% value, there would be a fuel control problem present

Select Monitor Compulsory Tests

The Select Monitor has a compulsory mode test that allows the technician to control the fuel pump indirectly by forcing the ECM to complete the fuel pump relay control circuit to test the fuel pump circuit.

The compulsory mode test data shows the command to the fuel pump. The ON value does not confirm that the fuel pump worked. The technician must listen for the fuel pump and have a fuel pump pressure gauge connected up to confirm that the fuel pump energized and that the fuel pump can actually deliver the correct fuel pressure. If the pump does not appear to be working, then the technician must confirm that the pump is receiving power and has a good ground.

The compulsory mode test indicates that the ECM is commanding the fuel pump to energize. The technician can now test the circuit to determine where the fault is if the circuit is not working.

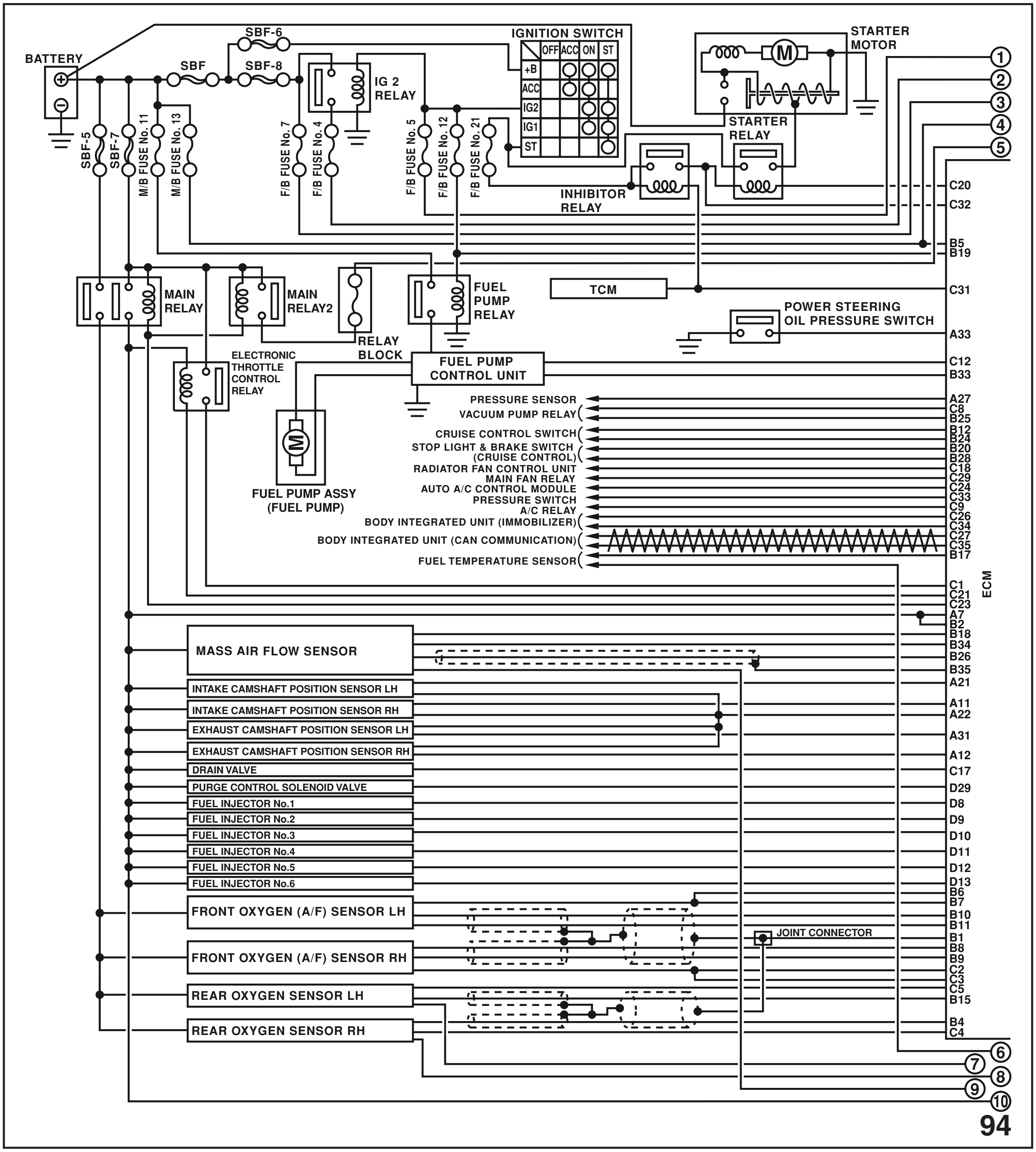
There are a number of reasons that this is a very useful test:

> If you suspect that the proper fuel pump relay enabling conditions are not present, you can at least verify that the ECM is capable of controlling the relay. If the pump works only during the test (besides the key-on fuel pump prime command), look for a missing enabling condition (i.e. and ignition switch, security system, or rpm (CKP) fault).

The most important use of the Fuel Pump compulsory Mode Test is during the testing for fuel pump pressure or volume.

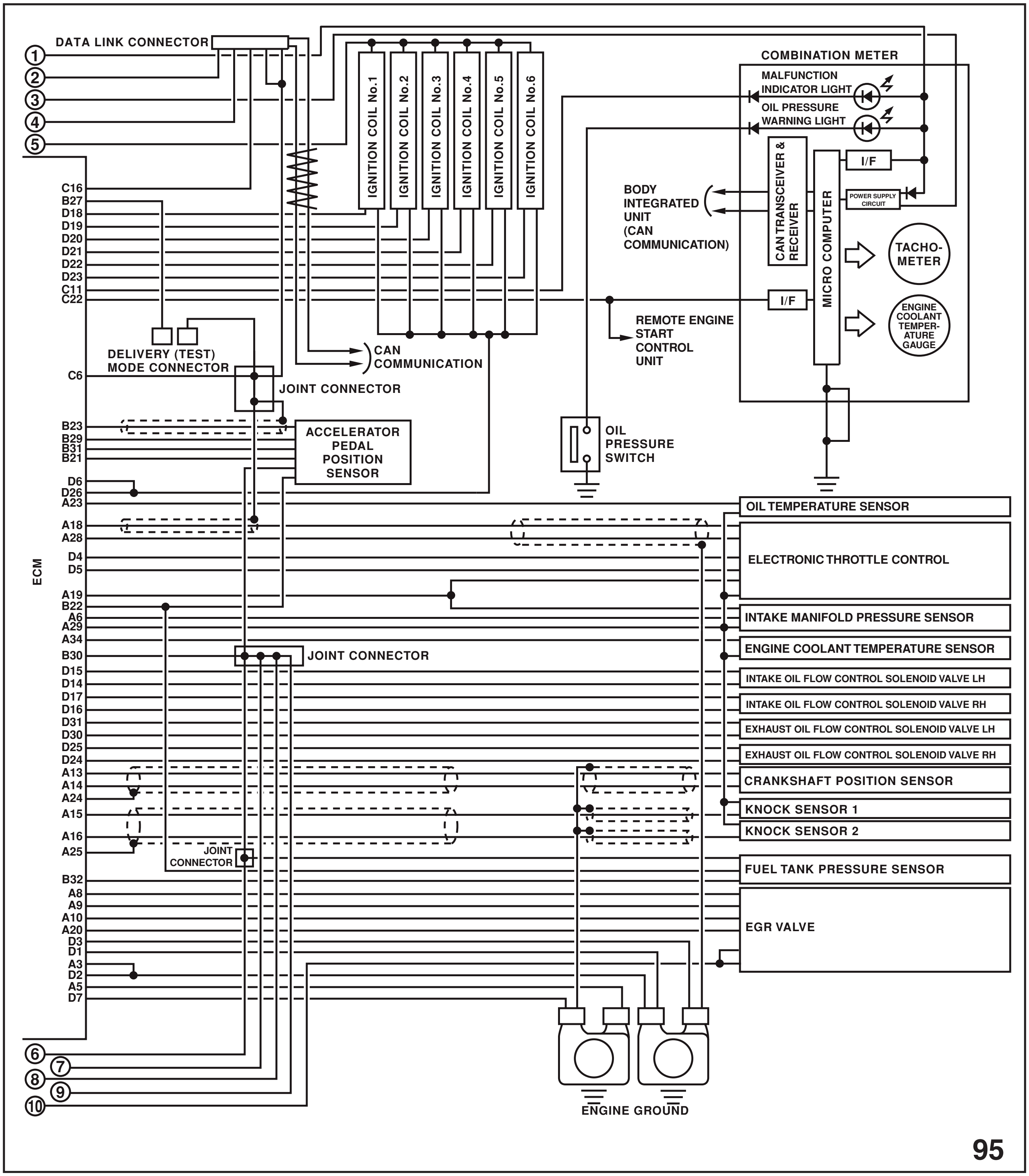
NOTES:

Power and Ground Supply



FUEL INJECTION POWER AND GROUND SUPPLY SCHEMATIC-1

Accurate and predictable control of the fuel injection system is dependant on a proper power and ground supply. These two items must be checked for the correct voltages and voltage drops before condemning any component or electrical circuit.

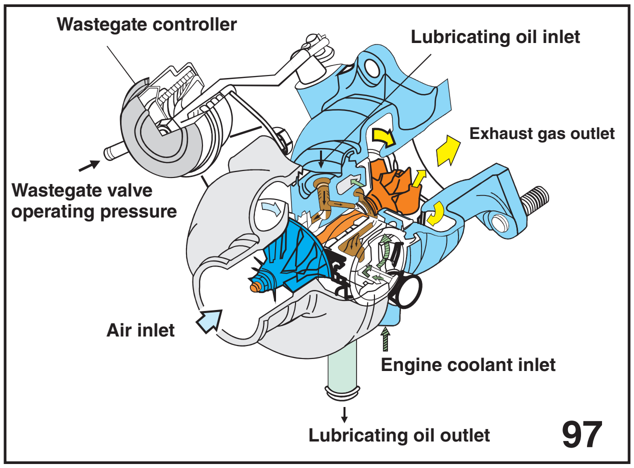


FUEL INJECTION AND GROUND SUPPLY SCHEMATIC-2

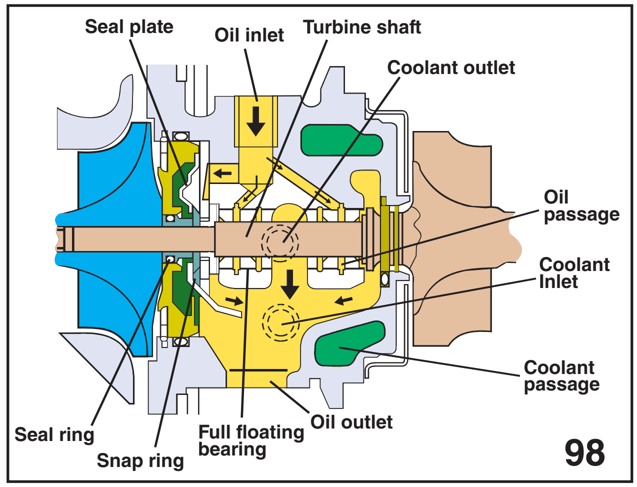
Several relays and grounding circuits are utilized to operate and control the various parts and circuits. Poor power supply and grounds will create driveability, CAN Communication or no engine start conditions.

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.

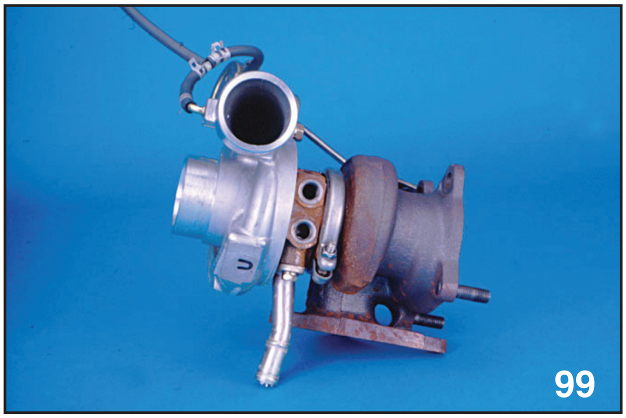


TURBOCHARGER (ARTWORK)

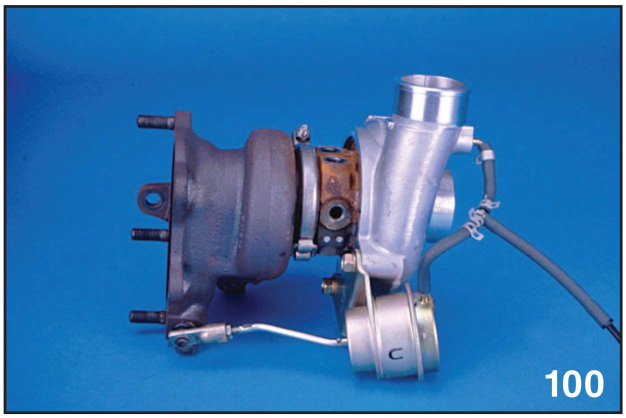


TURBOCHARGER HOUSING (ARTWORK)

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.

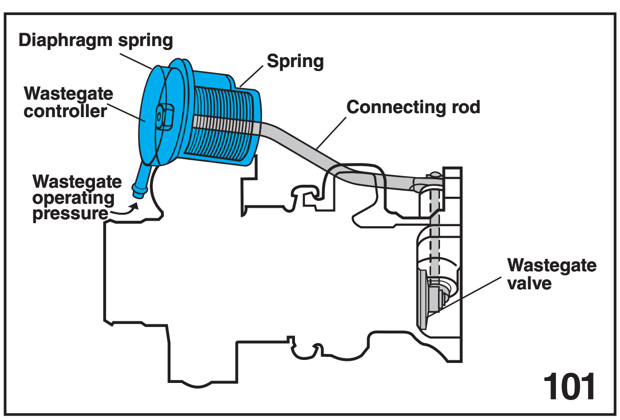


COOLANT CONNECTION AND OIL RETURN

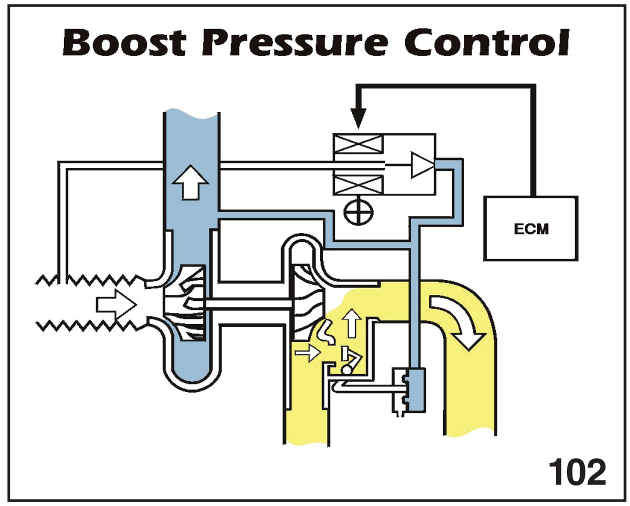


OIL SUPPLY AND CONNECTION

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.

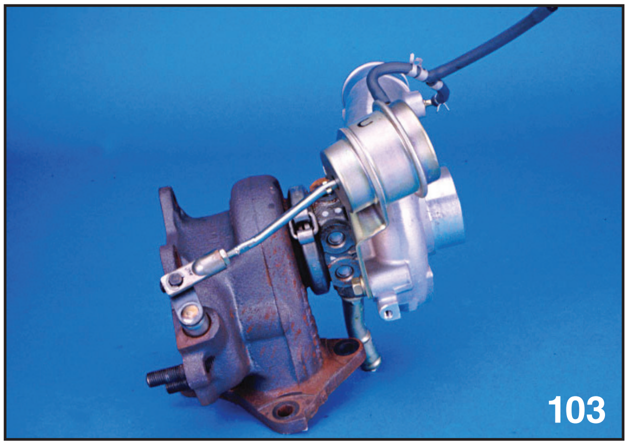


WASTEGATE (ARTWORK)

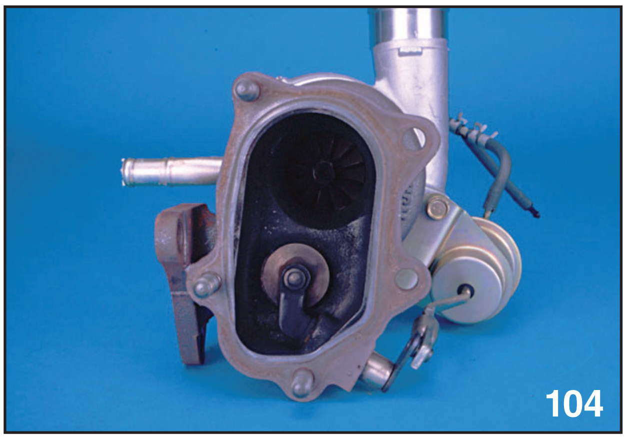


WASTEGATE OPERATION (ARTWORK)

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.

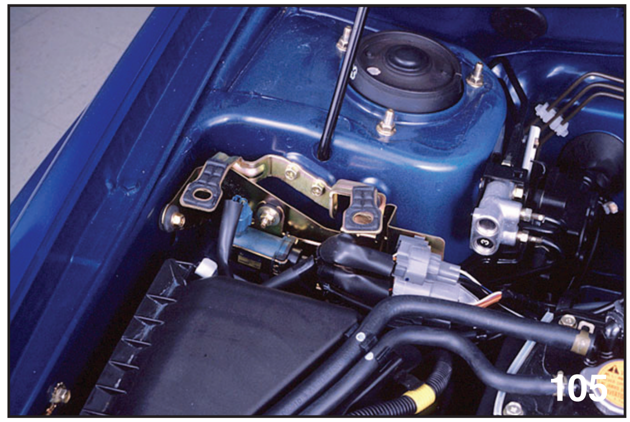


WASTEGATE ACTUATOR



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

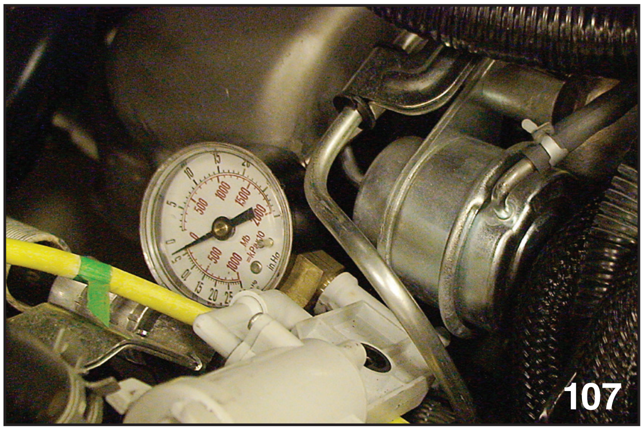
The Wastegate Controller (in response to the Duty Solenoid) opens the wastegate flap valve to bypass exhaust gas and so decrease the rotating energy of the turbine keeping the boost pressure to the desired level.

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



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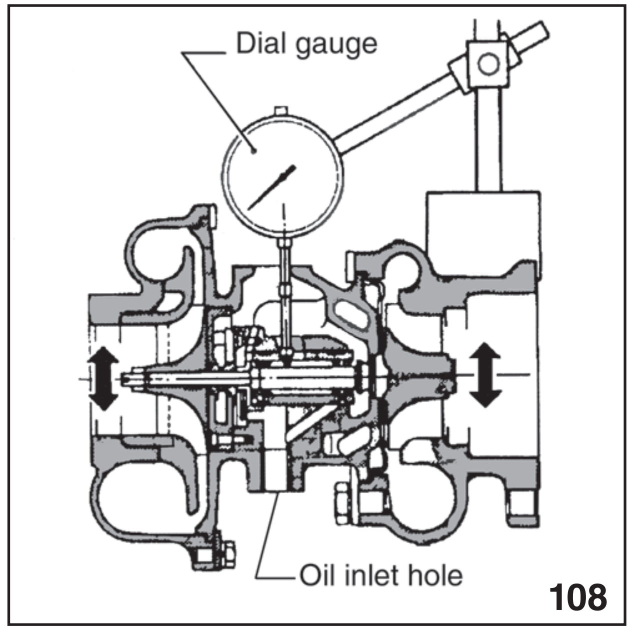
PRESSURE PUMP/GAUGE CONNECTION

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

The actuator should begin to open at approx. 50.0 - 60.0 kPa. (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.



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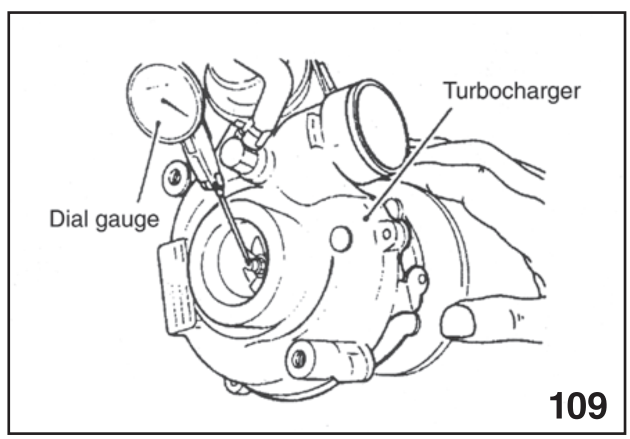
RADIAL MOVEMENT CHECK

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)



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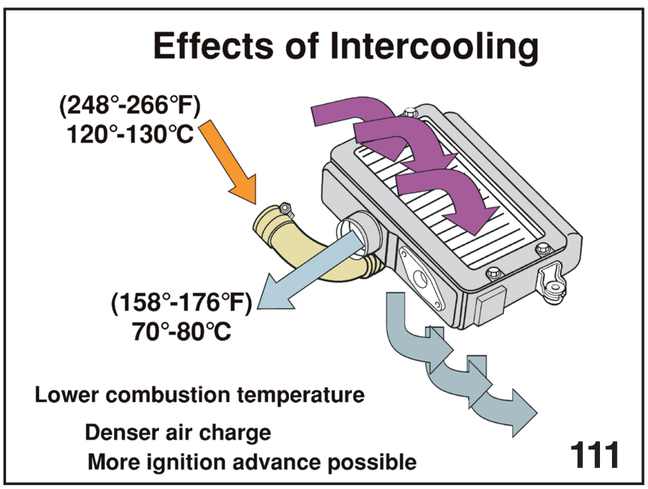
AXIAL MOVEMENT CHECK

Intercooler

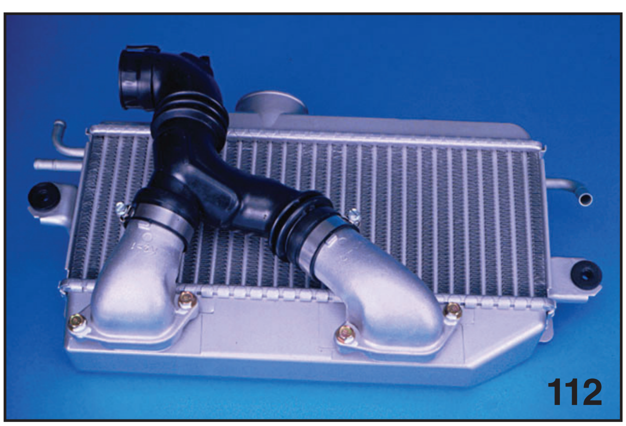
The Turbocharger compresses the intake air by using wasted exhaust gas energy. The Turbocharger turbine is driven by exhaust gas, causing the compressor wheel to rotate. By compressing the intake air, the volumetric efficiency of the engine is greatly improved.

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.

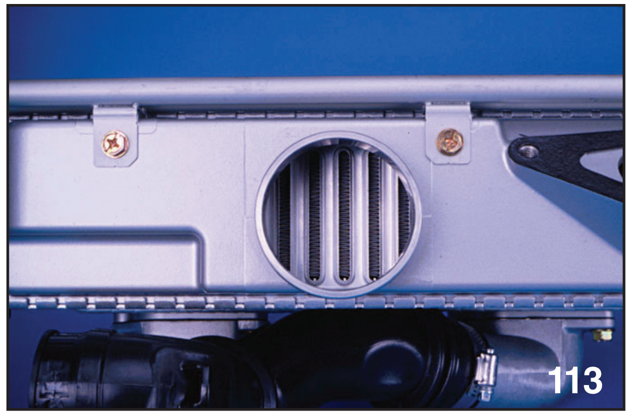
An Air Bypass Valve redirects high pressures from the intercooler back to the inlet side of the Turbocharger under deceleration.



EFFECTS OF INTERCOOLING (ARTWORK)



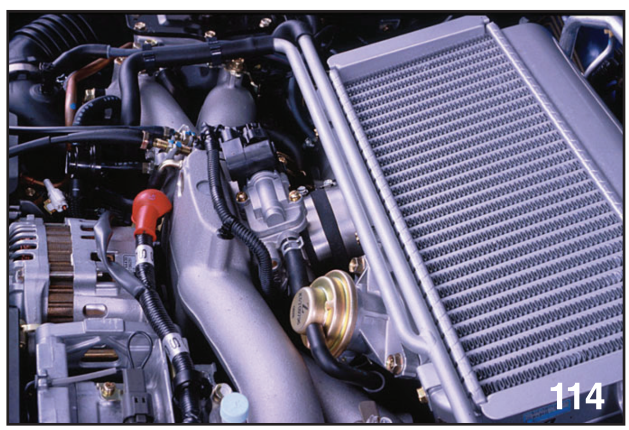
INTERCOOLER (BOTTOM VIEW)



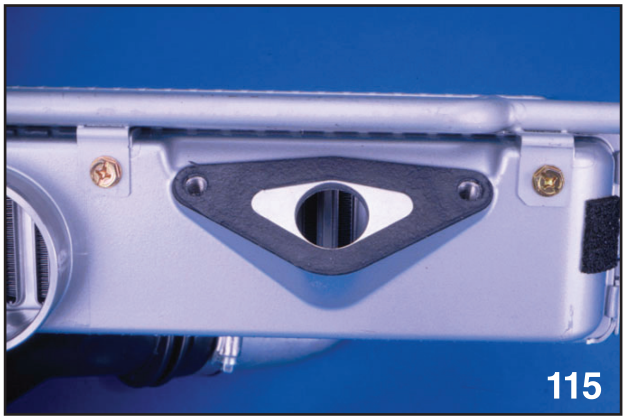
INLET TO THROTTLE BODY

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: 1; a reduction in combustion chamber temperature allowing for more advanced ignition timing, and 2; 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.

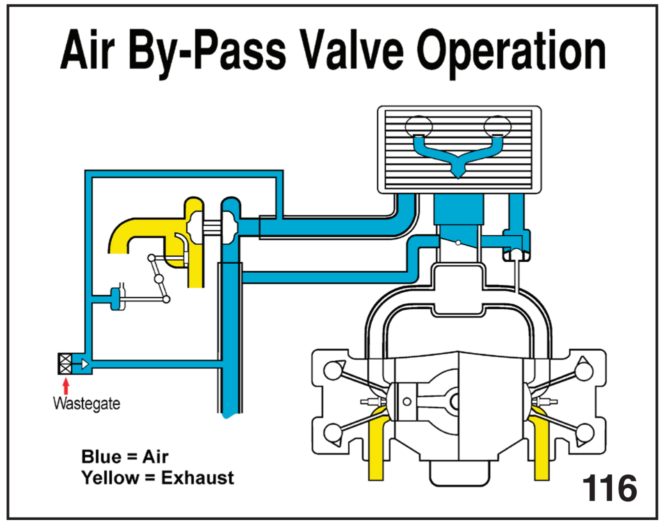


INTERCOOLER LOCATION

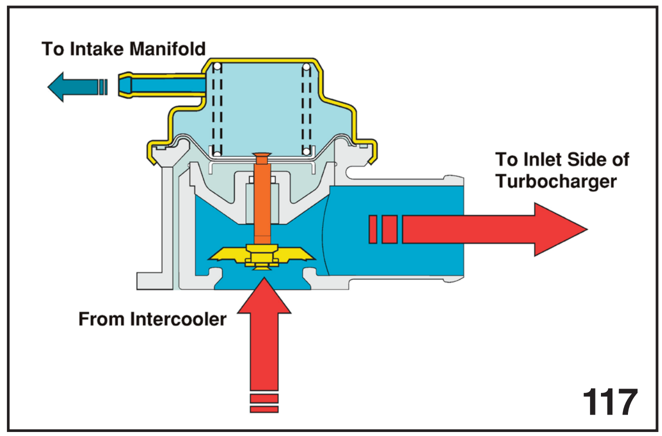


BYPASS VALVE CONNECTION

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.



AIR BYPASS VALVE OPERATION (ARTWORK)



BYPASS VALVE (ARTWORK)

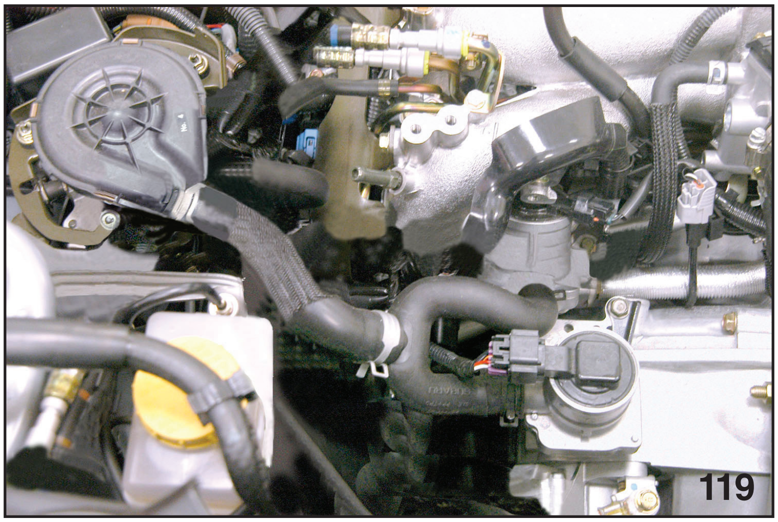
The upper chamber of the bypass valve is connected to the intake manifold, and the negative pressure (vacuum) during deceleration opens the valve by acting on the diaphragm.

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.

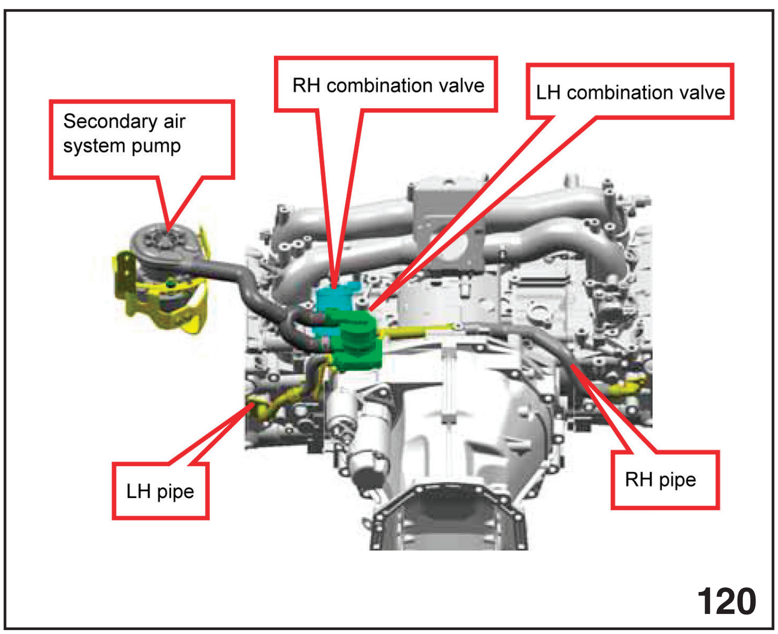
Secondary Air Injection System

2.5L Turbo Engines

Turbo engines INCLUDING the STi are equipped with a secondary air injection system.



SECONDARY AIR INJECTION SYSTEM



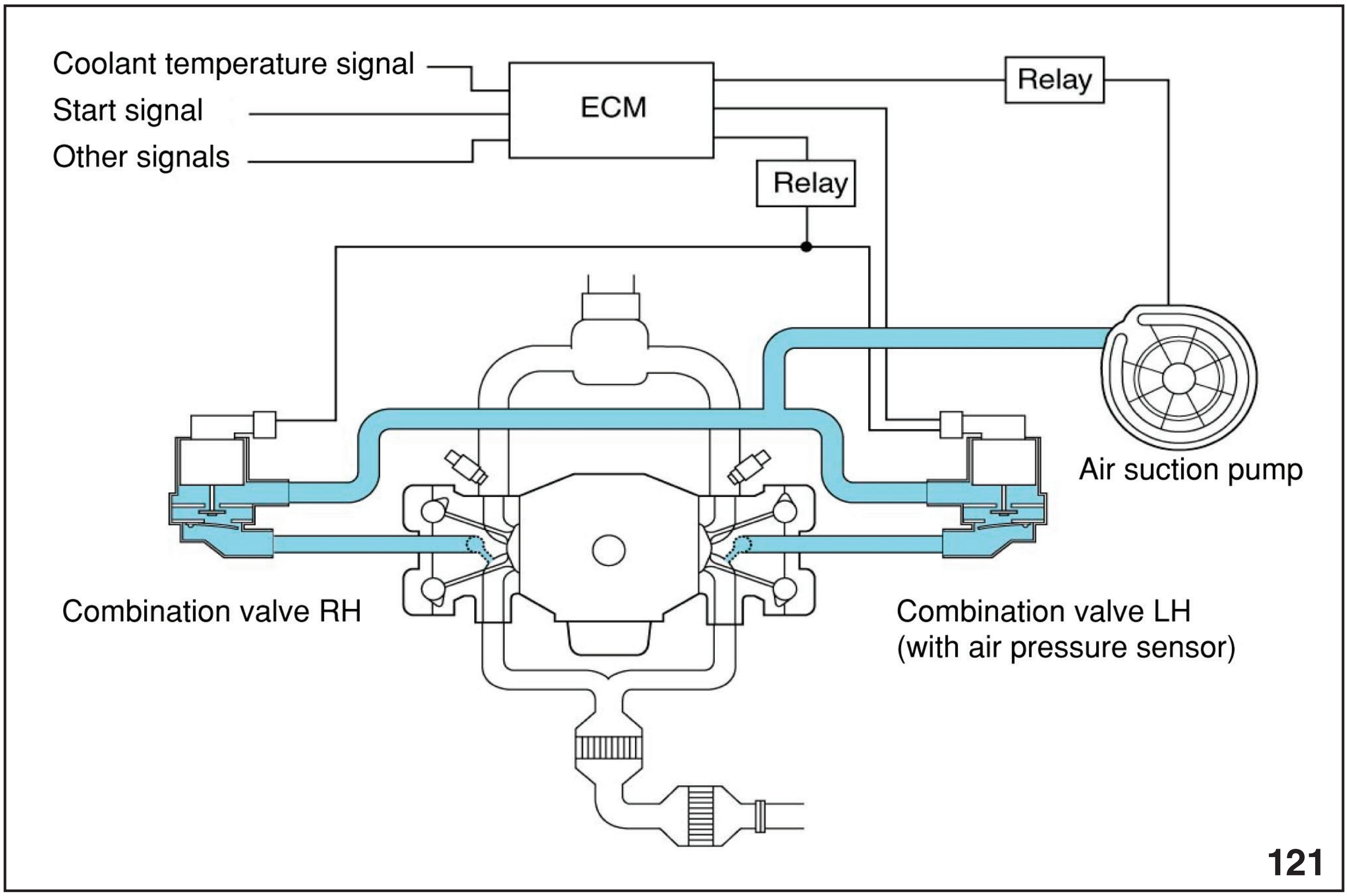
SECONDARY AIR INJECTION ARTWORK

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.

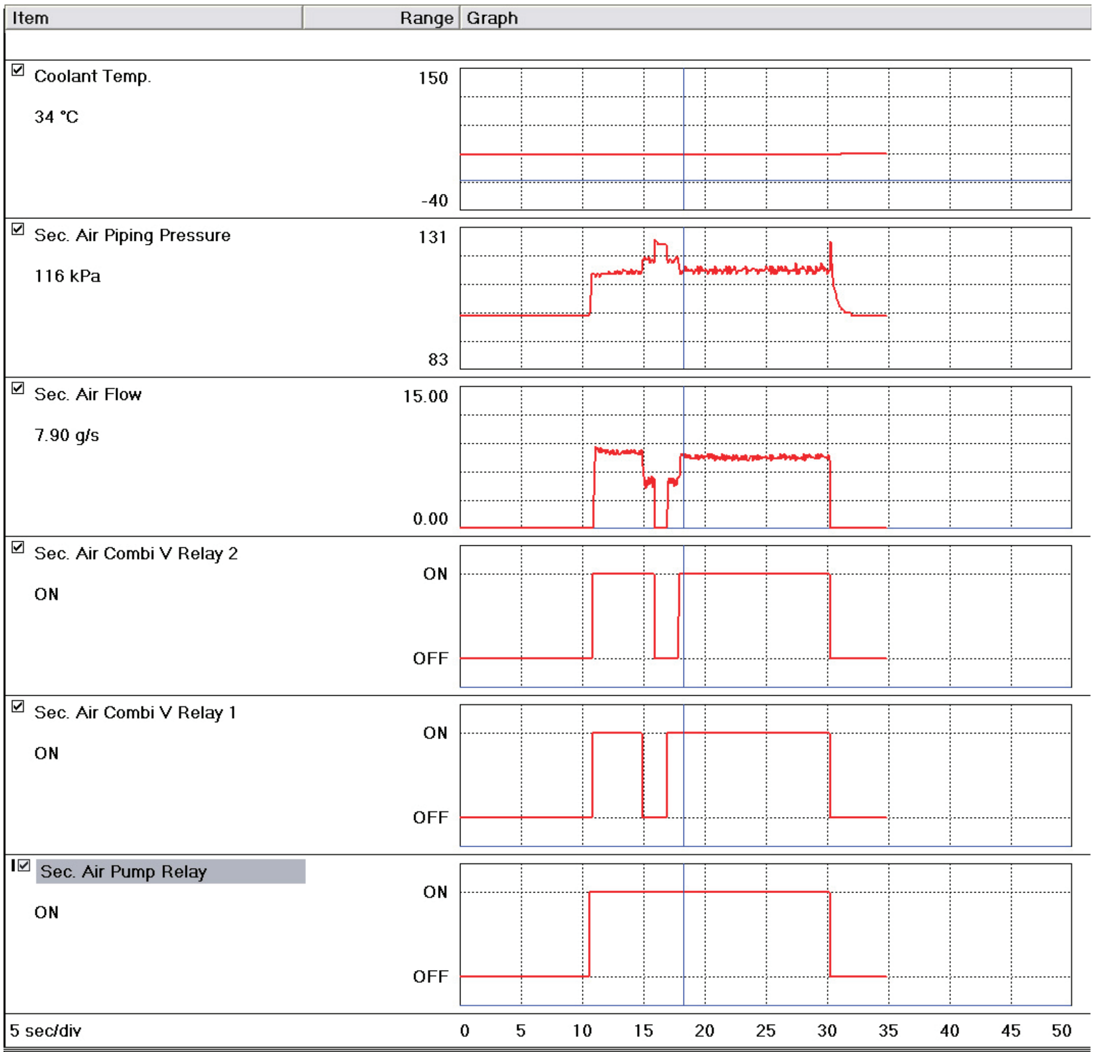
The fresh air enters the exhaust from behind a fresh air port located behind each exhaust valve. An electric Secondary Air Pump provides the force necessary to supply the quantity of air needed for mixing with the exhaust. The air from the secondary air pump is divided between the left and right side 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.

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.



SECONDARY AIR PUMP



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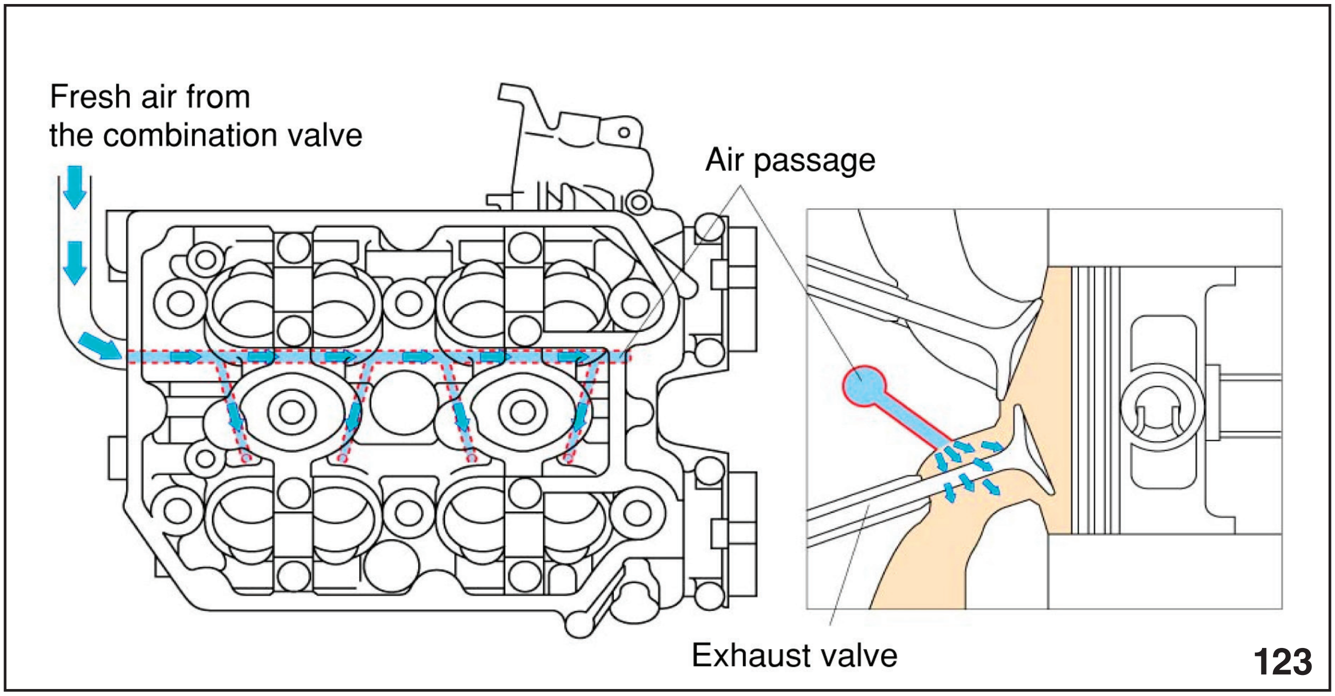
SECONDARY AIR PUMP SYSTEM OPERATION

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.

Cylinder Head



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.

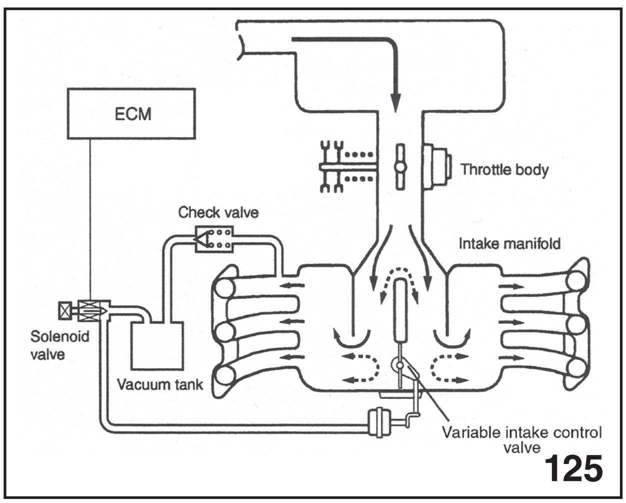
The ECM will activate the combination valve relays and the pump relay when the engine coolant temperature is below 150 degrees°F (70°C)

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

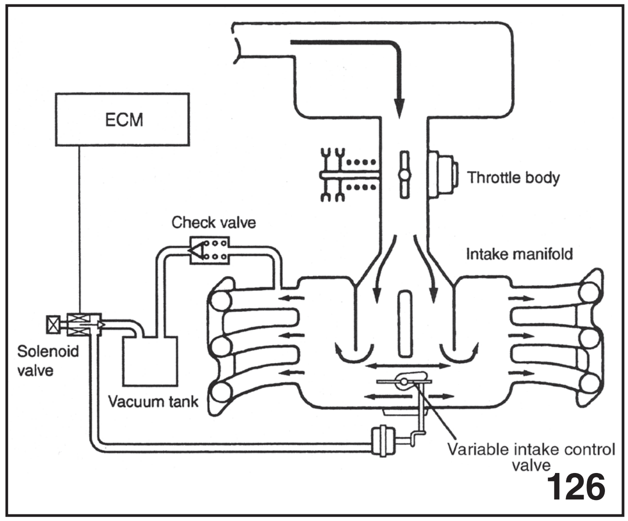
Variable Intake control and Intake Resonance Induction System

Beginning in 1992 through 2005 6 cylinder Subaru engines were equipped with metal type intake manifolds that utilized a system to enhance the airflow through them. The early system was named the “Intake Resonance Induction System” or IRIS system. This system was on all 3.3 liter engines. The newer system for the 3.0 liter engine was named the “Intake Air Control" or IAC system.

The 3.3 liter engine was discontinued after the production stop to SVX. The 3.0 liter is still being used on the Legacy and Outback but the introduction of the Variable Valve Lift system in 2005 took the place of the IAC system. This newer intake manifold design took advantage of the lighter weight resin material.



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.

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 Operation

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

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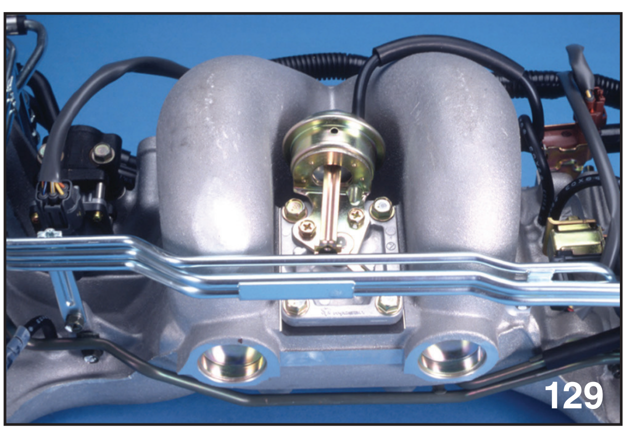
VARIABLE INTAKE CONTROL VALVE CHART

VARIABLE INTAKE CONTROL VALVE

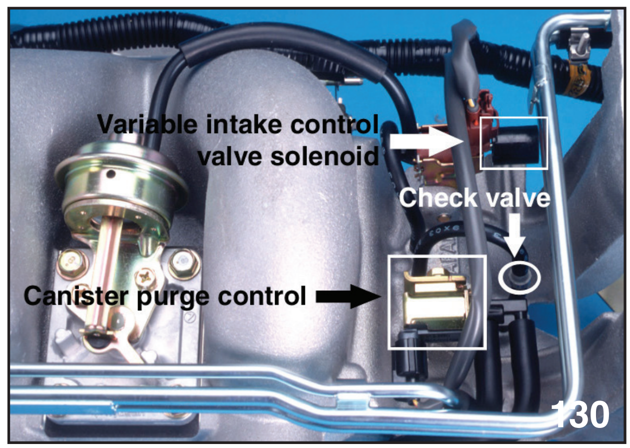


VARIABLE INTAKE CONTROL VALVE LOCATION

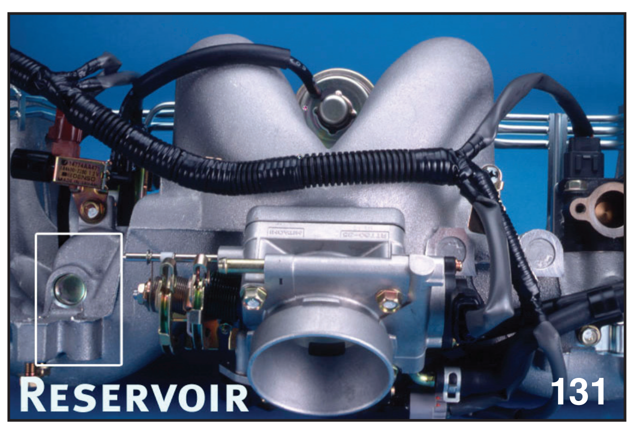
The Variable Intake Control valve is positioned on the under side of the intake manifold.

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.

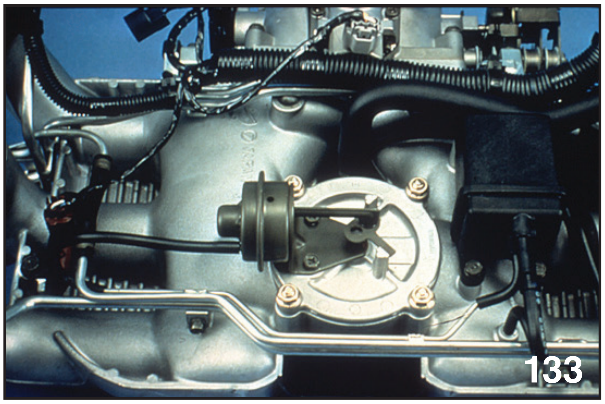


COMPONENT LOCATION



INTAKE MANIFOLD

Inertia Resonance Induction System (IRIS)

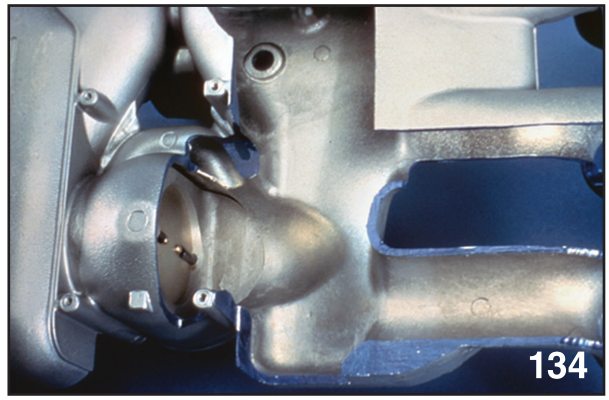


INTAKE MANIFOLD (UNDERSIDE)

Iris system components include:

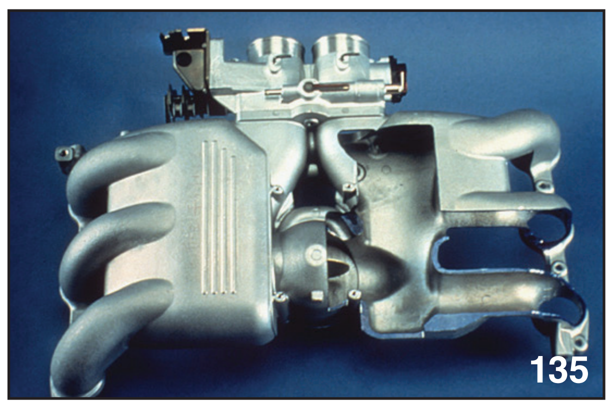
- IRIS Valve
- Vacuum Tank
- Check Valve
- Solenoid

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.



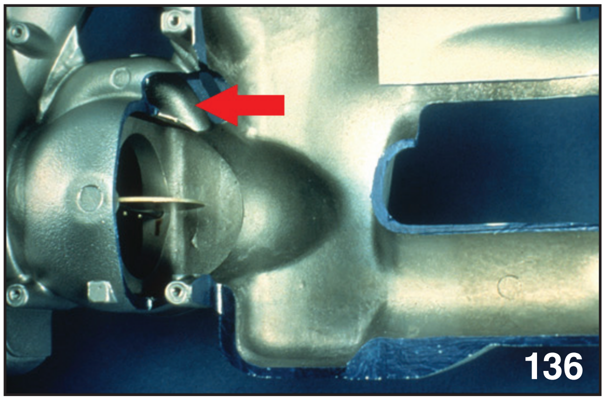
IRIS VALVE (CLOSED)

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

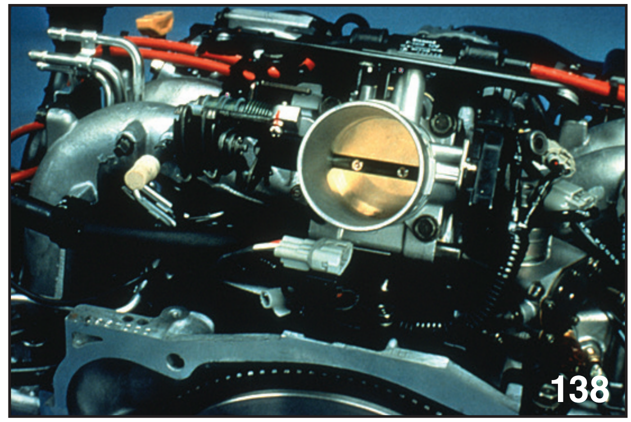
The IRIS valve is closed because the volume of air in mode one is moving too slow for the valve to be effective. Resonance tube operation maintains the speed of the moving air, keeping the pushing effect at maximum.



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.

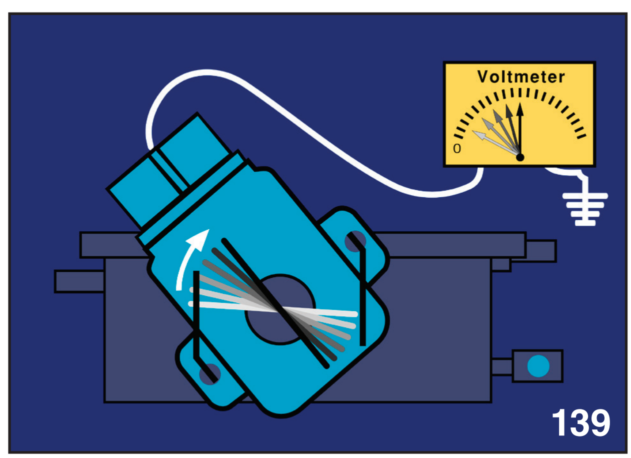
Pre-ETC (Electronic Throttle Control)



THROTTLE BODY WITH ACCEL CABLE & TPS

Pre-ETC (Electronic Throttle Control) vehicles relied on a cable to deliver the drivers's acceleration demands to a throttle body.

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

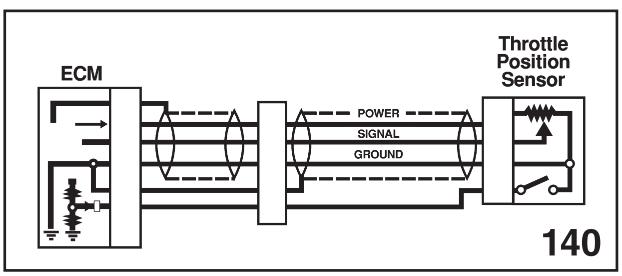
The throttle body was equipped with a throttle position sensor that would signal the ECM.

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.

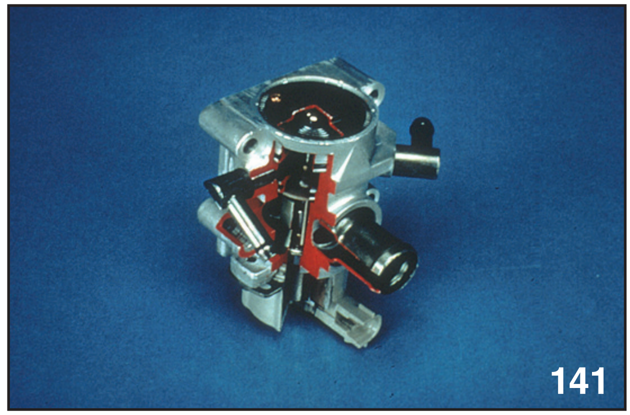
Adjustment is possible through the use of elongated mounting holes.

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



THROTTLE POSITION SENSOR CIRCUIT

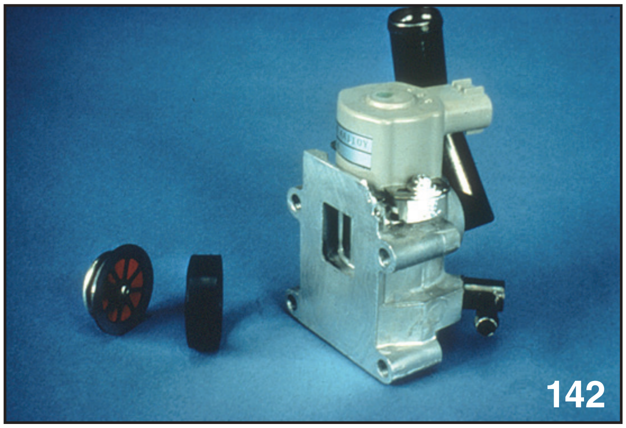
Testing is performed by observing voltage and resistance values. The Select Monitor on earlier models will display THV or throttle voltage and illuminate an LED when the idle switch signal is present. Newer models in addition will indicate throttle opening in degrees.



IDLE AIR CONTROL VALVE

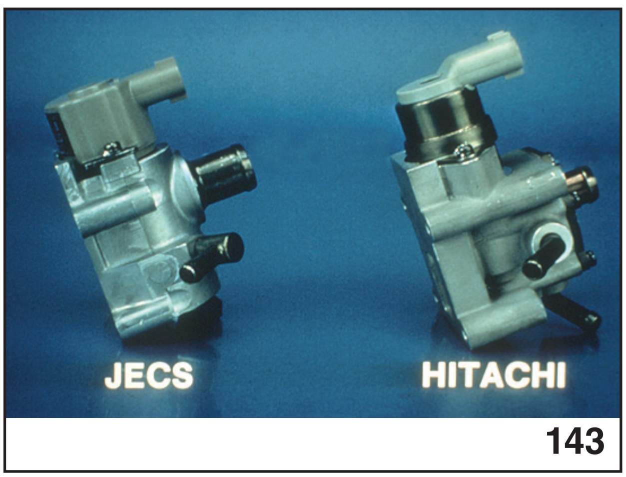
Idle Air Control Valve (IAC) operation controls all idle speeds. Construction includes an air cut valve, duty control valve, intake air passage and a coolant passage. These component parts create a dual control over the IAC. The air cut valve is influenced by the temperature of coolant flowing through 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

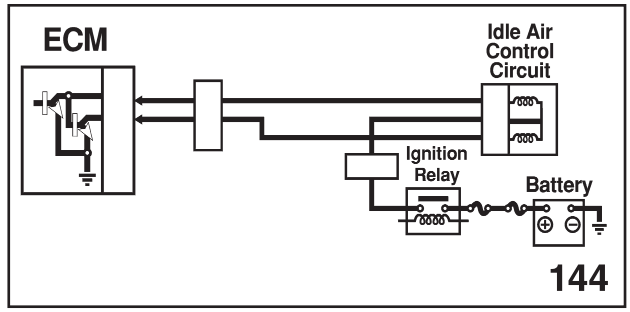
IAC duty ratio can be monitored with the select monitor. Higher duty ratio will keep the valve open longer increasing idle speed. Lower duty ratio provides lower idle speeds. Optimum idle speed for all engine conditions is part of the ECM logic and will increase or decrease IAC duty ratio as necessary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



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 OBDII 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.



IAC SCHEMATIC

Fail-safe results of the IAC can be misleading. Failure of the bimetallic spring with the air-cut valve in the more open position will result in no problem with a cold engine but as the engine warms the duty ratio of the IAC will be lower than normal to close the duty control valve more to maintain proper idle speed. Failure of the bimetallic spring in the more closed position will result in higher IAC duty ratio with a cold engine but will be normal with a warm engine.

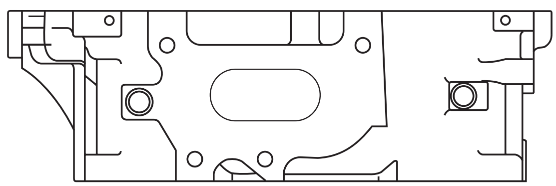
Failure of the duty control valve or loss of duty signal will leave the duty control valve fully open. With a cold engine the air cut valve is also fully open. This quantity of air flowing through the intake air passage would result in an improper high idle speed. To control this condition the ECM will turn off injectors to reduce idle speed. One injector for a warm engine and two injectors for a cold engine.

The intake air passage can be contaminated with carbon which reduces the air flow. This condition would result in a higher than normal IAC duty ratio. If this condition is suspected clean the IAC valve following procedures outline in the Subaru Service Manual on the STIS web site.

Partial Zero Emission Vehicle (PZEV)

Partial Zero Emission Vehicles (PZEV) have 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.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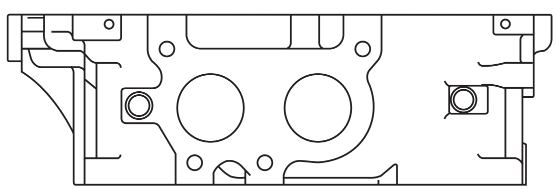
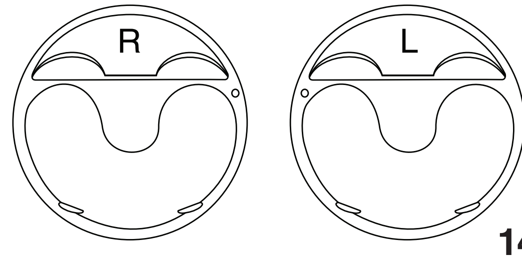
PZEV


147

FEDERAL

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



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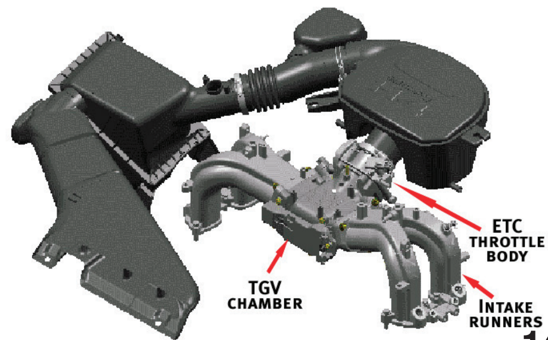
PISTON SHAPE

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



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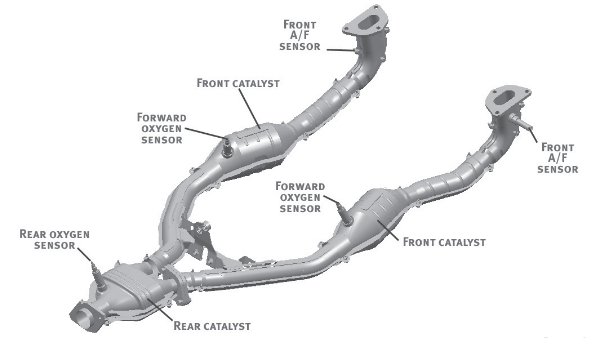
INTAKE MANIFOLD

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.



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EXHAUST SYSTEM

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

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

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

Newer PZEV vehicles (2006 and Newer) are the same as a federal vehicle. The only difference is the catalytic converter and the ECM programming.

Fuel Line Quick Connector Tools

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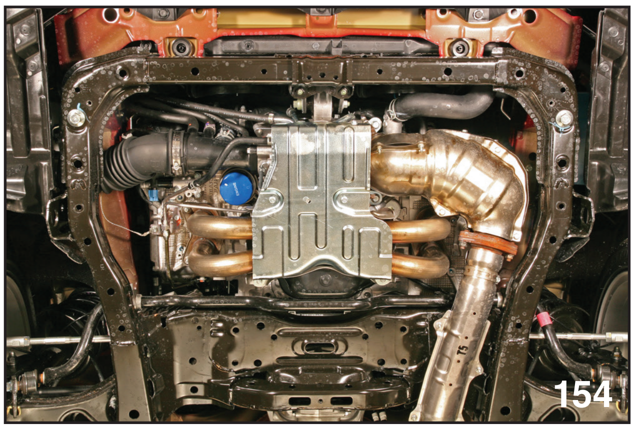
FUEL LINE QUICK CONNECTOR TOOLS

The tools pictured here are used to disengage the fuel line quick connectors in the engine compartment. Always relieve the fuel pressure before using these tools. Follow the instructions in the appropriate Subaru Service Manual on STIS for removing the fuel pressure. The quick connectors installed on the fuel lines and hoses of the engine compartment maybe reused but should be replaced if they show any signs of leakage or fatigue. Quick connectors are also found on the fuel pump and evaporative system. Quick connectors in those areas are designed to be used only once. Replace them if they are ever disengaged. Follow the instructions in the Subaru Service Manual on STIS for disengaging any quick connector.

2010MY Turbo Charger and Engine Related Enhancements

The turbo charger location for the 2010 Legacy is located in the front lower section of the engine compartment and is connected directly to the exhaust manifold. This improves turbo charger operation by shortening the distance between the turbine and the energy source that drives the turbo (Turbo lag).



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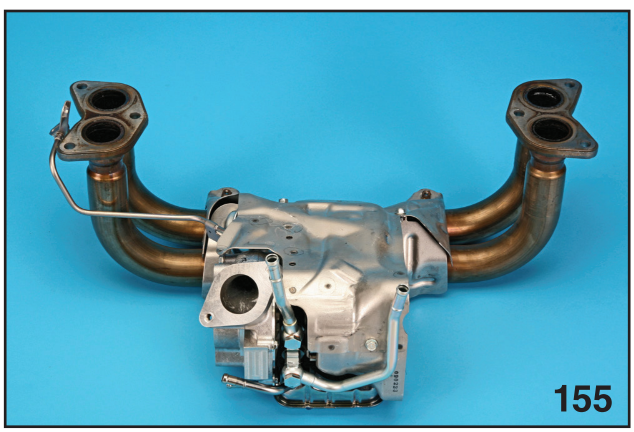
TURBO CHARGER IN CAR



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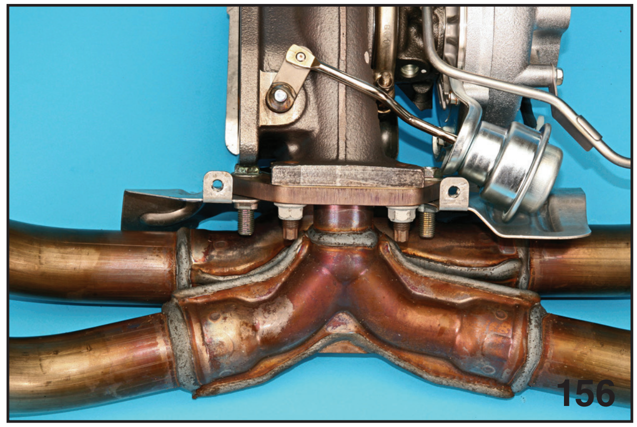
TURBO CHARGER WITH HEAT SHIELDS ON BENCH

The catalytic converter is bolted directly to the outlet of the turbo charger. This brings the catalyst to operating temperature much faster and eliminates the need for a secondary air system (the secondary air system is not equipped on 2010 Legacy).



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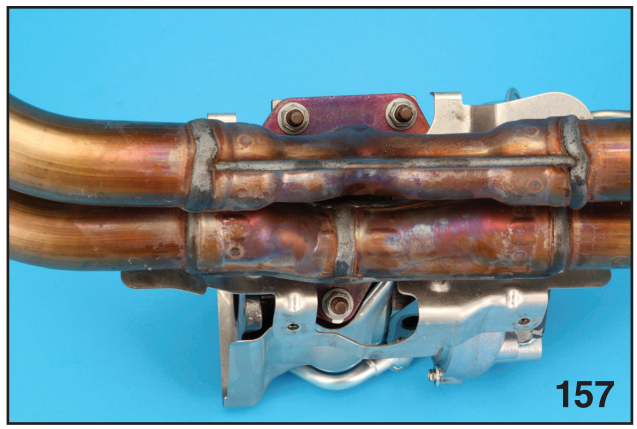
EXHAUST AND TURBO CHARGER ON BENCH

Three (3) studs secure the turbo charger to the collector of the right and left exhaust manifold.



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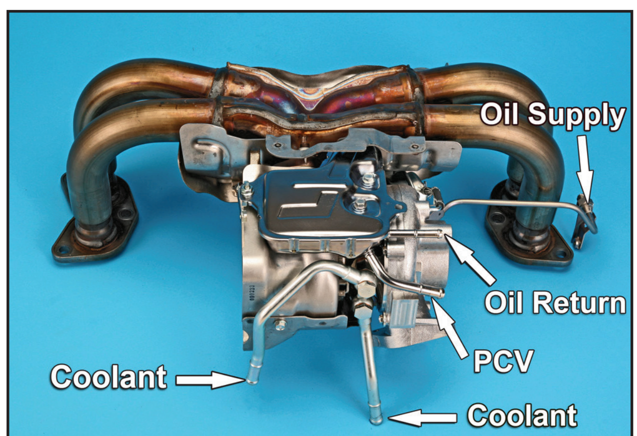
TURBO MOUNTING BOLTS



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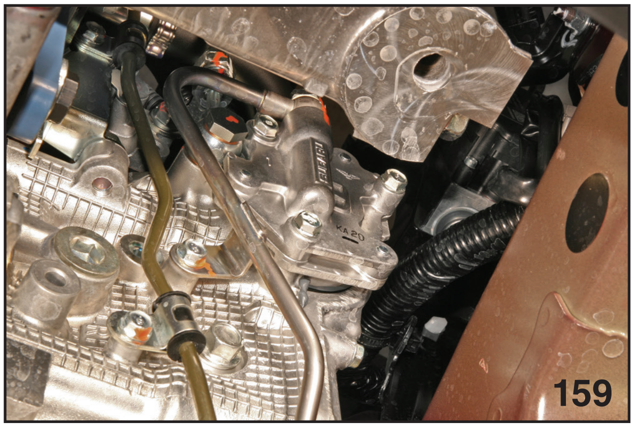
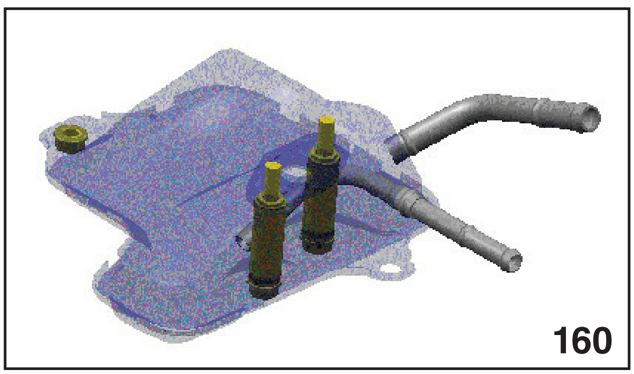
TURBO CHARGER BOTTOM VIEW ON BENCH

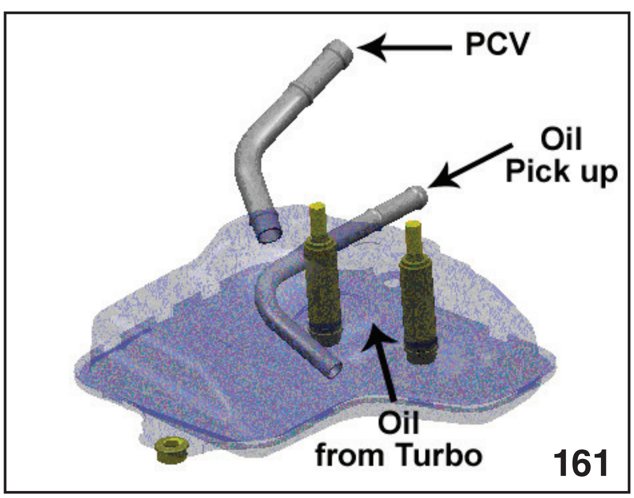


SCAVENGING OIL PUMP MOUNTED TO RIGHT CYLINDER HEAD

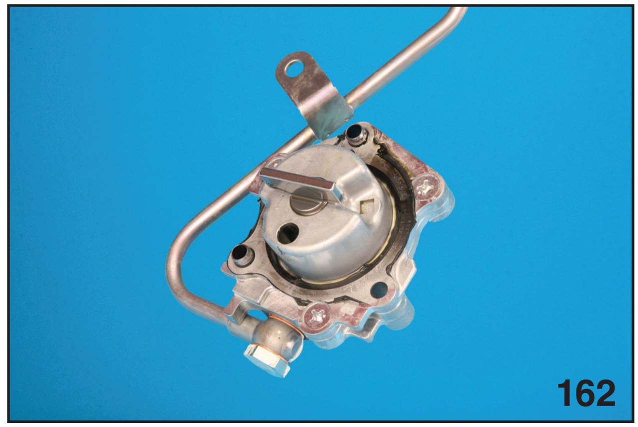
The turbo charger is now the lowest point on the lubrication system and requires a Scavenging Oil Pump to return oil that lubricates the turbo charger. The bottom of the turbo charger is equipped with a small oil pan that serves as a connection point for the Scavenging Oil Pump pick up.



OIL PAN

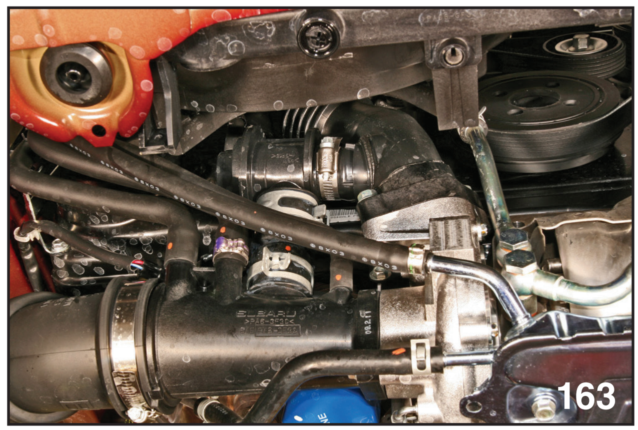


OIL PAN



SCAVENGING OIL PUMP ON BENCH

The Scavenging Oil Pump is mounted to the back side of the right bank cylinder head and is driven from a slot at the rear of the Intake Camshaft.

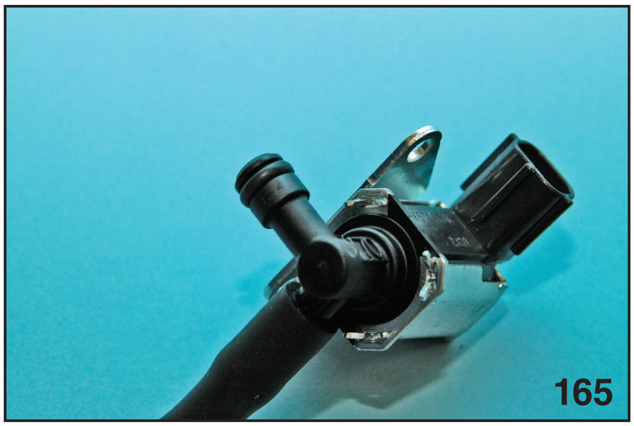


TURBO AREA

There are 8 hoses or lines in the turbo charger area. The coolant system has a supply and return. The lubrication system has a supply and return. There are three PCV hoses and one hose for CPC 2 that connect to the fresh air intake connector at the inlet side of the turbo charger.

NOTE: **The coolant expansion tank has been eliminated.**

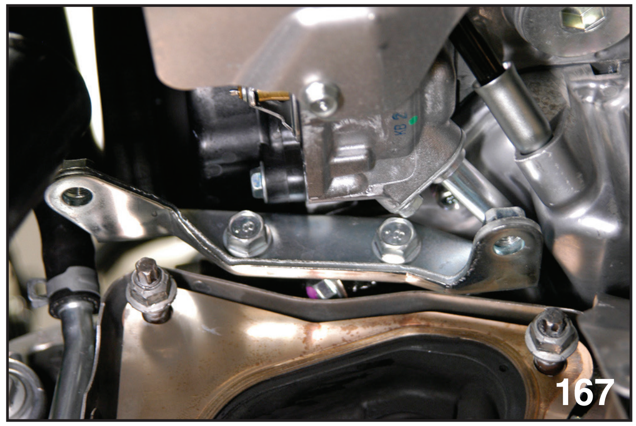
BY PASS VALVE



WASTEGATE SOLENOID

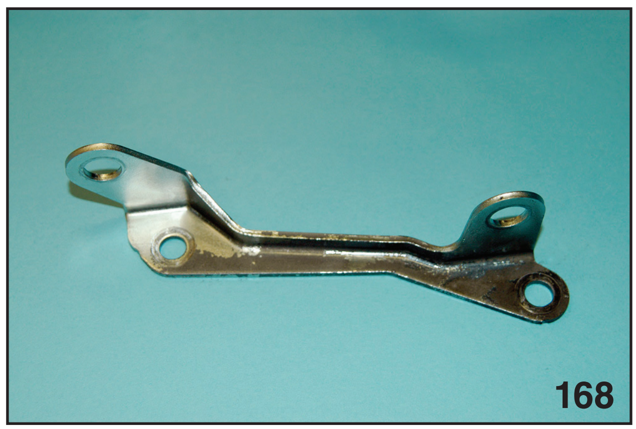
WASTEGATE SOLENOID MOUNTED

The Wastegate Solenoid connects at the outlet side of the turbo charger and a small hose connects to the vacuum "T" between the compressor (Outlet pressure) and the Wastegate.



TOP BRACKET MOUNTING PLATE

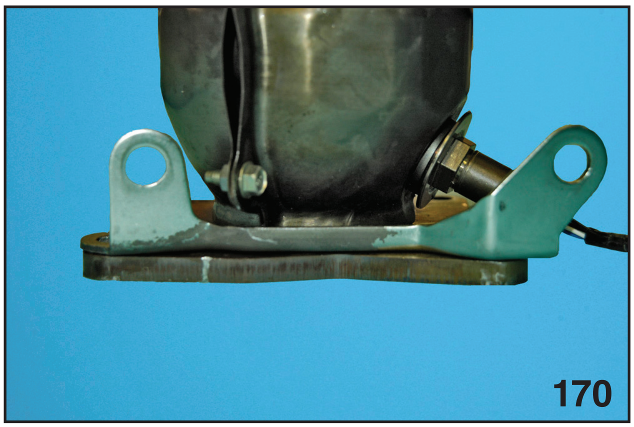
The Catalytic Converter and the turbo charger share a mounting bracket. The top two studs of the turbo charger on the turbine side first go through an exhaust gasket then the Catalytic Converter. Before the nuts go into place, the mounting bracket is placed onto over the studs.



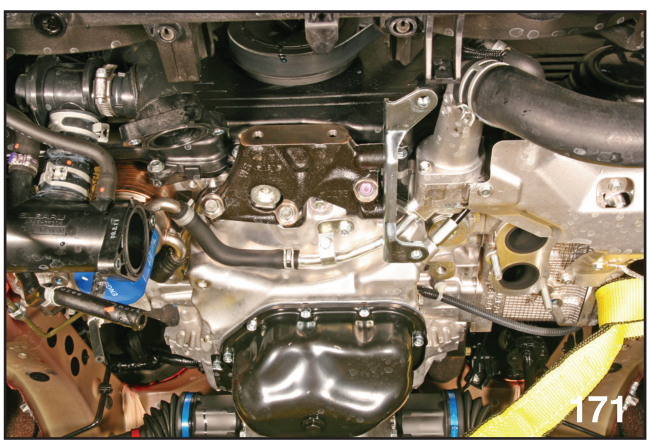
TOP BRACKET

The top holes of the bracket align with the threaded holes of the Turbo Charge/Catalytic Converter mount that is bolted to the side of the Front Engine Mount.

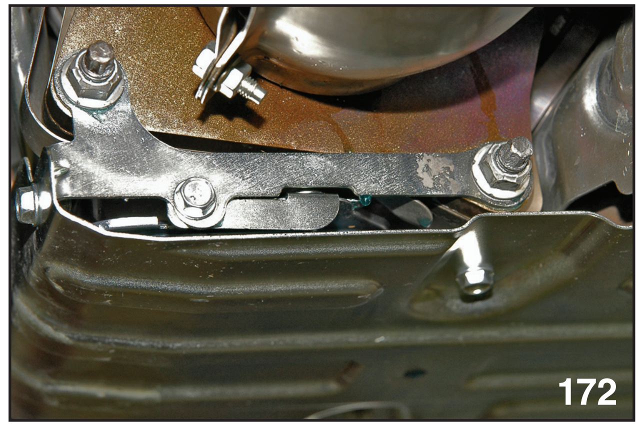
TOP BRACKET MOUNTED



TOP BRACKET ON CATALYTIC CONVERTER

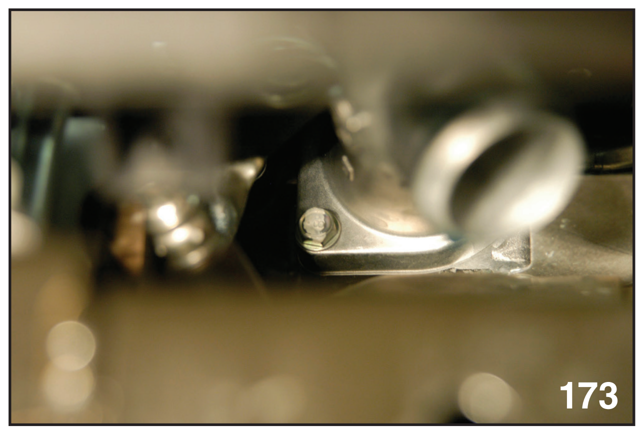


TOP BRACKET MOUNTING PLATE POSITION



TURBO CHARGER HEAT SHIELD

The bottom studs of the turbo charger pass through the Exhaust Gasket, Catalytic Converter and a mounting bracket for the turbo charger heat shield. Both brackets must be removed before the Catalytic Converter can be removed.

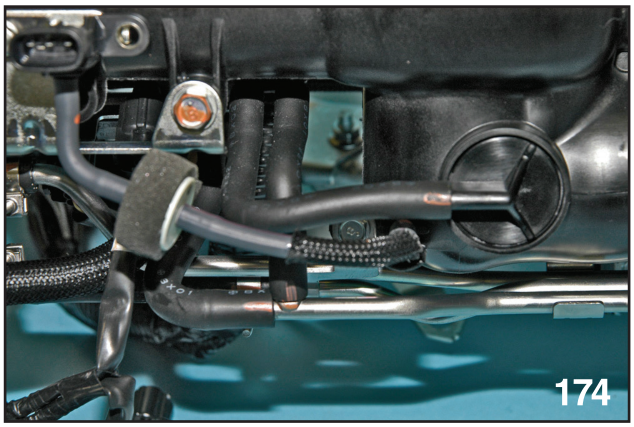


THERMOSTAT HOUSING

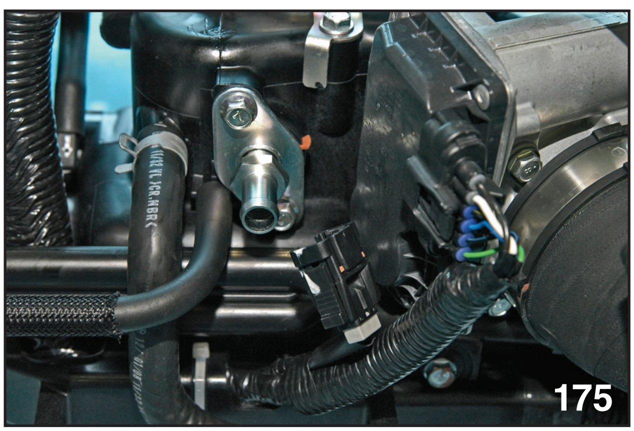
Additional room is provided for removal of the top bracket by removing the thermostat housing.

Intake Manifold

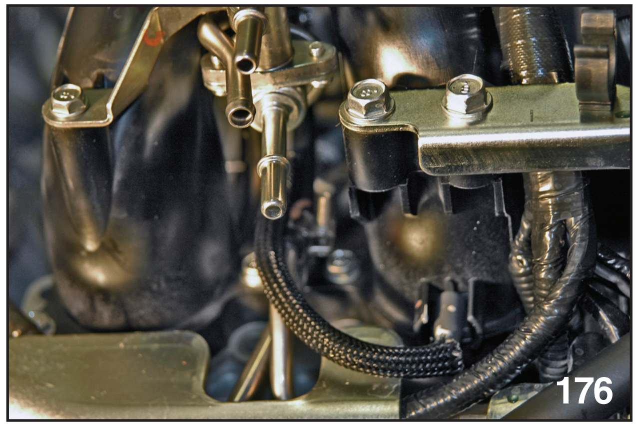
Note: **When removing the intake manifold on turbo charged vehicles, the wiring and connectors under the cylinder heads for the cam sensors and VVT solenoids must be disconnected and removed with the intake manifold. Remove the intake manifold by removing the bolts that secure the TGV runners to the cylinder heads.**



CPC 1 CONNECTION AND PRESSURE SENSOR

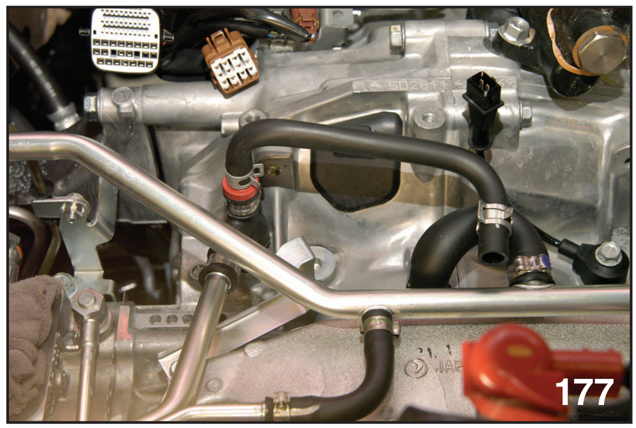


PCV CONNECTION, BRAKE BOOSTER CONNECTION AND BY PASS VALVE CONNECTION



FUEL PRESSURE REGULATOR-TURBO

PCV System



PCV HOSES ON BLOCK-TURBO

SUBARU
SR. MASTER TECHNICIAN

SUBARU
MASTER TECHNICIAN

SUBARU
CERTIFIED TECHNICIAN

SUBARU
MASTER TECHNICIANS
Quality driven. Technician powered.™

MSA5P0161C

Print Date:
05/2011