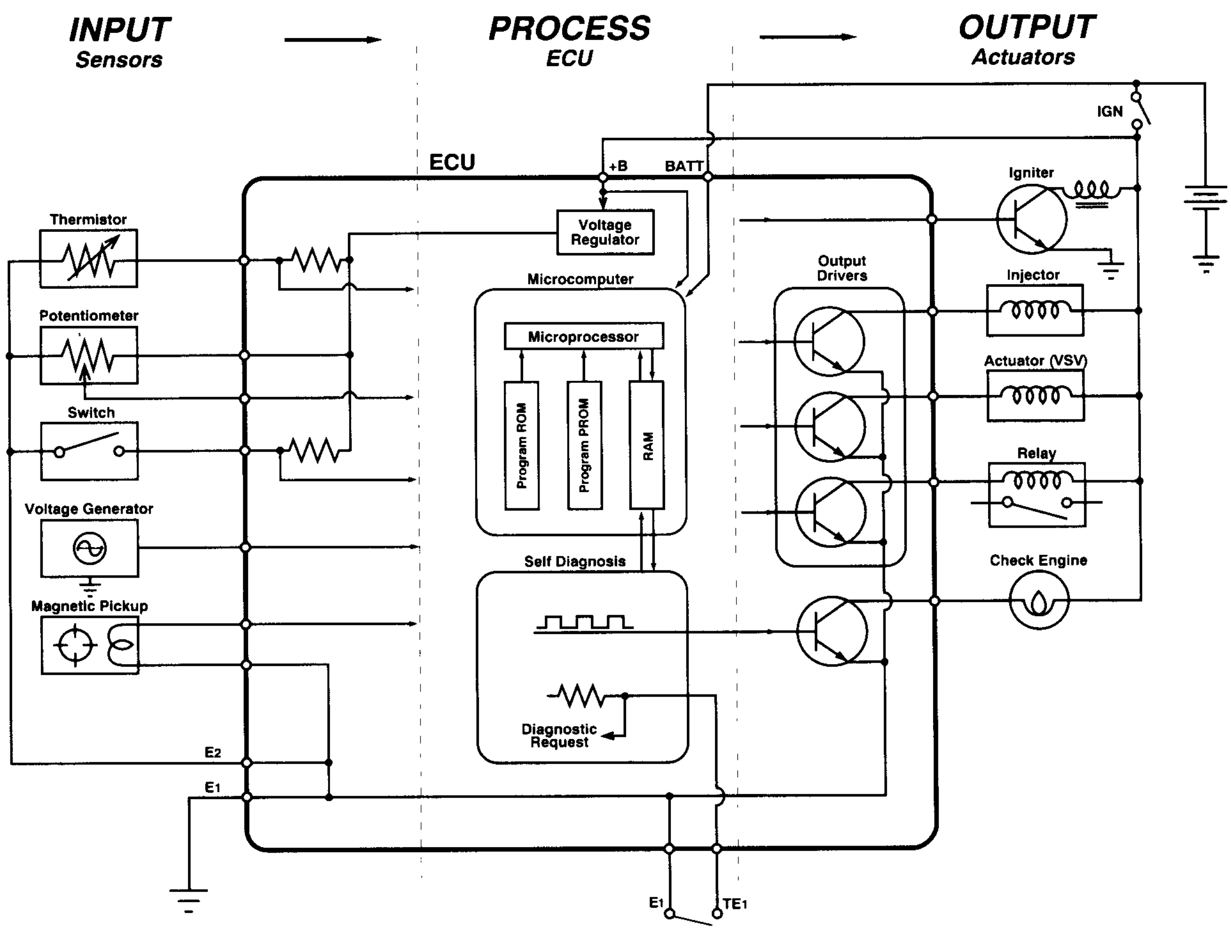
Overview

The EFI/TCCS system is an electronic control system which provides Toyota engines with the means to properly meter the fuel and control spark advance angle. The system can be divided into three distinct elements with three operational phases.

The three system elements are:

- Input Sensors
- Electronic Control Unit (A Microcomputer)
- Output Actuators



The electronic control system is responsible for monitoring and managing engine functions which were previously performed by mechanical devices like carburetors, vacuum, and centrifugal advance units. In an electronic control system, these functions are managed in three phases.

- The input phase of electronic control allow the Electronic Control Unit (ECU) to monitor engine operating conditions, utilizing information from the input sensors.

- The process phase of electronic control requires the ECU to use this input information to make operating decisions about the fuel and spark advance systems.

- The output phase of electronic control requires the ECU to control the output actuators, the fuel injectors, and igniter to achieve the desired fuel metering and spark timing.

In this chapter, we will explore the details of the electronic control system hardware and software. The chapter starts with a thorough examination of the system's input sensor circuits and the ECU power distribution system. It concludes with a closer look at the ECU process functions and the control strategy use(for optimum fuel metering and spark advance angle control.

The Microcomputer

The heart of the TCCS system is a **microcomputer.** A microcomputer is a device which receives information, processes it, and makes decisions based on a set of **program instructions**. The microcomputer exercises control over the output actuators to carry out these instructions.

The use of microcomputers has taken the science of engine management into the space age by increasing the speed with which information can be processed and allowing the electronic control system to manage more engine functions. With the ability to process information so rapidly, the modern ECU is capable of carrying out its programmed instructions with extreme accuracy. Engine management can address virtually every condition the engine will encounter so that for any engine condition, the ECU will deliver optimum fuel and spark.

Evolution of Toyota's Electronic Fuel Injection Systems

Early Conventional EFI computers were first configured from analog circuits, and they controlled only fuel delivery and injection. The modem Electronic Control Units (ECU) utilize digital circuits and microprocessors which have served to improve EFI system capabilities.

Modern TCCS engine controls, introduced to the U.S.A. market in 1983, are capable of managing fuel delivery, idle speed control (ISC), electronic spark advance (ESA), and emissions systems with extraordinary speed and accuracy.

In the evolution of Toyota's fuel injection, three levels of electronic control refinements have taken place.

- Conventional EFI

- P7/EFI

- EFI/TCCS

The main difference between these systems is the capability of the ECU. These capabilities have grown from simple fuel control to the addition of self-diagnostics to the control of ignition spark advance and more. The following chart summarizes basic capabilities by system and can be used as a guide in identification and troubleshooting.

Evolution of Toyota EFI Systems

	Fuel Control (EFI)	Spark Control (ESA)	Self Diagnosis	Fail Safe Strategy	Idle Speed Control (ISC)
Conventional EFI	YES	NO	NO	NO	NO
P7/EFI	YES	NO	YES	NO	NO
EFI/ TCCS	YES	YES	YES	YES	YES

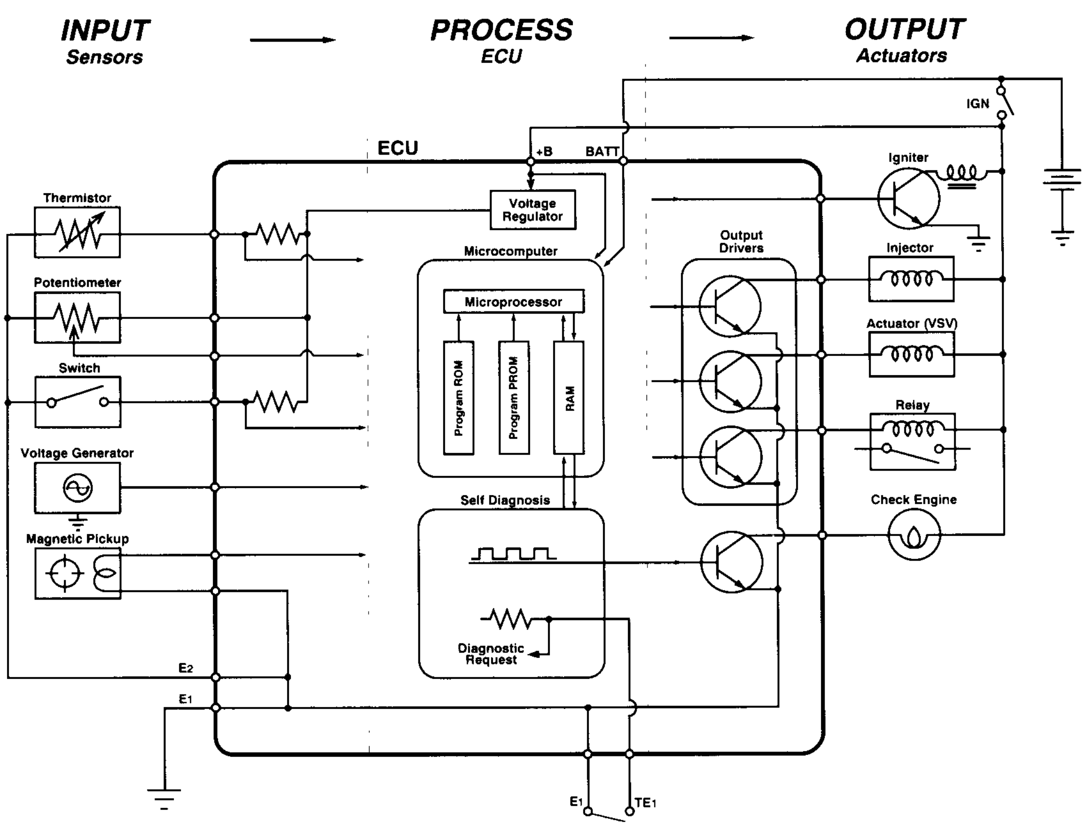
System identification is relatively simple.

- The Conventional EFI system has no check engine light.
- The P7/EFI system has a check engine light but has a mechanical advance distributor.
- The EFI/TCCS system has a check engine light and an electronic advance distributor.

The Input Sensors, Information Source for the ECU

In an electronic control system, the ECU uses its sensors in much the same manner as we use our five senses. Our sense of touch tells us when things are hot or cold; our sense of hearing allows us to distinguish one sound from another; our sense of smell tells us when fresh coffee is brewing somewhere nearby. Sensors give the ECU similar abilities: the ability to feel the temperature of the engine coolant, to listen for the sound of detonation, and to smell the exhaust stream for the presence of sufficient oxygen.

This lesson on input sensors will address how each major ECU input sensor circuit works. Each sensor circuit will be broken down so you can see its individual components: the sensor, electrical wiring, and the ECU.

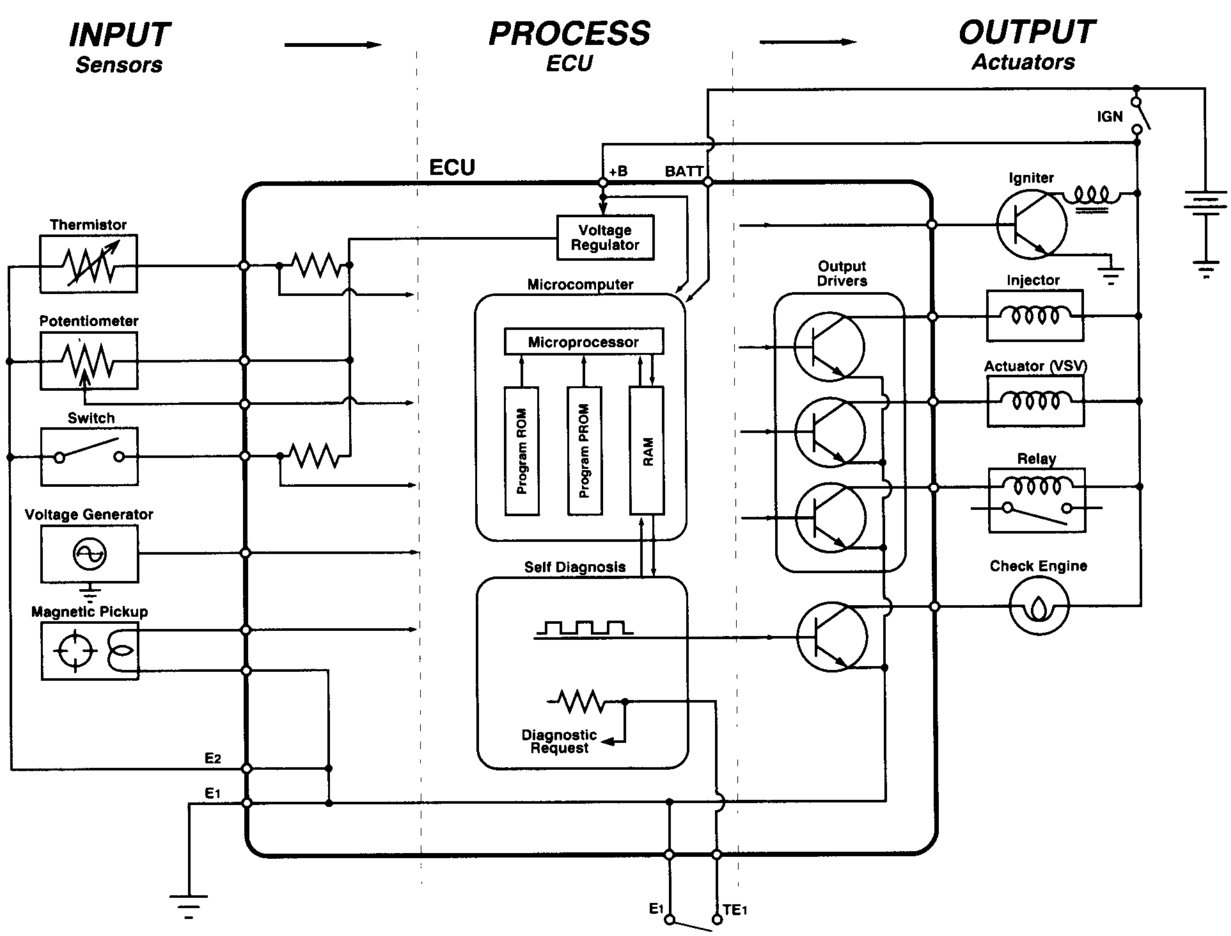


Overview

The EFI/TCCS system is an electronic control system which provides Toyota engines with the means to properly meter the fuel and control spark advance angle. The system can be divided into three distinct elements with three operational phases.

The three system elements are:

- Input Sensors
- Electronic Control Unit (A Microcomputer)
- Output Actuators



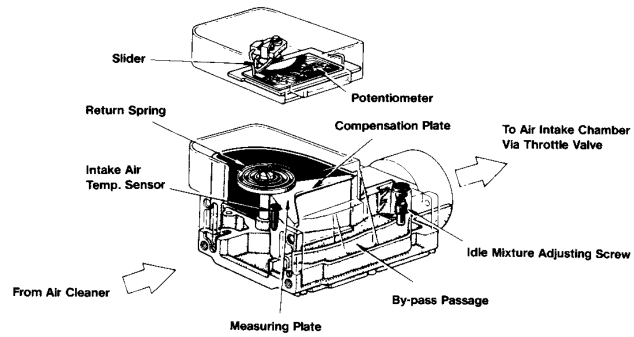
Input Sensors Used in Basic Injection and Spark Calculation

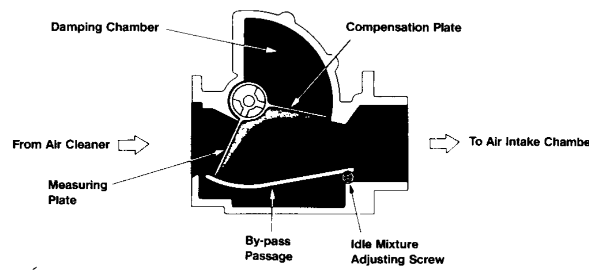
Engine Air Flow Sensing

Vane Type Air Flow Meters (Vs, General Information)
The vane type air flow meter is located in the air induction system inlet pipe between the air cleaner and the throttle body. It is composed of the measuring plate, compensation plate, return spring, potentiometer, and by-pass passage. The sensor also incorporates the idle mixture adjusting screw (factory sealed), the fuel pump switch, and the intake air temperature sensor (which will be addressed later in this lesson). Because intake air volume is a direct measure of the load placed on an engine, the vane type air flow meter provides the most important input to the ECU for fuel and spark calculations.

When air passes through the air flow meter, it forces the measuring plate open to a point where it balances with the force of the return spring. The damping chamber and compensation plate prevent vibration of the measuring plate during periods of sudden intake air volume changes.

The potentiometer, which is connected to the measuring plate and rotates on the same axis, converts the mechanical movement of the measuring plate into a variable voltage signal. Movement of the measuring plate and the analog voltage signal produced by this sensor are proportional to the volume of air entering the intake manifold.





Vane Air How Meter Electrical Circuit
The sensor movable contact is attached to the measuring plate and rides on a fixed resistor wired between the reference voltage input and the ground. As the volume of air entering the engine increases, the movable contact moves across the fixed resistor, causing a change in signal output voltage.

There are two designs of vane air flow meters used on Toyota L type EFI systems. The first design generates a signal which varies from low voltage at low air volumes to high voltage at high air volumes. The second design sensor has opposite signal characteristics. These sensors also operate on different reference voltages. Both sensor designs integrate an intake air temperature sensor into the air flow meter.

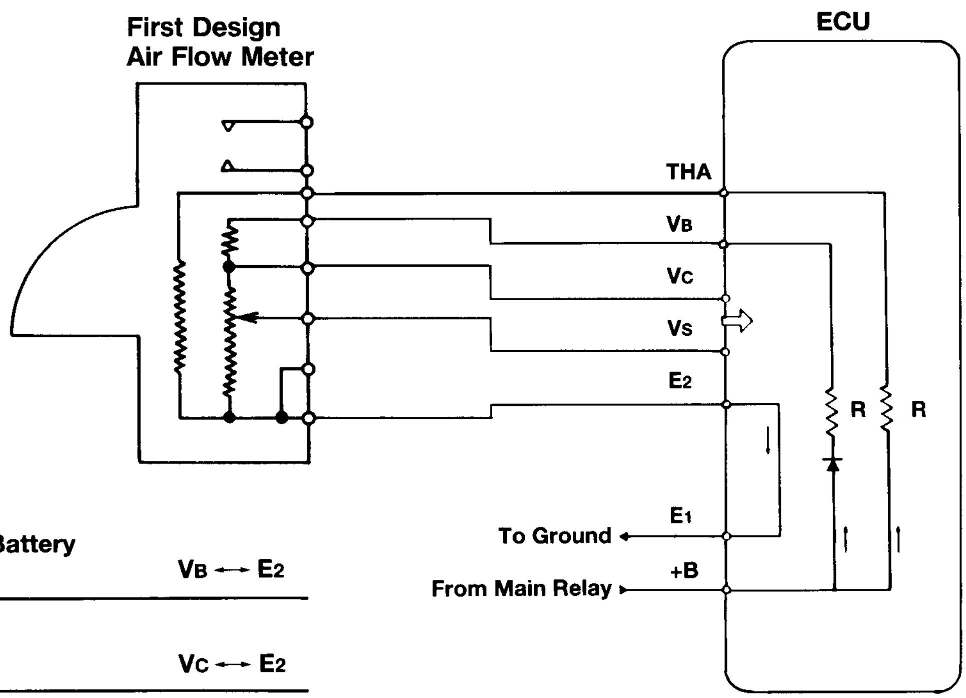
First Design Vane Air How Meter

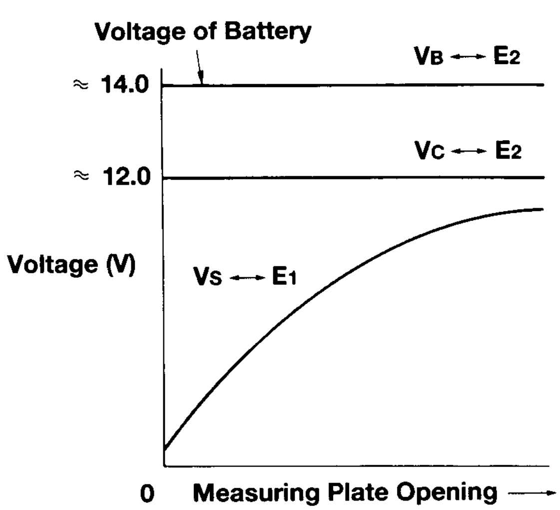
The first design air flow meter is found on all Conventional EFI engines and many later model TCCS equipped engines. This sensor has an electrical connector with seven terminals, four of which are used for air flow measurement.

Air Flow Sensor Terminal Identification (First Design Sensor)

V_B	Voltage Battery	Battery voltage supply to sensor
V_C	Voltage Constant	ECU constant reference voltage
V_S	Voltage Signal	Signal voltage representing air flow
E_2	Earth Ground	Sensor ground return path

The air flow meter and ECU are wired as shown in the diagram. Signal characteristics are depicted by the accompanying graph. The use of battery voltage, VB, as a sensor input necessitates the use of the Vc terminal as a constant reference signal for the ECU. This is because battery voltage may change with variances in electrical load and ambient temperatures. Without the use of a constant reference voltage, these changes would cause a change in the Vs signal value recognized by the ECU.





Second Design Air How Meter

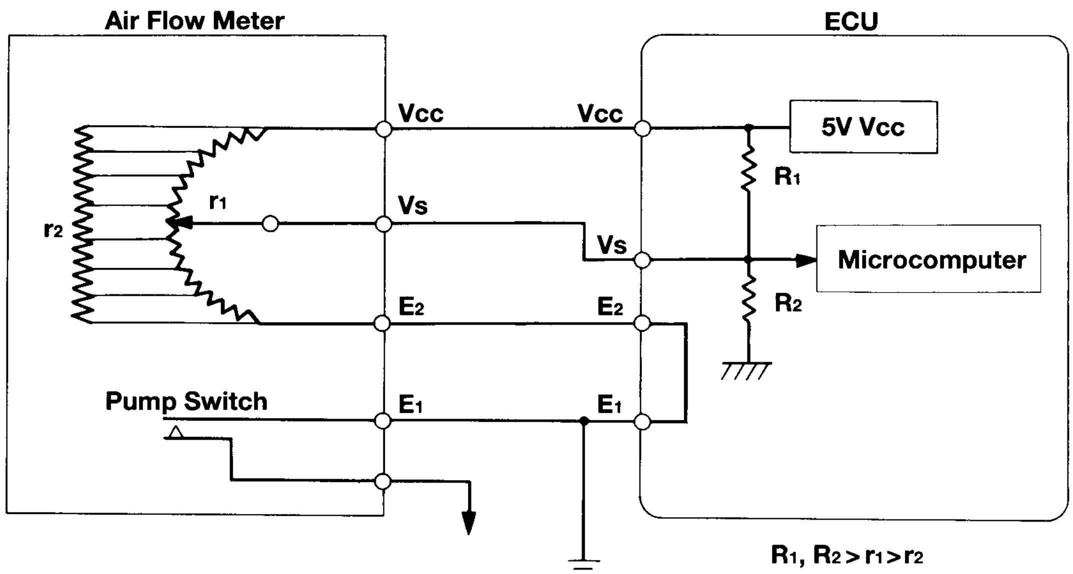
The second design air flow meter was introduced on the '85 5M-GE engine, and its use expanded with many late model TCCS equipped engines. This sensor has an electrical connector with seven terminals, three of which are used for air flow measurement.

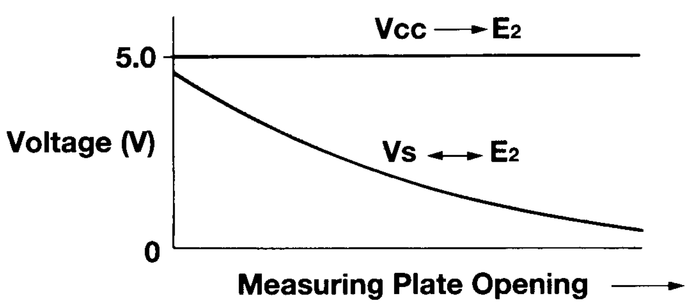
Air Flow Sensor Terminal Identification (Second Design Sensor)

Vcc	Voltage Constant Control	Regulated 5 volt reference
Vs	Voltage Signal	Signal voltage representing air flow
E_2	Earth Ground	Sensor ground return

The air flow meter and ECU are wired as shown in the diagram; signal characteristics are depicted by the accompanying graph. The use of a regulated 5 volt reference eliminates the need for the VB terminal with this sensor circuit.

Resistors R1 and R2 provide self diagnostic capabilities and allow for a fail-safe voltage at the ECU in the event of an open circuit. These two resistors have a very high resistance value (relative to r1 and r2) and essentially have no electrical effect on the circuit under normal operating conditions. They will, however, affect the open circuit voltage measured on the Vs wire at the ECU.





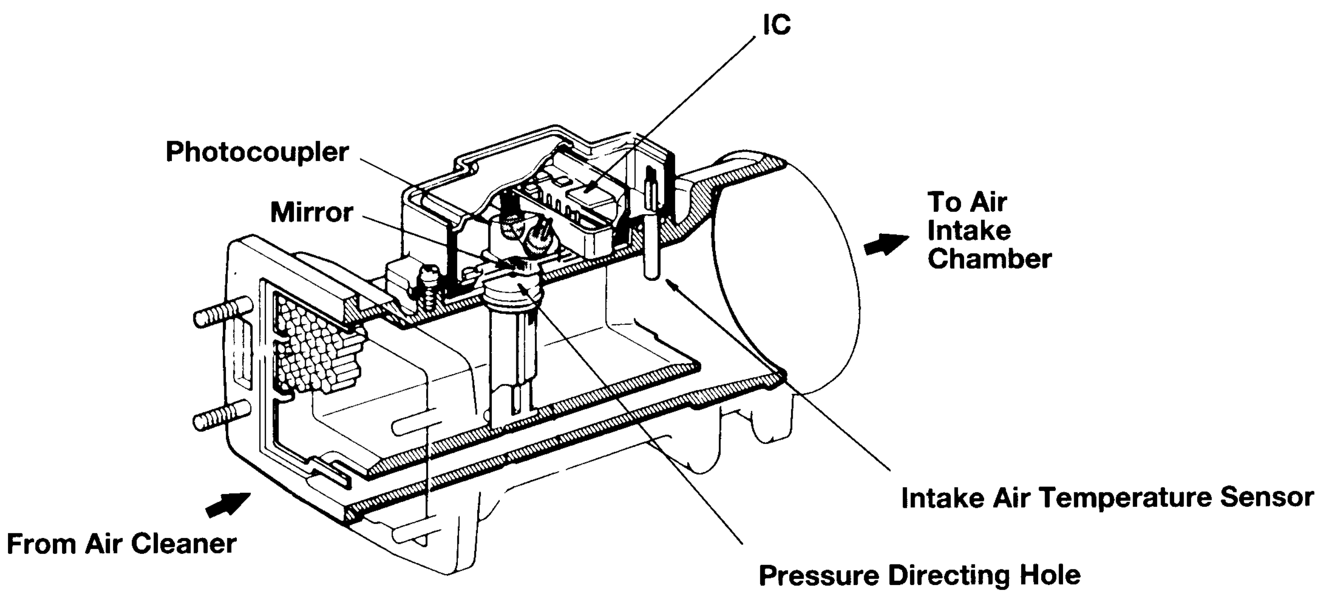
Karman Vortex Air Flow Meter (Ks)
The Karman vortex air flow meter is currently used on the 7M-GTE Toyota engine and the 2JZ-GE and 1UZ-FE Lexus engines. It is located in the air induction system inlet pipe between the air cleaner and the throttle body. The sensor is composed of a **photocoupler** and mirror, a vortex generator, and an integrated circuit (IC) which together, measure the frequency of the vortices generated by air entering the intake system.

When compared with the vane type air flow meter, the Karman vortex meter is smaller, lighter, and offers less restriction to incoming air. Similar to the vane type air meter, the Karman vortex meter integrates the intake air temperature sensor into the meter assembly.

The sensor has an electrical connector with five terminals, three of which are used for air flow measurement.

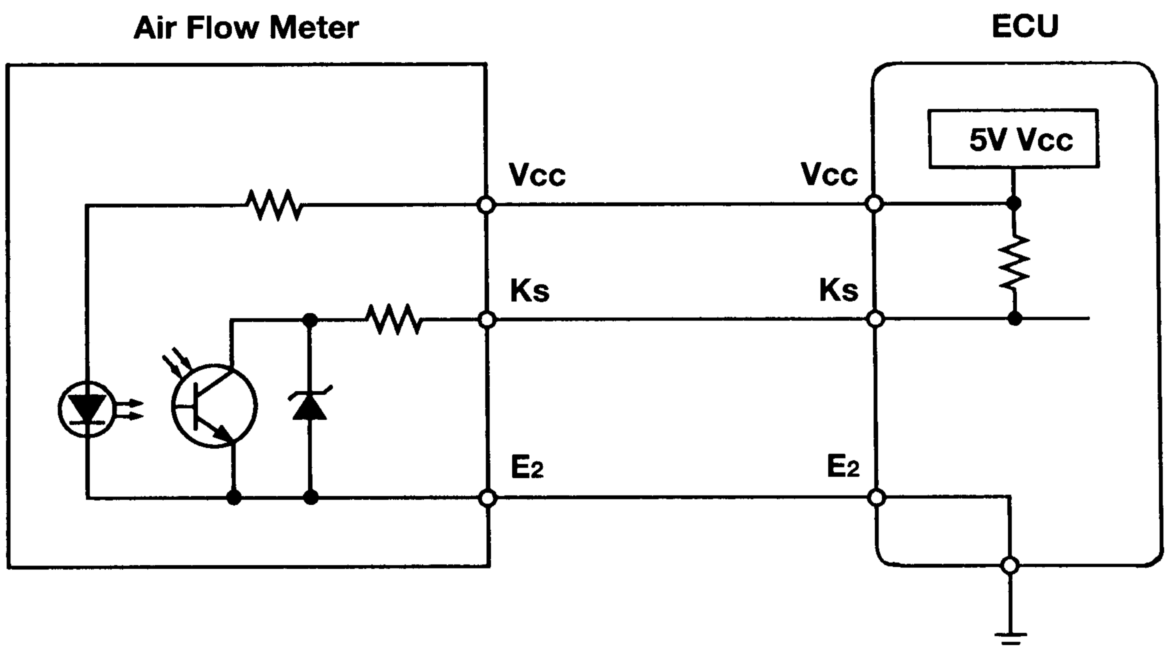
Karman Vortex Air Flow Meter Terminal Identification

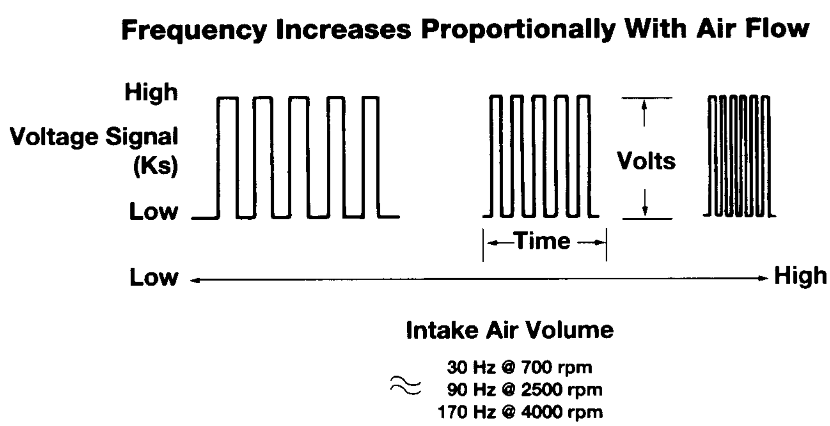
V_{CC}	Voltage Constant Control	Regulated 5 volt reference
K_S	Karman Signal	Digital frequency signal representing air flow
E_2	Earth Ground	Sensor ground return



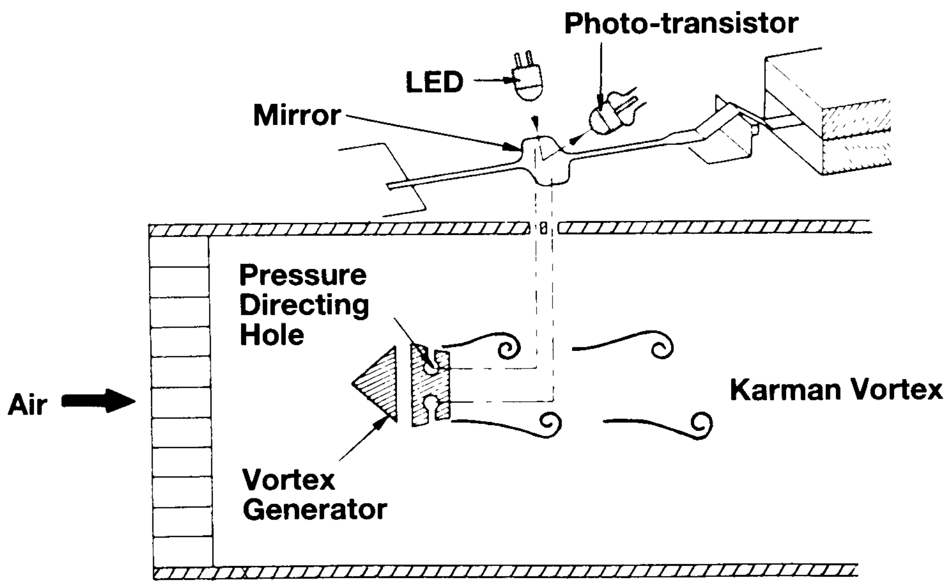
The Karman vortex air flow meter and ECU are wired as shown in the diagram. Signal characteristics are represented by the illustration of the variable frequency square wave. Because of the pull-up resistor wired between the Vcc and Ks circuit, the Ks signal will go to 5 volts if the circuit is opened.

When air passes through the air flow meter, the vortex generator creates a swirling of the air downstream. This swirling effect is referred to as a "Karman vortex." The frequency of this Karman vortex varies with the velocity of the air entering the air flow meter and other variables. The photocoupler and metal foil mirror are used to detect changes in these vortices.





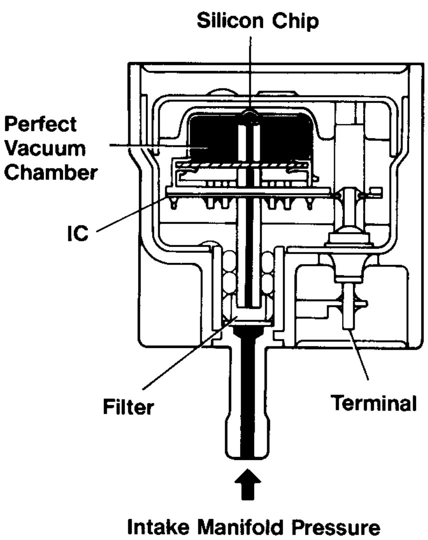
The metal foil mirror is used to reflect light from the LED to the photo transistor. The foil is positioned directly above a pressure directing hole which causes it to oscillate with the changes in vortex frequency. As the mirror oscillates, the 5 volt Vcc reference is switched to ground by a photo transistor within the sensor. The resulting digital signal is a 5 volt square wave which increases in frequency in proportion to increases in intake air flow.

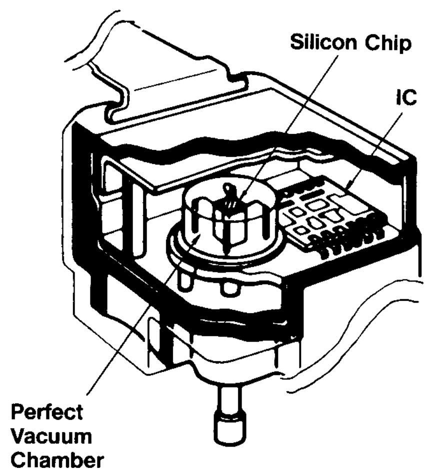


Manifold Absolute Pressure Sensor

The manifold absolute pressure sensor (sometimes referred to as vacuum sensor) is used on engines equipped with D type EFI. It is typically located somewhere on the bulkhead with a vacuum line leading directly to the intake manifold. It measures intake air volume by monitoring changes in manifold absolute pressure, a function of engine load.

The sensor consists of a piezoresistive silicon chip and an Integrated Circuit (IC). A perfect vacuum is applied to one side of the silicon chip and manifold pressure applied to the other side. When pressure in the intake manifold changes, the silicon chip flexes, causing a change in its resistance. The varying resistance of the sensor causes a change in signal voltage at the PIM (Pressure Intake Manifold) terminal.





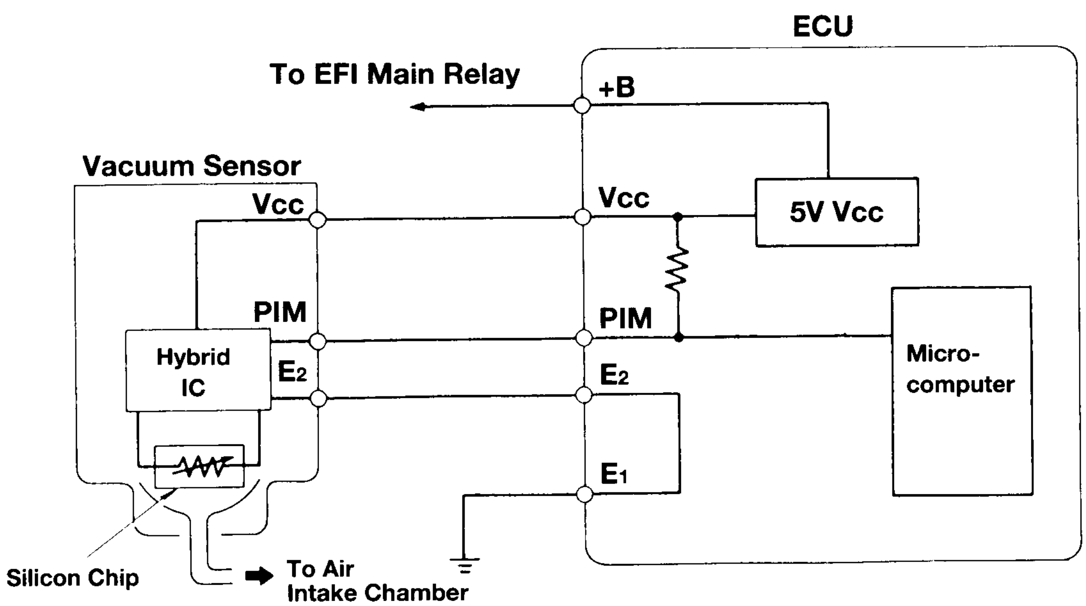
The manifold absolute pressure sensor has an electrical connector with three terminals.

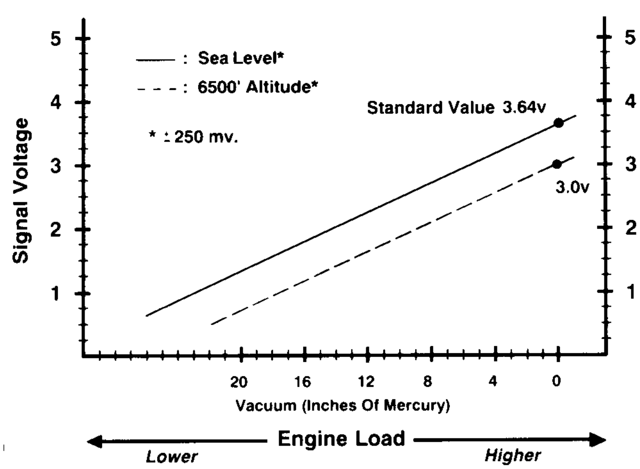
Manifold Absolute Pressure Sensor Terminal Identification

Vcc	Voltage Constant Control	Regulated 5 volt reference
PIM	Pressure Intake Manifold	Signal voltage representing manifold pressure
E2	Earth Ground	Sensor ground return path

The sensor and ECU are wired as shown in the diagram. As manifold pressure increases (approaches atmospheric pressure) there is a proportionate increase in PIM signal voltage. This analog signal characteristic is depicted in the accompanying graph.

TO check sensor calibration, signal voltage should be checked against the standards shown on the graph, and a voltage drop check should be performed over the entire operating range of the sensor.





Voltage Drop

Applied Vacuum kPa (mm Hg / in. Hg)	13.3 (100 / 3.94)	26.7 (200 / 7.87)	40.0 (300 / 11.81)	53.5 (400 / 15.75)	66.7 (500 / 19.69)
Voltage drop V	0.3 - 0.5	0.7 - 0.9	1.1 - 1.3	1.5 - 1.7	1.9 - 2.1

Engine Speed and Crankshaft Angle Sensing

On TCCS equipped engines, the Ne and G1 signals inform the ECU of engine rpm and crankshaft angle. This information, along with information from the air flow or manifold pressure sensor, allows the ECU to calculate the engine's basic operating load. Based on measured load, basic injection and spark advance angle can be accurately calculated.

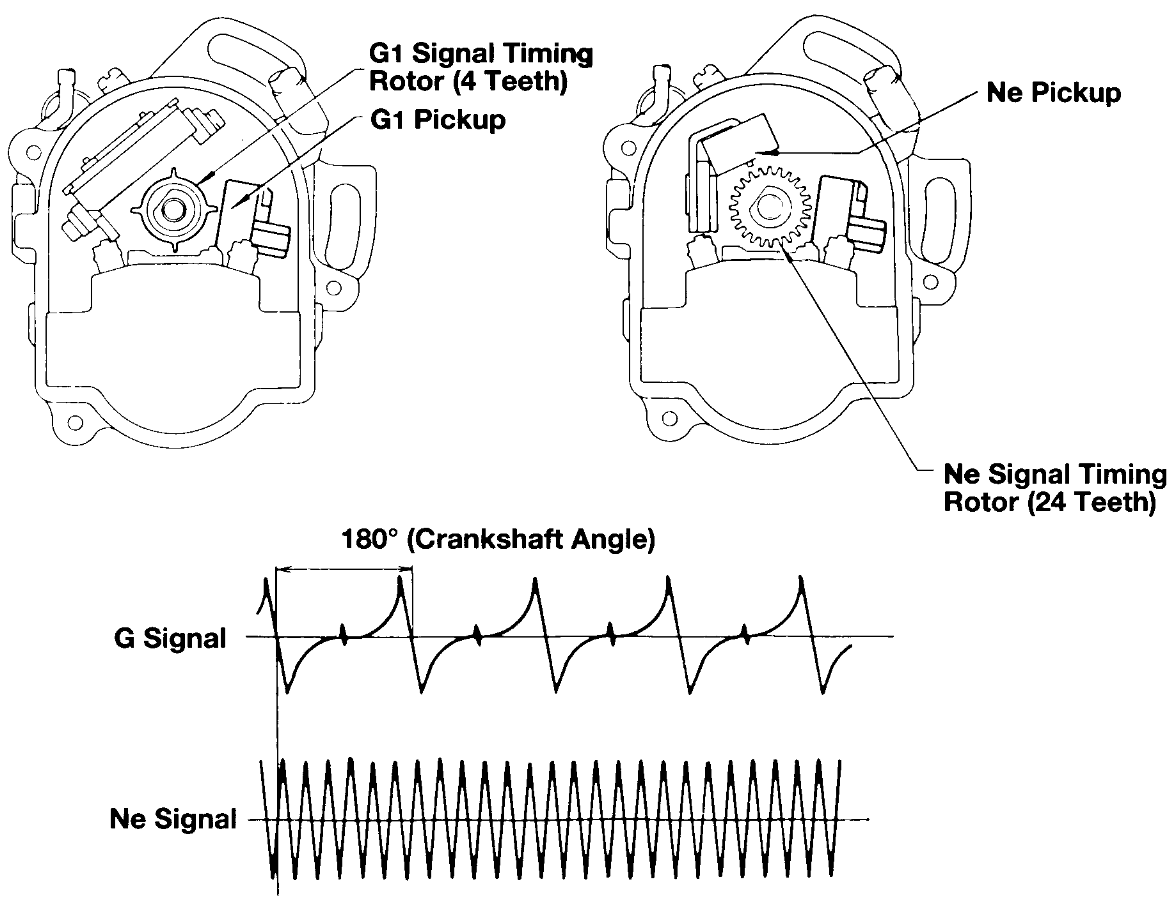
Ne Signal (Number of Engine Revolutions)

The Ne signal generator consists of a pickup coil and toothed timing rotor. The number of teeth on the signal timing rotor is determined by the system used. The Ne sensor produces an alternating current waveform signal and is of critical importance to the ECU. If this signal fails to reach the ECU, the engine will not run.

G or G1 Signal (Group #1)

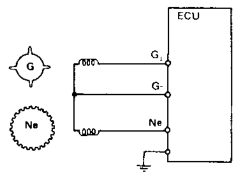
The G signal generator is very similar to the Ne signal generator. The G1 signal represents the standard crankshaft angle and is used by the ECU to determine ignition and injection timing in relation to TDC.

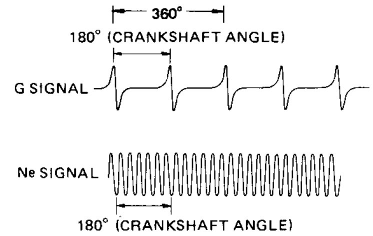
Depending on engine, there are different variations of Ne and G1 signal generators. The following illustrations show the relationship between the Ne and G1 signals and the different variations of signal generators.



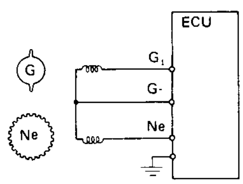
Ne AND G SIGNAL VARIATIONS

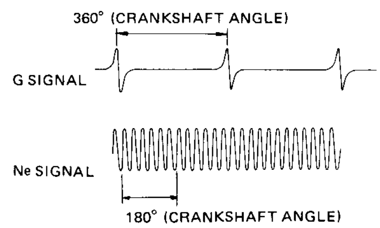
G signal (1 pickup coil, 4 teeth)
Ne signal (1 pickup coil, 24 teeth)



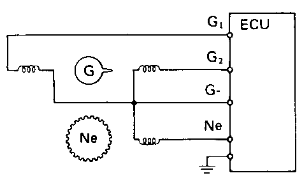


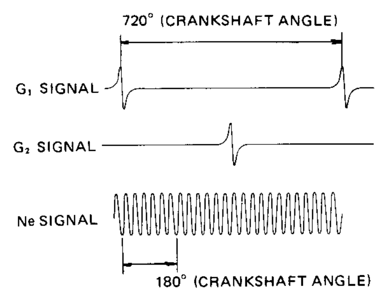
G signal (1 pickup coil, 2 teeth)
Ne signal (1 pickup coil, 24 teeth)



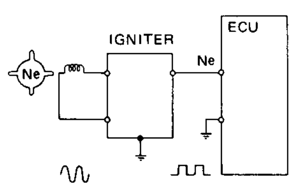


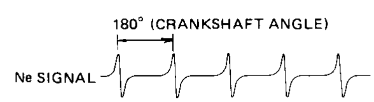
G_1 and G_2 signal (2 pickup coils, 1 tooth)
Ne signal (1 pickup coil, 24 teeth)



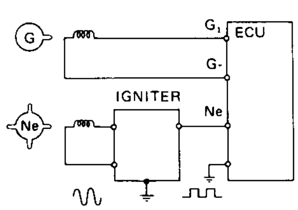


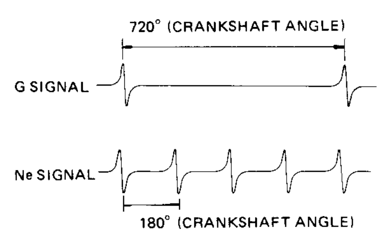
Ne signal (1 pickup coil, 4 teeth)





G signal (1 pickup coil, 1 tooth)
Ne signal (1 pickup coil, 24 teeth)

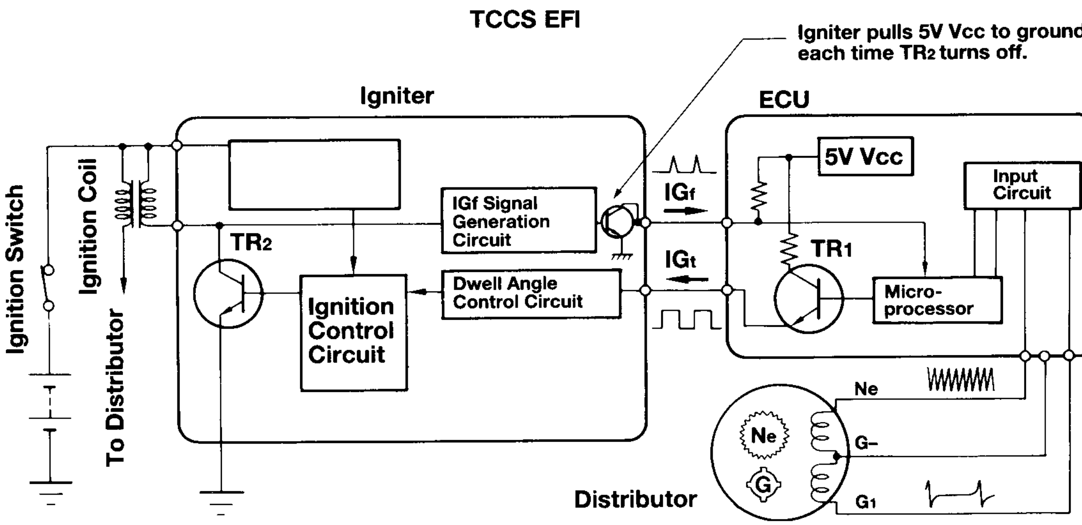




IGf Signal

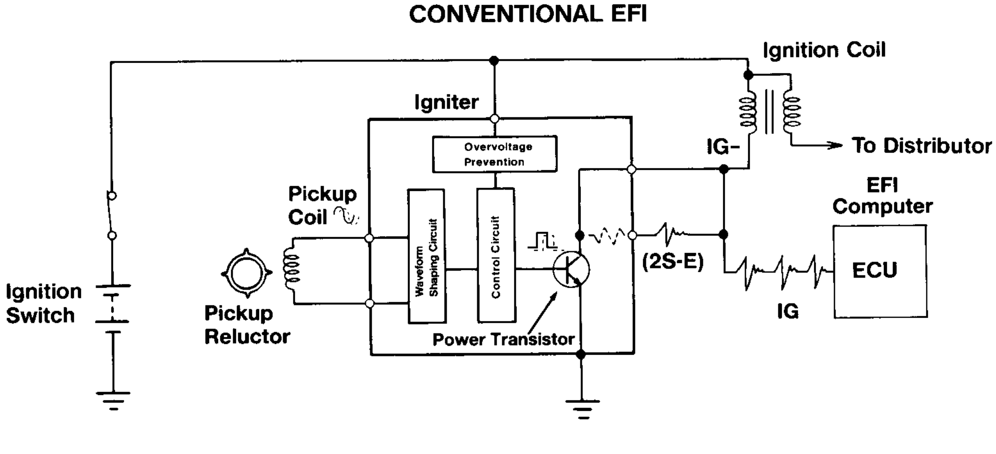
The IGf signal is generated by the igniter on EFI/TCCS systems. The ECU supplies a 5 volt reference through a pull-up resistor to the IGf signal generation circuit in the igniter. When a spark plug fires, the IGf signal generation circuit pulls the five volts to ground, causing a pulse to be sensed at the ECU. One pulse is generated by the igniter for each ignition event which is carried out.

The IGf signal confirms that ignition has actually occurred. In the event of a failure to trigger an ignition event, the ECU will shut down injector pulses to protect the catalyst from flooding with raw fuel. Typically this fail-safe shutdown occurs within eight to eleven IGt signals after the IGf signal is lost. This condition can occur with any primary ignition system fault, an igniter failure, a problem with the IGf circuit wiring, or with a faulty ECU.



IG Signal

On Conventional EFI engines, the IG signal is used to inform the ECU of engine rpm. This signal is generated directly from the coil negative terminal or from an electrically equivalent point inside the igniter on the early P-7 2S-E engine. Conventional EFI engines do not use an Ne or G sensor and do not use an IGf signal. The IG signal is also used by the ECU to trigger injection pulses; therefore, if this signal is lost, the engine will stall for lack of injection pulse.

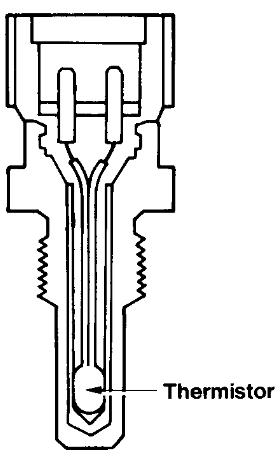


Input Sensors Used For Injection and Spark Corrections

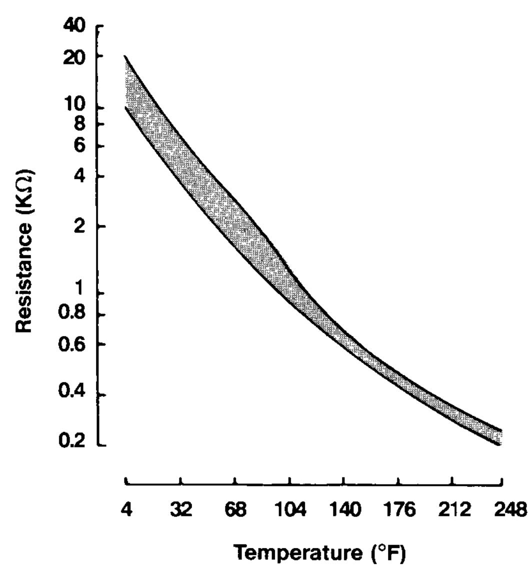
Water Temperature Sensor (THW)
The water temperature sensor is typically located near the cylinder head water outlet. It monitors engine coolant temperature by means of an internally mounted thermistor. The thermistor has a negative temperature coefficient (NTC), so its resistance value decreases as coolant temperature rises. The accompanying resistance graph demonstrates this relationship.

The water temperature sensor is required because fuel vaporization is less efficient when the engine is cold. Internal engine friction is also higher during cold operation, increasing operating load. The THW signal is used by the ECU to determine how much fuel enrichment correction is necessary to provide good cold engine performance. In addition to fuel calculations, the THW signal plays a major role is almost every other function that the ECU serves.

THW SENSOR



THW RESISTANCE

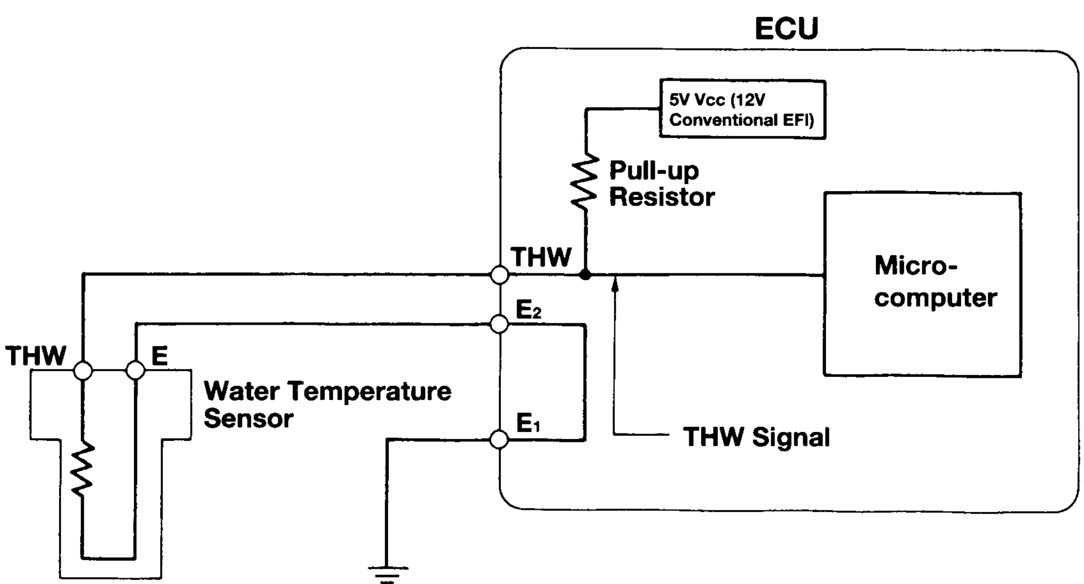


The water temperature sensor has a two terminal electrical connector attached to either end of the thermistor element.

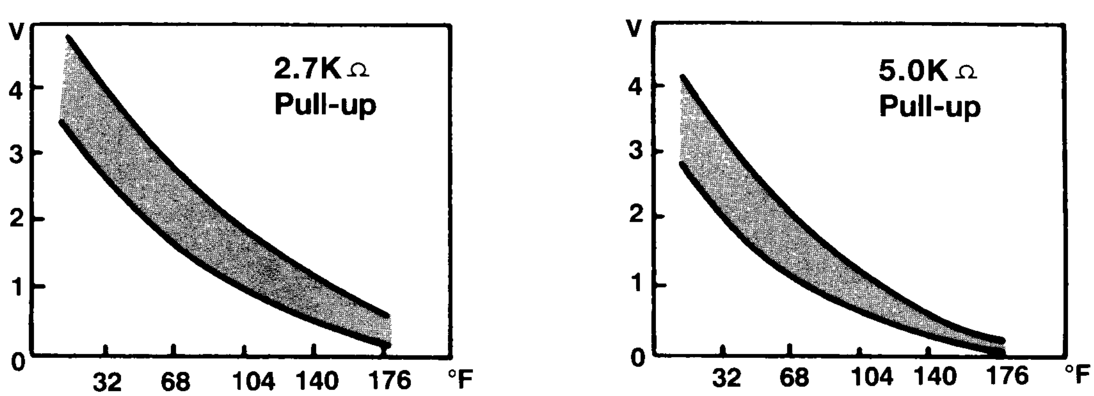
Water Temperature Sensor Terminal Identification

THW	Thermo Water Sensor	Analog signal representing engine coolant temperature
E_2	Earth Ground	Sensor ground return path

The sensor and ECU are wired as shown in the diagram. Signal voltage characteristics are determined by the value of the **pull-up resistor**, located inside the ECU, either 2.7 KΩ or 5 M. The graphs accompanying the diagram give approximate voltage specifications. To determine which pull-up resistor a particular ECU uses, refer to the technical reference charts in Appendix B of this book.

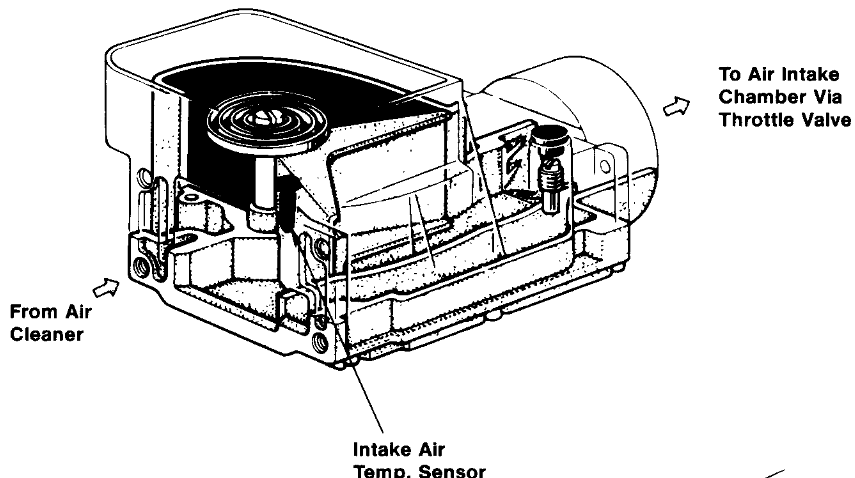


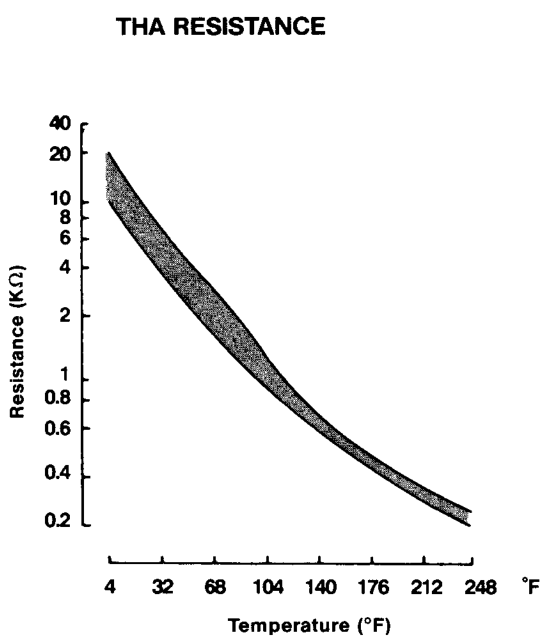
THW SIGNAL VOLTAGE

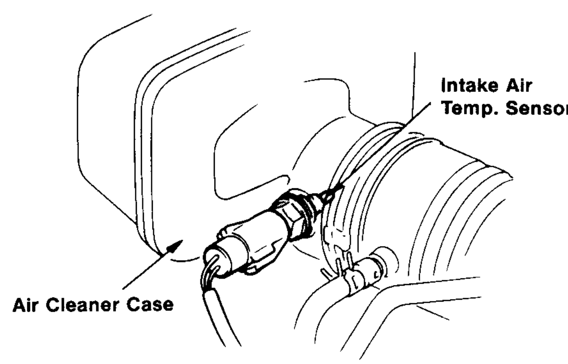


Air Temperature Sensor (THA)

The air temperature sensor monitors the temperature of air entering the intake manifold by means of a thermistor. This thermistor is integrated within the air flow meter on L type systems and located in the intake air hose just downstream of the air cleaner on D type systems. It has the same resistance characteristics as the water temperature sensor.







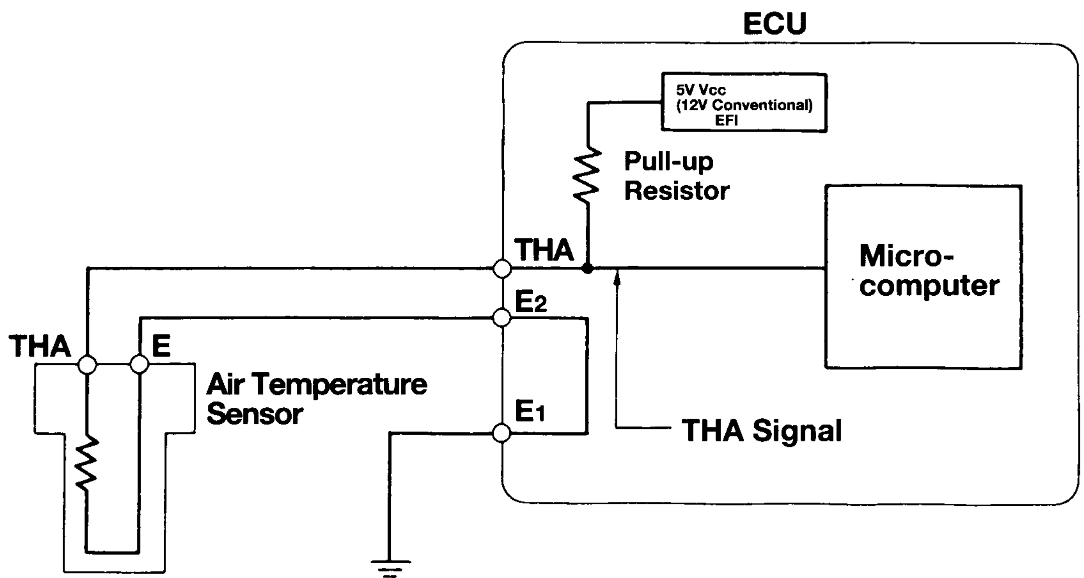
This sensor has a two-terminal electrical connector attached to either end of the thermistor element.

Air Temperature Sensor Terminal Identification

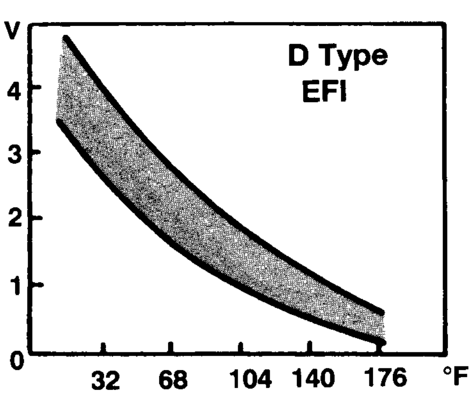
THA	Thermo Air Sensor	Analog signal representing intake air temperature
E_2	Earth Ground	Sensor ground return path

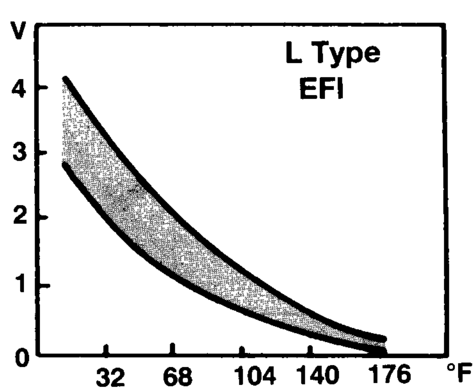
The air temperature sensor and ECU are wired as shown in the diagram. Resistance and voltage signal characteristics are represented by the accompanying graphs.

An intake air temperature monitor is necessary in the EFI system because the pressure and density of air changes with temperature. Because air is more dense when cold, the ECU factors intake air temperature into the fuel correction program.



THA SIGNAL VOLTAGE





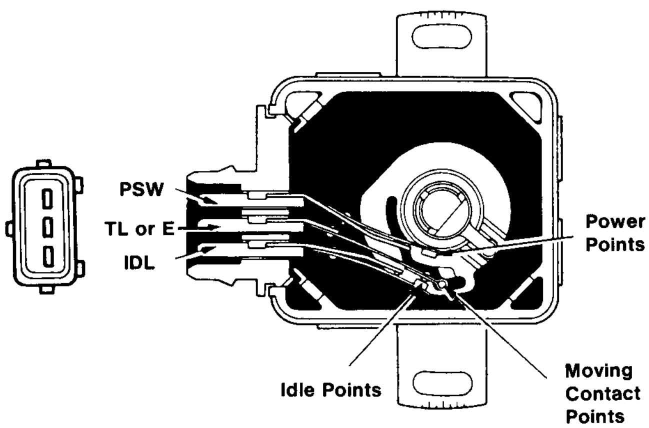
Throttle Angle and Closed Throttle Sensing

Throttle position sensors typically mount on the throttle body, directly to the end of the throttle shaft. Depending on engine and model year, Toyota EFI equipped engines use one of two different types of throttle position sensors. These sensors are categorized as on-off type and linear type. The linear type sensor is typically used on most late model Electronically Controlled Transmission (ECT) equipped vehicles.

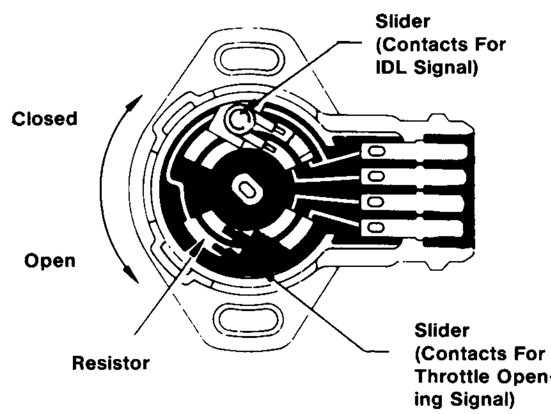
The on-off type sensor circuits can be further broken down into first and second design. This sensor is typically used on manual or non-ECT transmission equipped applications.

All throttle sensors, regardless of design, supply the ECU with vital information about idle status and driver demand. This information is used by the ECU to make judgments about power enrichment, deceleration fuel cut-off, idle stability, and spark advance angle corrections.

ON-OFF THROTTLE POSITION SENSOR



LINEAR THROTTLE POSITION SENSOR

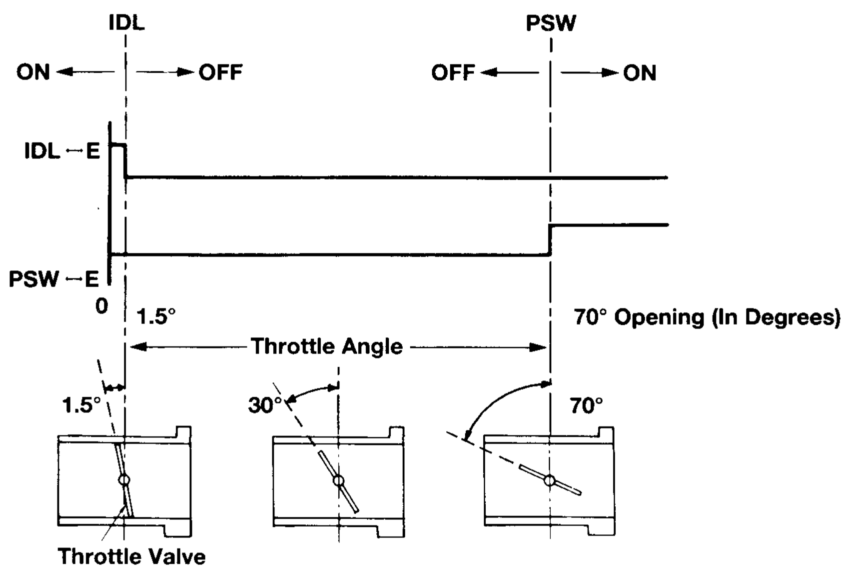


On-Off Type Throttle Position Sensors (IDL & PSW)

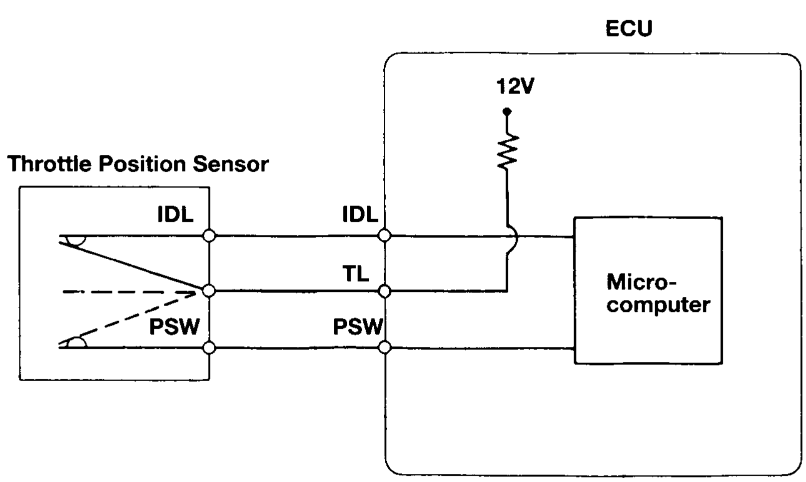
The on-off type throttle position sensor is a simple switch device which, depending on application, either pulls a reference voltage to ground or sends a battery voltage signal to the ECU. The on-off throttle position sensors are electrically wired to the ECU as shown in the accompanying diagrams.

First Design On-Off Type Sensor
The first design sensor is used on Conventional EFI engines. It utilizes a dual position contact which switches a battery voltage signal to either the IDL or PSW inputs at the ECU. This switching action causes the voltage signal at the ECU to go high whenever the switch contacts are closed.

Referring to the voltage graph, IDL signal voltage is high when the throttle is closed and goes low when the throttle exceeds a 1.5' opening. PSW voltage is low until the throttle exceeds about a 70' opening; then it goes high.



1ST DESIGN THROTTLE SENSOR



Second Design On-Off Type Sensor

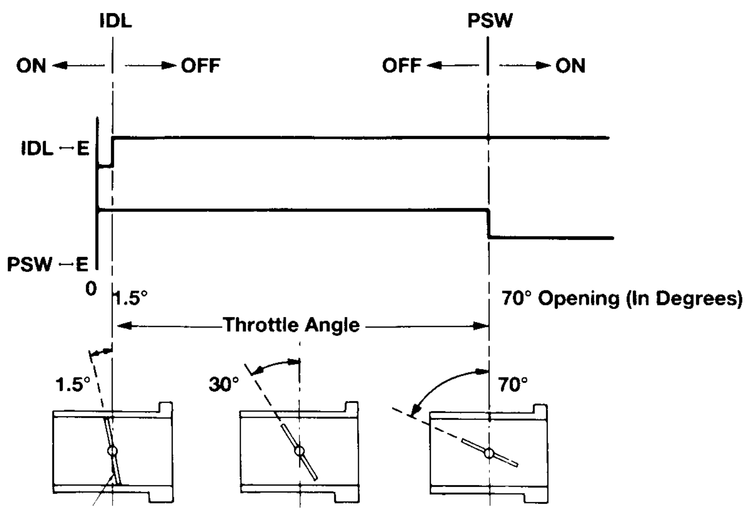
The second design sensor, which is used on many late model TCCS equipped engines, utilizes a dual position contact to switch an ECU reference voltage to ground. This switching action causes the signal at the ECU to go low whenever the switch contacts are closed.

Referring to the voltage graph, IDL signal voltage is low when the throttle is closed and goes high when the throttle exceeds a 1.5' opening. PSW voltage is high until the throttle opens to about 70'; then it goes low.

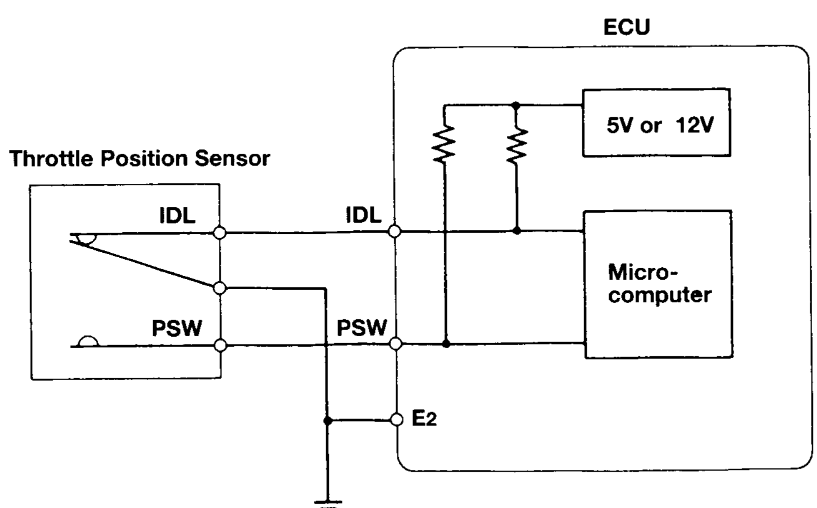
The three wire electrical connector terminals are identified as follows.

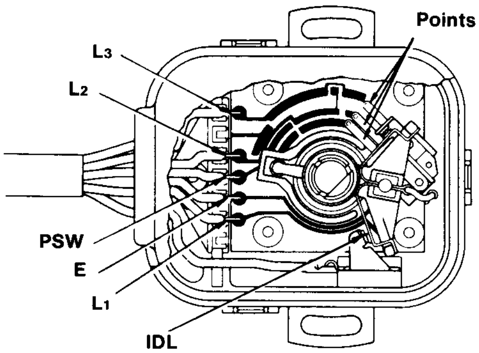
1 st and 2nd Design On-Off Throttle Position Sensor Terminal Identification

IDL	Idle Switch	Digital signal representing closed throttle status
PSW	Power Switch	Digital signal representing near wide open throttle demand
TL 1st design	Throttle Position	Power supply for throttle position sensor (from ECU)
E_2 2nd design	Earth Ground	Sensor ground return path

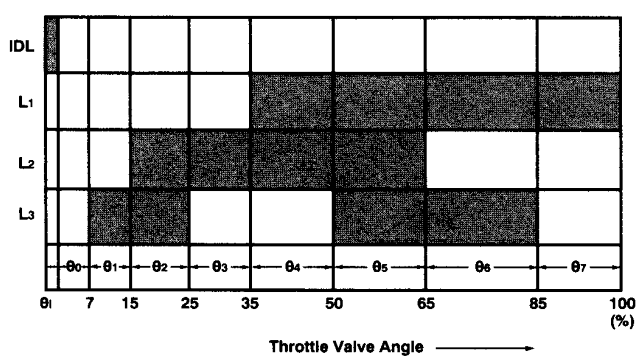


2ND DESIGN THROTTLE SENSOR



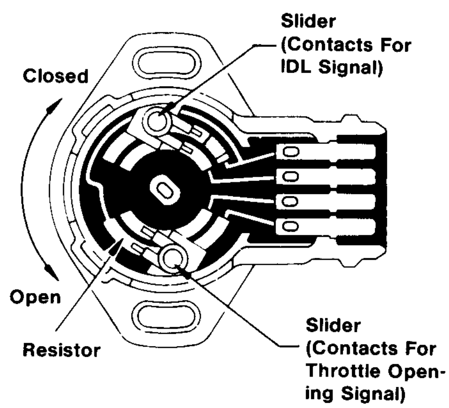


On '83 and '84 Cressidas/Supras and '83 through '86 Camrys equipped with an Electronically Controlled Transmission (ECT), a modified sensor, which incorporates three additional signal wires designated L1, L2, and L3, is used. These signals represent throttle opening angles in between the 1.5' IDL and 70' PSW signals. The L1, L2, and L3 signals are used by the ECT system and are generated in a similar manner as the IDL and PSW signals on the 2nd design sensor. The TCCS ECU only uses the IDL and PSW signals from this sensor.



Linear Throttle Position Sensor (VTA)

The linear throttle position sensor is mounted to the throttle body. It is composed of two movable contacts, a fixed resistor, and four electrical terminals. The two movable contacts move along the same axis as the throttle valve. One is used for the throttle opening angle signal (VTA) and the other for the closed throttle signal (IDL).



As the throttle opens, a potentiometer circuit converts the mechanical movement of the throttle valve into a variable voltage signal. The voltage produced by this sensor is proportional to the throttle valve opening angle.

The Linear Throttle Position Sensor has an electrical connector with four terminals.

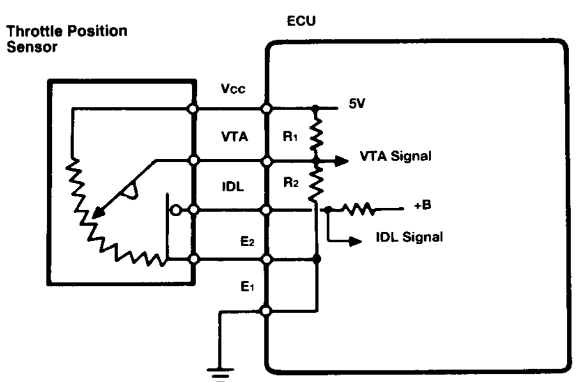
Linear Throttle Position Sensor Terminal Identification

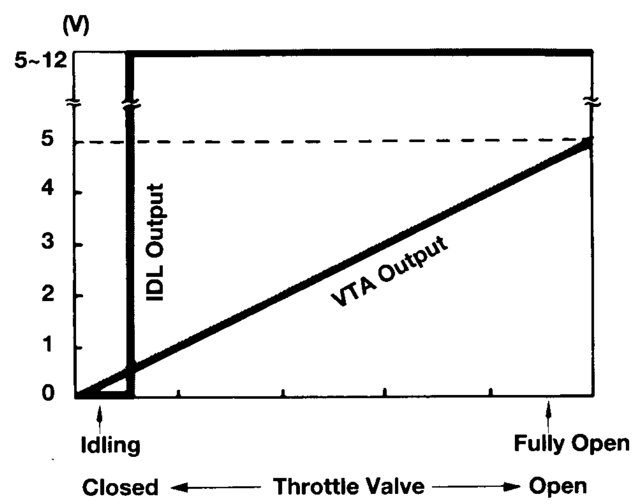
Vcc	Voltage Constant Control	Regulated 5 volt reference
VTA	Voltage Throttle Angle	Analog signal voltage representing throttle angle
IDL	Idle Switch	Digital signal voltage representing closed throttle position
E2	Earth Ground	Sensor ground return path

The sensor and ECU are wired as shown in the diagram. As the throttle valve opens, the sensor VTA contact moves closer to the voltage source, causing a signal voltage increase.

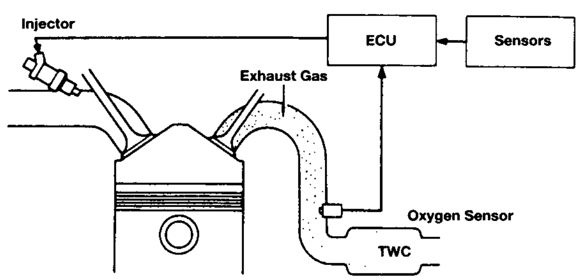
At closed throttle, the IDL contact is held closed. This pulls the IDL signal circuit to ground. As the throttle opens, the IDL contact breaks, causing the digital IDL signal voltage to go from low to high. These signal characteristics are depicted in the accompanying graph.

Resistors R1 and R2 provide self diagnostic capabilities and allow for a fail-safe voltage at the ECU in the event of an open circuit. These two resistors have a very high resistance value and essentially have no electrical effect on the circuit under normal operating conditions. They will, however, affect the open circuit voltage measured on the VTA wire at the ECU.





Exhaust Oxygen Content Sensing (OX1)
Exhaust oxygen sensors are used on Toyota EFI and EFI/TCCS equipped engines to provide air/fuel ratio feedback information to the ECU. This information is used to constantly adjust the air/fuel ratio to stoichiometry during warm idle and cruise operating conditions. The **stoichiometric** air/fuel ratio delivers one pound of fuel for each 14.7 pounds of air entering the intake manifold and results in the most efficient combustion and catalyst operation. When the electronic control system is using information from the oxygen sensor to adjust air/fuel ratio, the system is said to be operating in **closed loop**.



Exhaust oxygen sensor efficiency is dependent upon its operating temperature. The sensor will only generate an accurate signal when it has reached its minimum operating temperature of 750'F. Therefore, the oxygen sensor is typically located in the exhaust stream at the manifold collector. This location is close enough to the exhaust valves to maintain adequate operating temperature under most driving conditions and allows a representative exhaust sample from all cylinders.

Open and Closed Loop Operation
In addition to promoting efficient combustion and catalyst operation, a stoichiometric air/fuel ratio also promotes excellent fuel economy. This relatively lean mixture is desirable during cruise and idle operation; however, other operating conditions often require a richer air/fuel ratio. When the electronic control system ignores signals from the oxygen sensor and does not correct the air/fuel ratio to 14.7:1, the system is said to be operating in open loop.

In order to prevent overheating of the catalyst and ensure good driveability, open loop operation is required under the following conditions:

- During engine starting
- During cold engine operation
- During moderate to heavy load operation
- During acceleration and deceleration

During open loop operation, the ECU ignores information from the exhaust oxygen sensor and bases fuel injection duration calculations exclusively on the other input sensors.

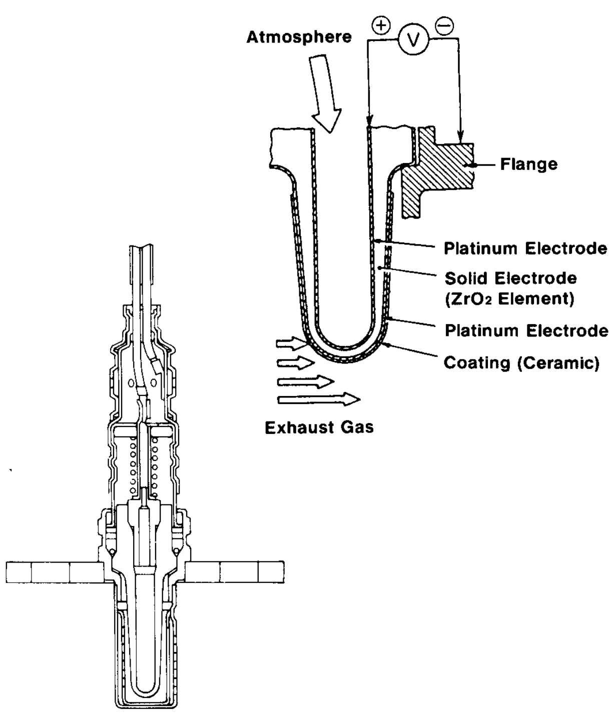
Exhaust Oxygen Sensors

Toyota engines utilize two different types of oxygen sensors. The zirconium dioxide sensor is used on all engines except the '90 and later 4A-GE Federal and 3VZ-E California 2WD truck engines. These two engines use a titania oxide sensor.

To bring the system to closed loop operation more rapidly, many engines use a heated exhaust oxygen sensor. The heated sensor provides more accurate exhaust sampling during idle and low speed operation when exhaust temperatures are relatively low. Use of a heated sensor allows closed loop operation earlier during engine warm-up cycles and also allows more flexibility in oxygen sensor location. These factors help in meeting strict exhaust emissions control standards.

Engines produced for sale in California also incorporate a Sub-Oxygen Sensor which helps improve the efficiency of the catalyst system. This sensor is located after the catalyst and is used to fine tune the air/fuel ratio delivered by the injectors, helping to optimize catalyst efficiency.

ZIRCONIUM DIOXIDE OXYGEN SENSOR



Zirconium Dioxide Sensor The zirconium dioxide oxygen sensor is an electro-chemical device which compares the oxygen content of the exhaust stream with the oxygen in an ambient air sample. It consists of a zirconium dioxide (Zr02) element sandwiched between two platinum electrodes.

This sensor behaves very similar to a single cell battery. The electrodes act as the positive (+) and negative (-) plates, and the zirconium dioxide element acts as the electrolyte.

Rich air/fuel ratio: If the oxygen concentration on the inside plate differs greatly from that on the outside plate, as it would with a rich air/fuel ratio, electrons will flow through the Zr02 element to the plate exposed to the high oxygen concentration. During rich operating conditions, the inside, or positive plate, is exposed to a much higher concentration of oxygen than the outside, or negative plate. This creates a difference in electrical potential, or voltage, which is measured by a **comparator circuit** in the E CU.

Lean air/fuel ratio: When the air/fuel ratio becomes lean, the oxygen content of the exhaust gas increases significantly. Because both plates are now exposed to a relatively high concentration of oxygen, electrons balance equally between the two plates. This eliminates the electrical potential between the plates.

Zirconium Dioxide Oxygen Sensor Operating Characteristics

Air/ Fuel Ratio	Exhaust Oxygen Concentration	Ambient Oxygen Concentration	Electron Concentration	Signal Voltage
Rich	Low	High	Positive plate	High
Lean	High	High	Positive and Negative plates	Low

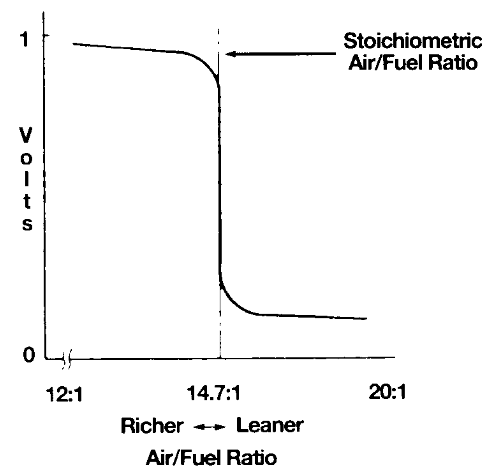
Zr02 sensor voltage signal and ECU processing: The voltage signal produced by. the oxygen sensor is relatively small. During the richest operating conditions, this signal approaches 1000 millivolts (1 volt).

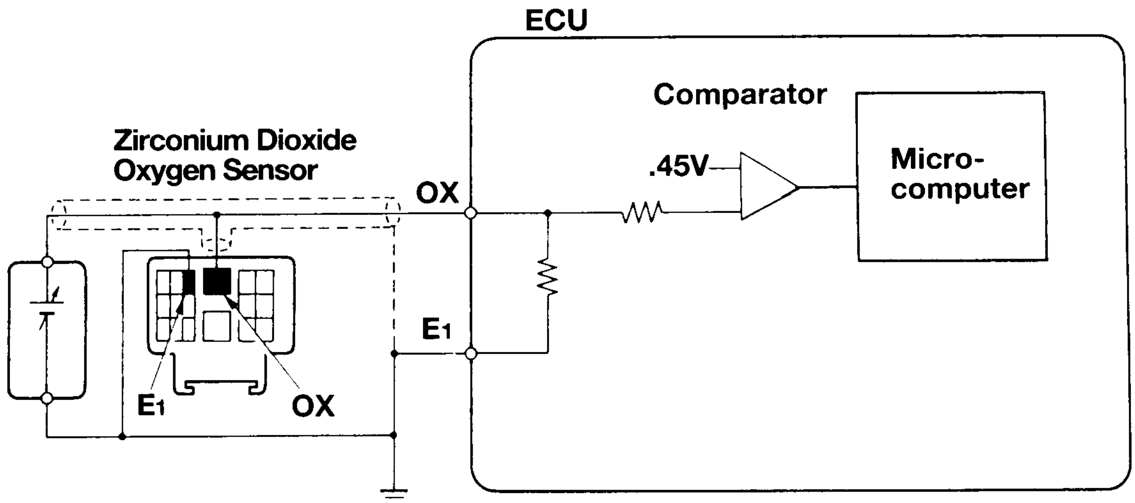
The Zr02 oxygen sensor is wired as shown in the diagram. Voltage characteristics are depicted in the accompanying graph.

As the voltage graph illustrates, the output of the Zr02 sensor acts almost like a switch. As the air/fuel ratio passes through the stoichiometric range, voltage rapidly switches from high to low.

The ECU comparator circuit is designed to monitor the voltage from the sensor and send a digital signal to the microprocessor. If sensor voltage is above the comparator switch point, z 1/2 volt, the comparator output will be high. If the sensor voltage is below the comparator switch point, the comparator output will be low. The microcomputer monitors the output of the comparator to determine how much oxygen remains in the exhaust stream after combustion occurs.

ZIRCONIUM DIOXIDE SENSOR SIGNAL VOLTAGE CHARACTERISTICS

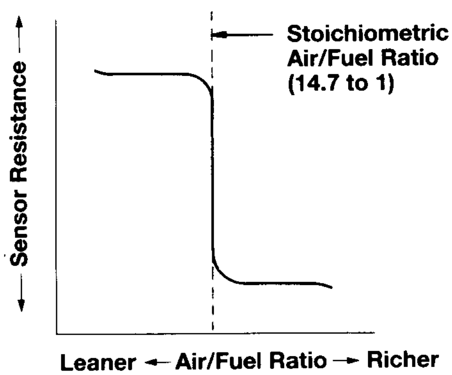


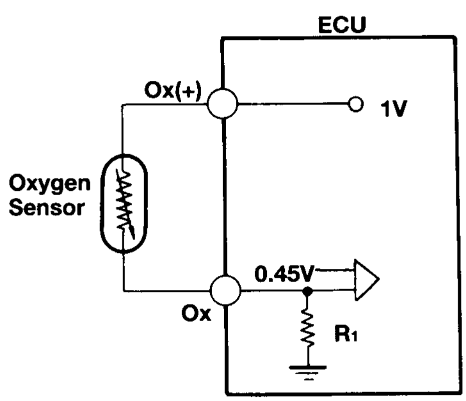


Titania Oxide Sensor This four-terminal device is a variable resistance sensor with heater. It is connected in series between the OX+ reference and a fixed resistance located inside the ECU. This circuit operates similarly to a thermistor circuit.

The properties of the thick film titania element are such that as oxygen concentration of the exhaust gas changes, the resistance of the sensor changes. As the sensor resistance changes, the signal voltage at the ECU also changes.

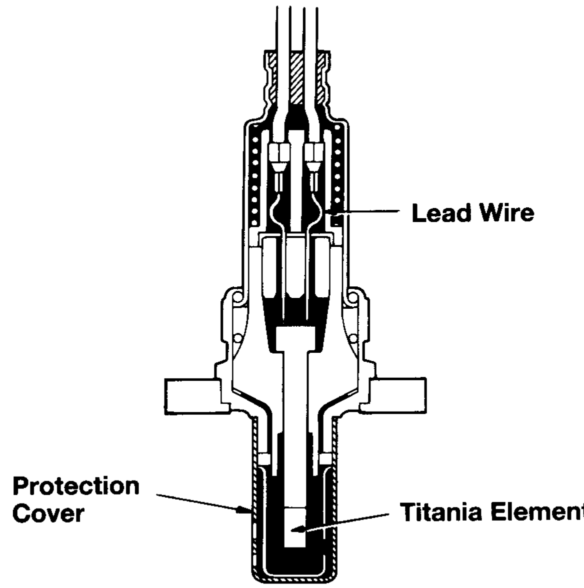
TITANIA OXIDE SENSOR RESISTANCE CHARACTERISTICS





The titania sensor and ECU are wired as shown in the diagram. A one-volt potential is supplied at all times to the OX+ terminal of the sensor. The resistance value of the sensor changes abruptly as the stoichiometric boundary is crossed. The accompanying voltage and resistance graphs depict these characteristics and their influence on OX signal voltage.

TITANIA OXIDE OXYGEN SENSOR



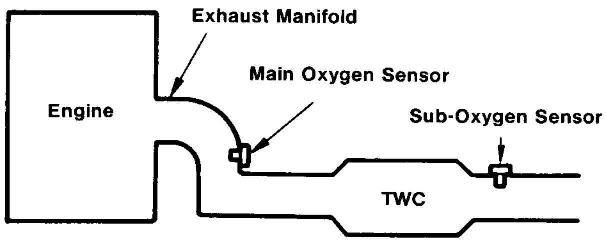
The ECU comparator circuit is designed to monitor the voltage drop across R1. As the voltage drop across the sensor increases, the drop across R1 decreases and vice versa. This gives the OX signal voltage the same characteristic as the Zr02 sensor.

If sensor voltage drop is low, as it would be with a rich mixture, OX signal voltage will be above the comparator switch point, 450 millivolts, and the comparator output will be high. If the sensor voltage drop is high, OX signal voltage will be below the comparator switch point and the comparator output will be low.

Sub-Oxygen Sensor (OX2)

The sub-oxygen sensor is used on California and some Federal engines. It is used to monitor the exhaust stream after the catalyst to determine if the air/fuel mixture is within the range for efficient converter operation.

The sub-oxygen sensor is identical to the Zr02 main oxygen sensor located ahead of the catalyst. Information from this sensor is used by the ECU to fine tune the air/fuel ratio and improve emissions.



Oxygen Sensor Terminal Identification

OX_1	Main Oxygen Sensor	Analog signal representing pre-catalyst exhaust oxygen content
OX_2	Sub-Oxygen Sensor	Analog signal representing post-catalyst exhaust oxygen content
OX	Oxygen Sensor Signal	Titania Oxygen Sensor Analog Signal
OX+	Oxygen Sensor Reference	Titania Oxygen Sensor Reference Voltage
HT	Oxygen Sensor Heater	Sensor heater current path
E_1	Earth Ground	Sensor ground return path

Oxygen Sensor Heater Circuits (HT)

Oxygen sensors work very efficiently when the sensing element temperature is above 750'F (400'C). At warm cruise, it is not difficult to maintain oxygen sensor temperatures at or above this point. However, when the engine is first started or when idling or when driving under very light load, the oxygen sensor can cool down, forcing the fuel system to return to open loop operation.

The oxygen sensor heater control system maintains sensor accuracy by turning on the heater element whenever intake air volume is low (exhaust temperatures are low under these conditions). By heating the sensor electrically, sensor detection performance is enhanced.

This allows feedback operation under conditions which might otherwise require open loop fuel control. The ECU monitors the following parameters and cycles the oxygen sensor heater on:

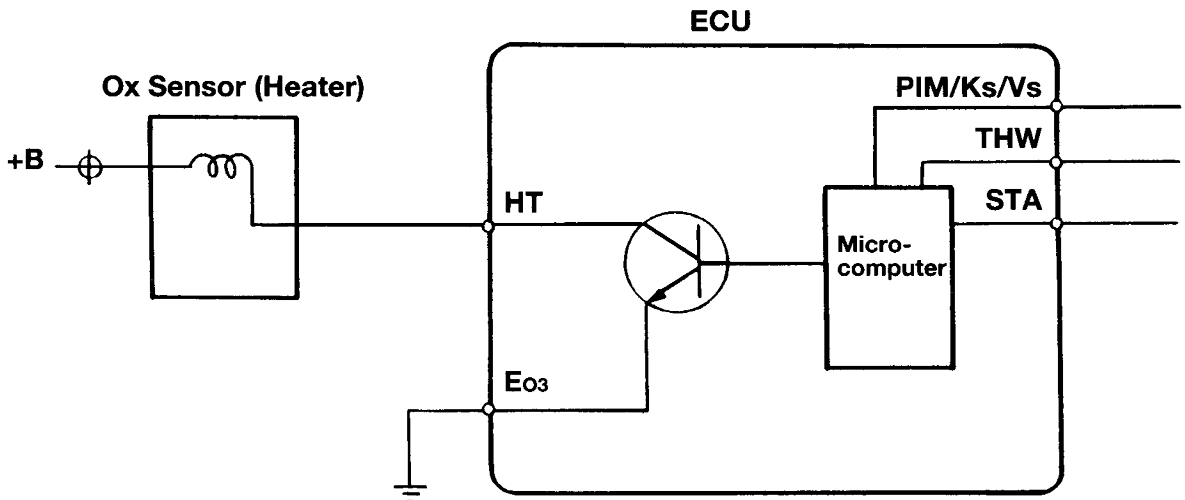
• When intake air flow is below a given point.

and

• coolant temperature is above approximately 32'F (O'C).

• specified time has elapsed after starting.

The oxygen sensor heater and ECU are wired as shown in the diagram. Whenever the above mentioned conditions are met, the ECU turns on the driver transistor to supply a ground path for heater current.

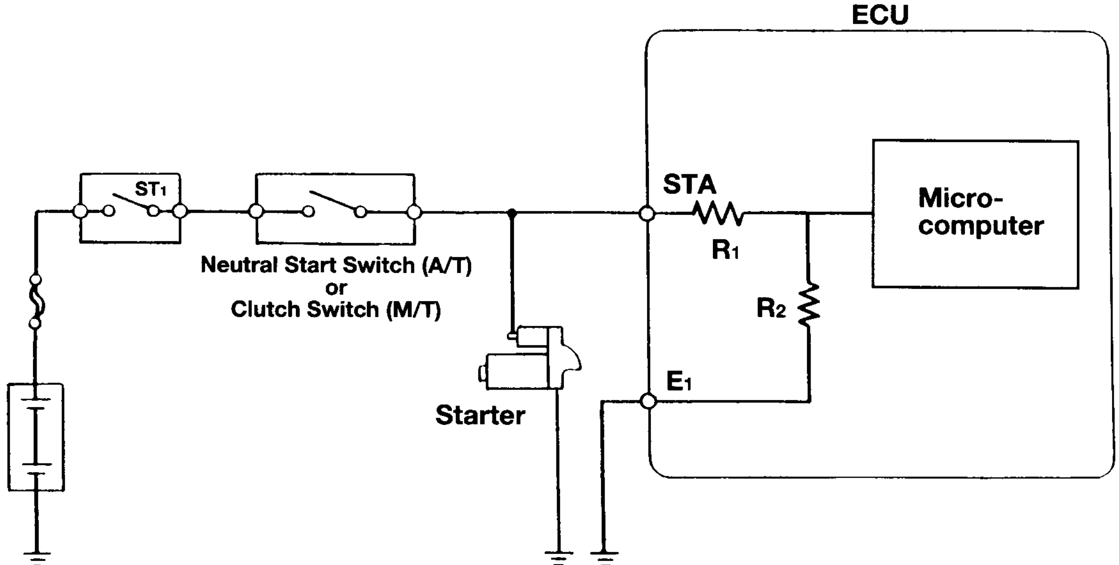


Other Inputs Affecting Injection and Spark Correction

Engine Cranking Signal (STA)

STA is a digital signal which is used by the ECU to determine if the engine is being cranked. The signal is generated at the ST1 terminal of the ignition switch and is used by the ECU primarily to increase fuel injection volume during cranking.

The STA circuit is wired to the ECU as shown in the diagram. The ECU will sense cranking voltage at the STA terminal whenever the ignition is switched to the "start" position as long as the neutral or clutch switch is closed.



Engine Detonation (Knock) Signal (KNK)

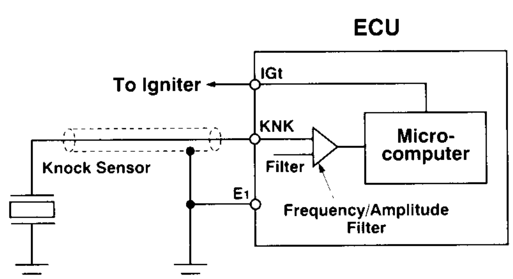
Knock Sensor

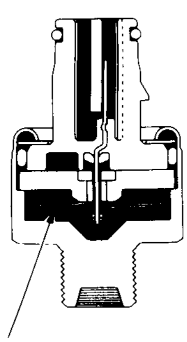
The knock sensor is a **piezoelectric** device mounted to the cylinder block which generates a voltage whenever it is exposed to vibration. When engine detonation occurs, vibration of the cylinder block causes the sensor to generate a voltage signal. The sensor signal varies in **amplitude** depending on the intensity of knock.

Typically, detonation vibration occurs in the 7KHz range (7 thousand cycles per second). Knock sensor and ECU designs take advantage of this fact.

There are two different types of knock sensors used on Toyota engines. The mass type sensor produces a voltage output over a wide input frequency range; however, its signal output is greatest at a vibration frequency of approximately 7KHz. With this type of sensor, the ECU uses a filter circuit to distinguish between background noise and actual engine knock.

The resonance type sensor is tuned into a very narrow frequency band and only produces a significant signal voltage when exposed to vibrations in the 7KHz range. The ECU requires less complicated filter circuitry with this type of sensor.

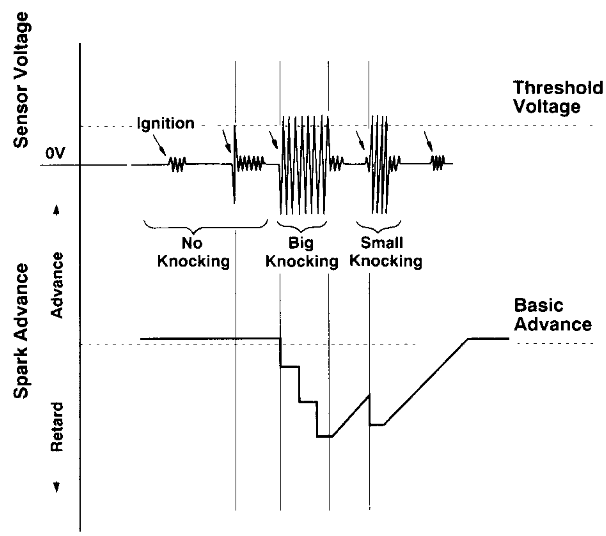




Piezoelectric Element

ECU Detonation Control

The ECU and knock sensor are wired as shown in the diagram. When engine detonation occurs, the ECU monitors knock sensor signal feedback to determine the degree of detonation taking place. This is accomplished by filtering out sensor signal voltage which does not go above preprogrammed amplitude parameters. Because other background noise and vibration cause some signal output from the knock sensor, the ECU is also programmed to filter out any signal which does not fall within certain frequency ranges.

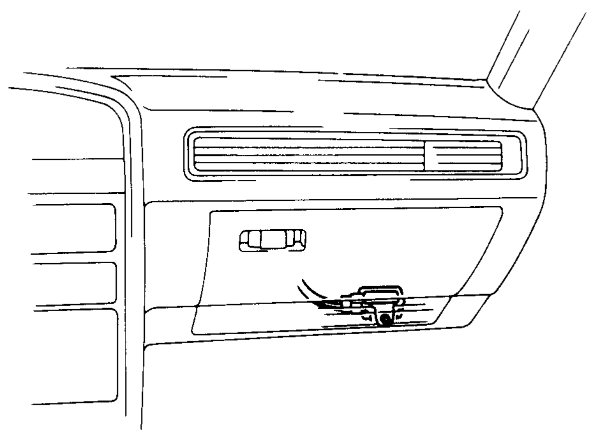


When the ECU judges that detonation is taking place, it retards ignition timing until the knocking stops. Timing is then advanced back to calculated value or, if detonation again begins, retarded again until detonation is stopped. In this manner, the ignition system can be operated at maximum efficiency, on the borderline of detonation, while avoiding an audible "ping." In the event that the ECU continues to sense detonation, timing retard is limited based on a clamp value stored in memory. If the ECU determines that the knock retard is not functional, it will enter a fail-safe mode and fix the retard angle to prevent engine damage.

Altitude Sensing (HAC)

Some TCCS equipped engines like the 3F-E, 3VZ-E (Cab and Chassis), and the 7M-GTE incorporate an altitude sensor in the TCCS system to shorten injection duration when the vehicle is operated at higher altitudes.

'87 – '88 SUPRA (7M-GTE)



Because the density of oxygen in the atmosphere is lower at high altitudes, the air volume measured by the air flow meter will not accurately represent actual oxygen entering the engine. This would result in a mixture which is excessively rich, causing emissions and driveability concerns.

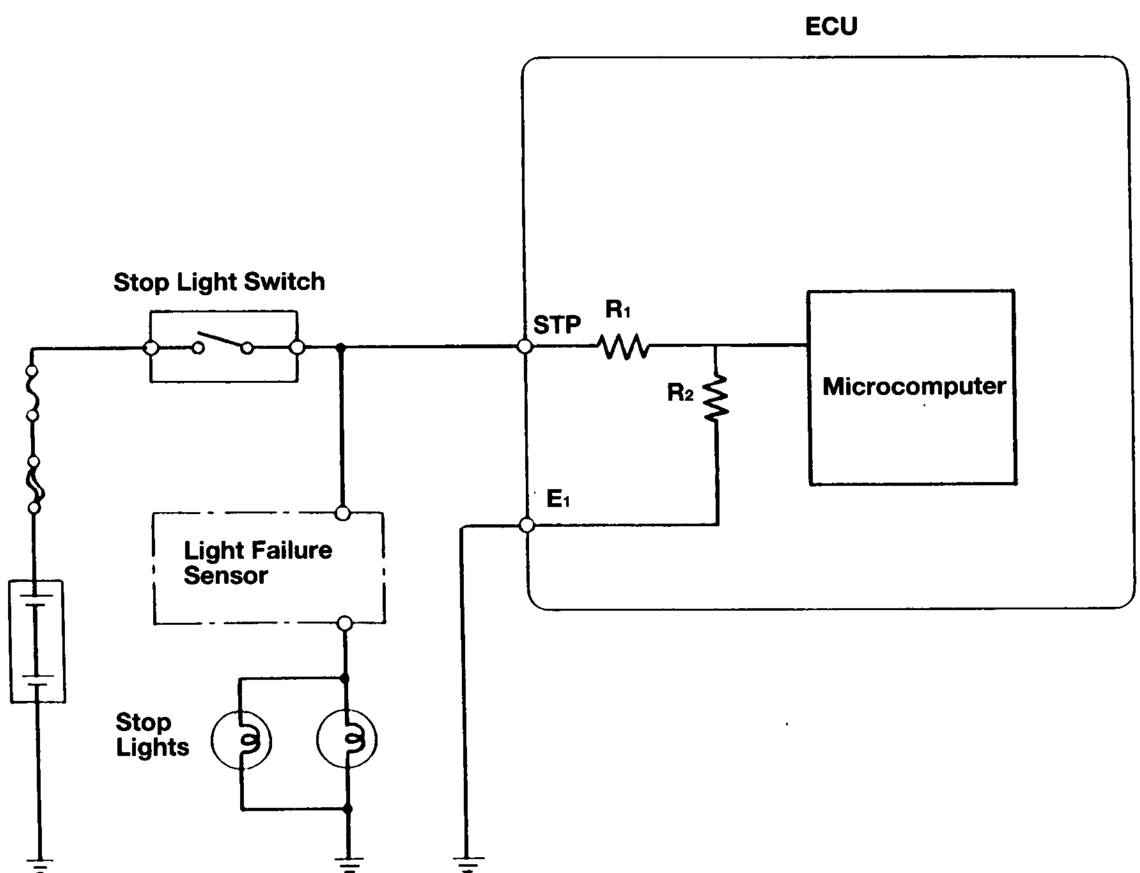
The HAC sensor is integrated with the ECU on the 3-FE, 3VZ-E, and 1989 and later 7M-GTE engines. It is remotely mounted behind the glove box on the '87 and '88 7M-GTE Supra. The remotely mounted HAC sensor is wired to the ECU exactly the same as the manifold pressure sensor is wired on D type EFI. In fact, the HAC sensor circuit is electrically the same as a manifold pressure sensor circuit. The HAC sensor simply measures atmospheric pressure rather than intake manifold pressure.

The signal from the HAC circuit in the ECU is used to determine the fuel correction coefficient to be used after basic injection has been calculated. The accompanying graph represents how this correction factor affects final injection duration.

Stop Light Switch (STP)
The stop light switch input to the ECU is used to modify the deceleration fuel cut program when the vehicle is braking. Whenever the STIR signal is high (brake pedal is depressed), fuel cutoff and resumption rpm is reduced to improve driveability characteristics of the vehicle.

In the event the STP signal is lost, fuel cut will take place at the standard deceleration speed, causing an objectionable feel when fuel is canceled.

The STP signal at the ECU will be low as long as the brake pedal is not applied. When the pedal is depressed, current flows through the normally open stop light switch to the stop lamps and the ECU, causing the STP voltage to go high.



The ECU, Process Center of the Electronic Control System

The ECU is an extremely reliable piece of hardware which has the capability to receive and process information hundreds of times per second. At the heart of the ECU is the microprocessor. It is the processing center of the ECU where input information is interpreted and output commands are issued. The process and output functions of the ECU can be divided into the following six areas:

• Fuel Injection Control

• ESA / VAST Spark Advance Control

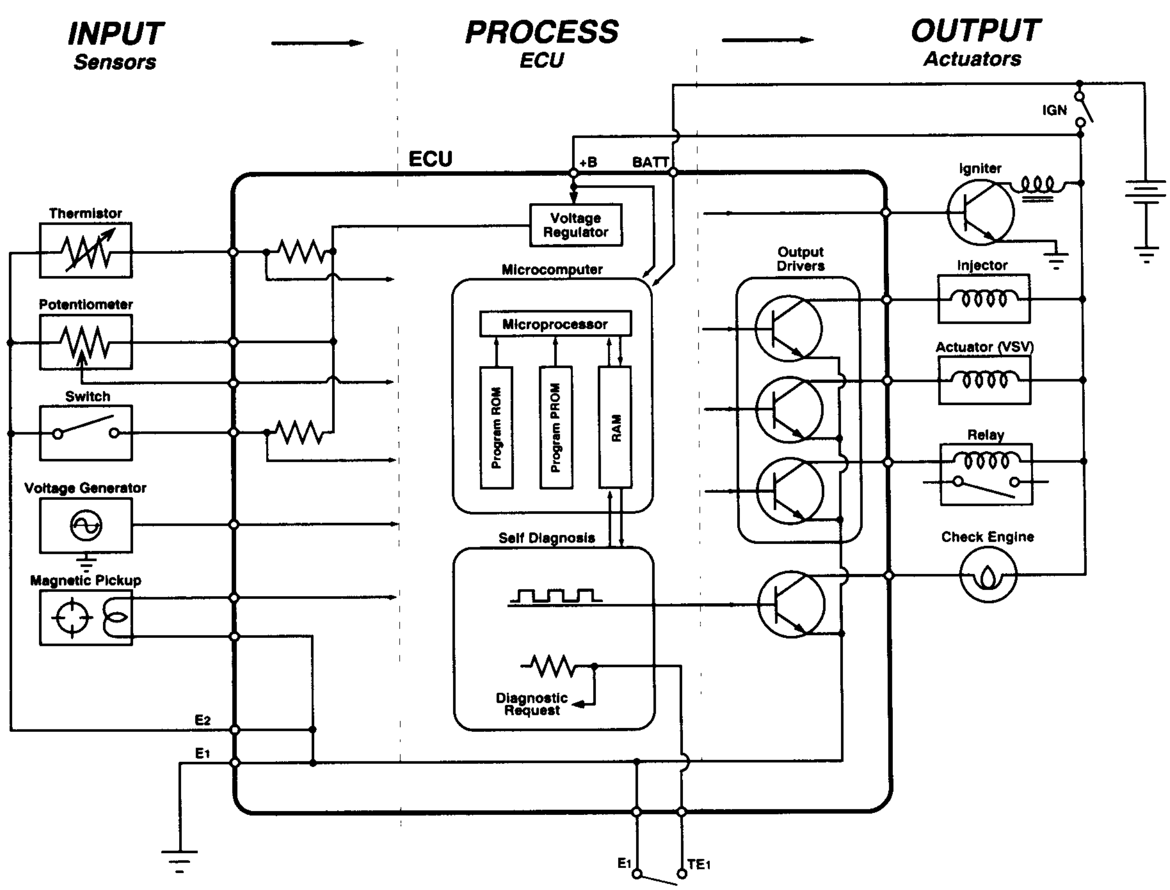
• Idle Speed Control

• Self Diagnosis

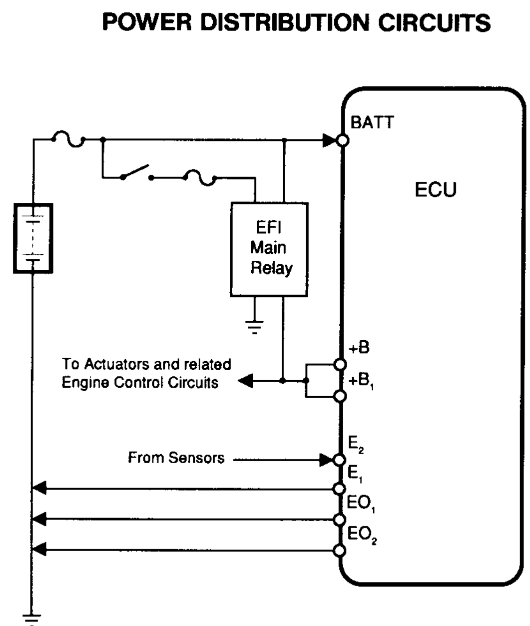
• Related Engine and Emissions Control

• Failure Management (fail-safe and back-up)

Fuel, spark, and failure management functions will be covered individually in this chapter. Idle Speed Control, related engine systems, emissions control systems, and the self diagnosis system will be the subject of chapters 6, 7, 8, and 9, respectively.



ECU Power Distribution and EFI Main Relay Circuits



The ECU cannot properly function without dependable power feeds and ground circuits. The power distribution system involves several electrical circuits, protection devices, relays, and grounds.

ECU Power Feeds

The ECU receives its ignition-switched power from the EFI main relay on all of Toyota's EFI systems. In addition to the ignition +B power feed, all P7 and TCCS ECUs have a direct battery feed, identified as BATT, supplied from either the EFI, STOP, or ECU +B fuse. The EFI main relay +B output is the power source which feeds the ECU and related engine control circuits. The direct battery feed (terminal BATT) serves to maintain voltage to the ECU **keep alive memory** when the ignition switch is off. Conventional EFI has no keep alive memory capabilities and, therefore, uses only an ignition switched power feed from the EFI main relay.

Main Relay Circuits

Toyota utilizes several different EFI Main Relay
circuits depending on application. These circuits
can be categorized into four distinct types.

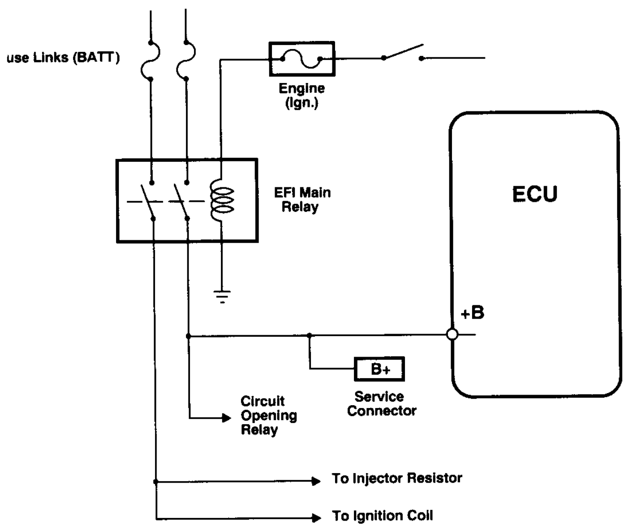
1) Dual contact EFI Main Relay, ignition switch controlled
2) Single contact EFI Main Relay, ignition switch controlled
3) Dual EFI Main Relays, ignition switch or ECU controlled
4) Single contact EFI Main Relay, ECU controlled

Generally speaking, the EFI Main Relay supplies current to the following major circuits:

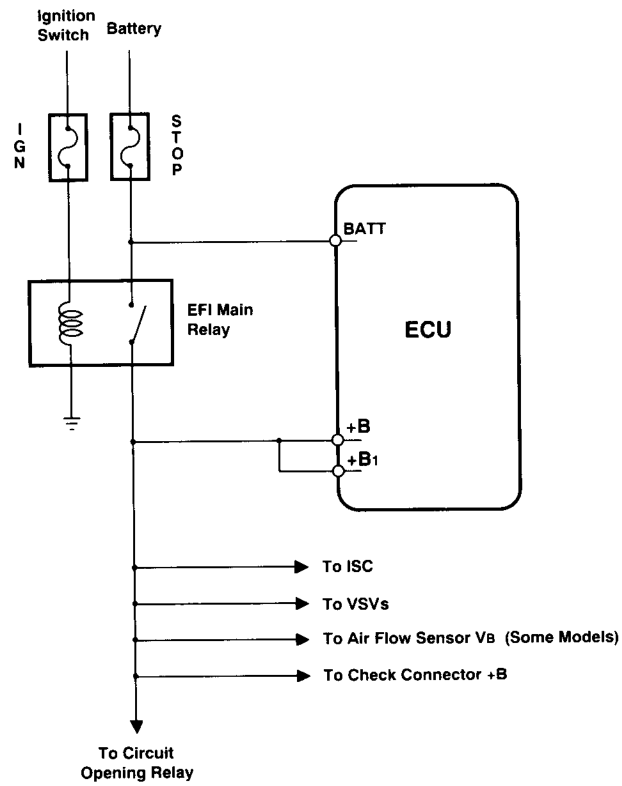
- ECU +B and +B1
- Injectors (dual relay or dual contact relay only)
- Circuit opening relay (power contact and pull-in windings)
- Air flow meter VB circuit (when so equipped)
- Output Actuator Vacuum Switching Valves (VSV)
  - Fuel Pressure Up (FPU)
  - Exhaust Gas Recirculation (EGR)
  - Throttle Opener
- ISC motor/solenoid windings
- Check connector +B terminal

Because the EFI Main Relay supplies battery voltage to the +B terminal of the check connector when the ignition switch is in the run position, this is an excellent place to perform a quick check of the relay function.

DUAL CONTACT, IGNITION CONTROLLED
CONVENTIONAL EFI (4M-E)



EFI MAIN RELAY
SINGLE CONTACT, IGNITION CONTROLLED



Dual Contact (Single Relay), Ignition Switch Controlled

This EFI Main Relay configuration is used on the Conventional EFI system. It uses separate power contacts to supply current to the fuel injector/ignition circuits and the ECU/circuit opening relay circuit. This limits current flow that the ECU power contact must handle.

This configuration improves the reliability of the relay, reduces possible voltage drop, and also isolates any inductive noise from the injectors to the EFI Computer by utilizing the battery as a large capacitor.

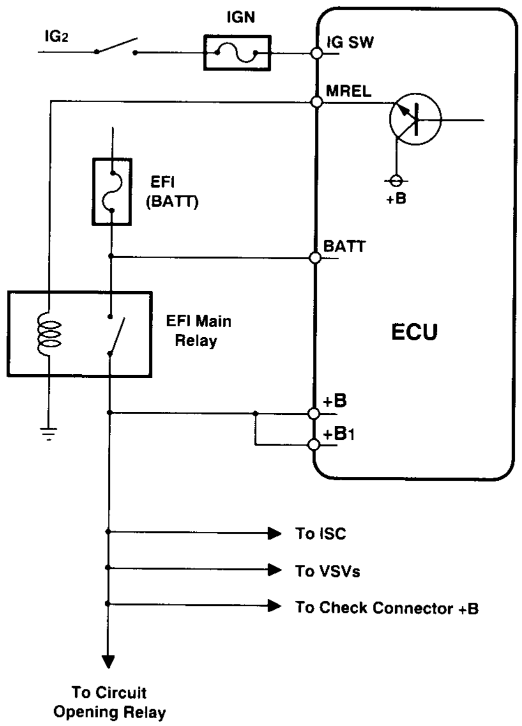
When the ignition switch is turned to the "run" or "start" position, current is supplied to the pull-in winding of the relay. Pull-in ground is wired directly to the vehicle chassis. The only power feed to the ECU on this system is the +B circuit.

Single Contact, Ignition Switch Controlled

This EFI Main Relay circuit is one of the most popular power distribution schemes used on late model TCCS equipped engines. It is used on most applications without a stepper type Idle Speed Control Valve (ISCV).

When the ignition switch is turned to the "run" or "start" position, current is supplied to the pull-in winding of the relay. Pull-in ground is wired directly to the vehicle chassis. ECU BATT voltage is supplied from the STOP fuse on these applications.

EFI MAIN RELAY
SINGLE CONTACT, ECU CONTROLLED



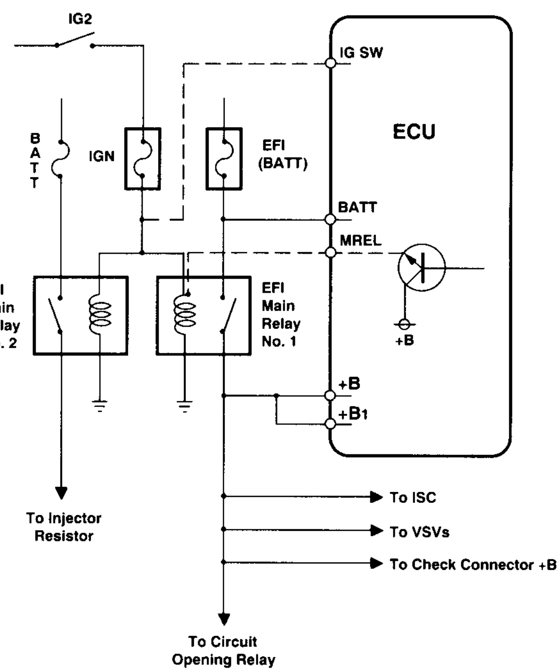
Single Contact, ECU Controlled

This EFI Main Relay circuit is used exclusively on applications equipped with the stepper type Idle Speed Control Valve. This relay is powered by the ECU rather than the ignition switch to allow control of the relay for approximately two seconds after the ignition is switched off. This allows the ECU to step the ISCV back to engine restart position after ignition power down.

When the ignition switch is turned on or engine cranked, the ECU receives a voltage signal at the IG SW terminal. This causes the ECU to supply current from the MREL terminal to the EFI Main Relay pull-in winding. The pull-in winding is grounded directly to the vehicle chassis. ECU BATT voltage is supplied from the EFI fuse on these applications.

When the ignition switch is turned off, the ECU will maintain current flow through the EFI Main Relay pull-in winding for a few seconds after power down to allow time to reset the stepper ISCV.

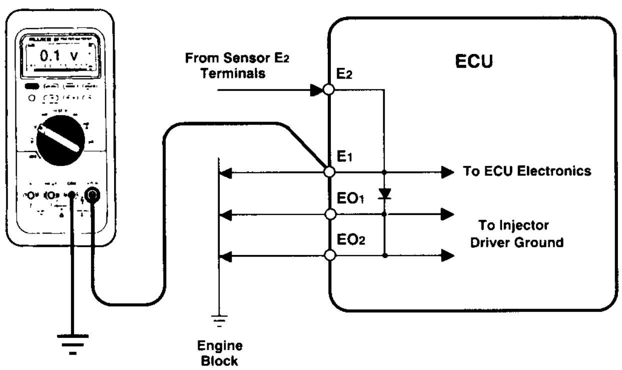
DUAL EFI MAIN RELAY
IGNITION SWITCH OR ECU CONTROLLED



Dual Relays, Ignition Switch or ECU Controlled

This configuration utilizes two separate relays identified as EFI Main Relay #1 and EFI Main Relay #2. Relay #2 supplies current to the fuel injector circuit. Relay #1 supplies current to the ECU, Circuit Opening Relay, and other circuits depending on application. If a stepper ISCV is used ('85 and '86 5M-GE), the ECU will drive relay #1 so the ISCV can be operated after the ignition is switched off.

ECU GROUND CIRCUITS



ECU Grounds and Quick Checks
No electrical circuit will function normally without a dependable ground. Toyota EFI systems use a redundant ground system which significantly reduces the chance of ground problems; however, this circuit should never be overlooked when troubleshooting ECU related systems.

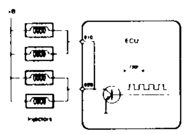
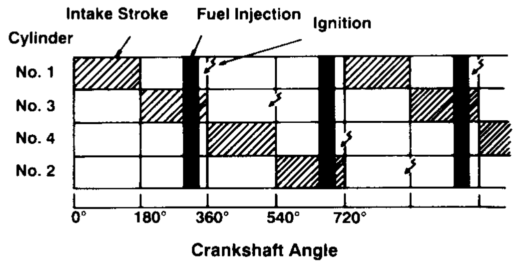
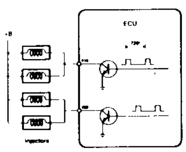
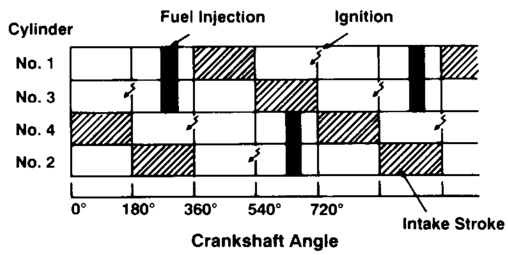
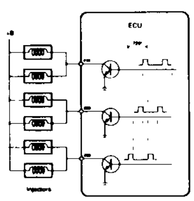
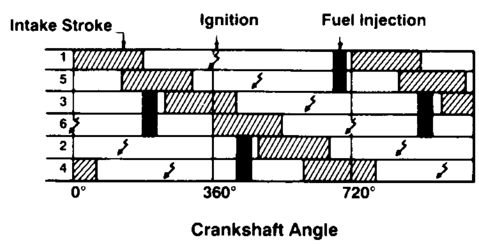
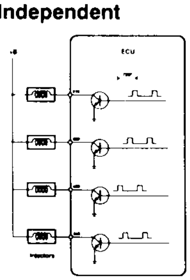
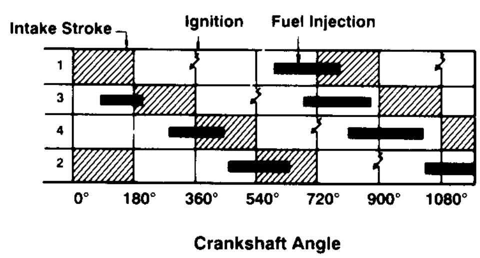
The E2 circuit serves as a signal return or sensor ground. Referring to an EWD, you will notice that the throttle position sensor, water and air temperature sensors, and air flow meter all flow current to ground through circuit E2. The ECU supplies a chassis ground through the E1 circuit which typically terminates somewhere on the engine.

Circuits E01 and E02 serve as grounds for the fuel injector driver circuits. To provide a redundant ground for the ECU, these two grounds are tied to the E1 circuit through a diode. In the event that the E1 wiring to chassis is open circuit, E1 circuit current could flow through the diode to ground. The diode serves to prevent voltage spikes from the injectors from interfering with other ECU circuits.

It is not uncommon for many or even all ECU grounds to terminate at the same point and fasten to the engine with the same fastener. Sometimes a ground fault is due to one fastener being left loose after a service procedure has been performed.

It is a fairly simple task to confirm the integrity of all ECU ground circuits in fairly short order. Two methods can be used to identify and isolate a ground fault; these are the circuit continuity check and the voltage drop check. These procedures along with checks of the power distribution circuits are addressed in exercises 5-1 and 5-2.

Fuel Injection Control

Injection Pattern	Injection Timing	Engines
Simultaneous 		4K-E, 4A-FE 2S-E, 3S-FE, 5S-FE (GEN 1) 4M-E, 5M-E, 5M-GE, 3Y-E, 4Y-E 22R-E, 22R-TE 3VZ-E, 3F-E 3E-E
2 Groups 		4A-GE (L type EFI) 4A-GZE 5S-FE (GEN 2) 5E-FE
3 Groups 		7M-GE 7M-GTE 2VZ-FE
Independent 		3S-GE 3S-GTE 3VZ-FE

Injector Timing

Injection Timing Control

Injection timing control determines when each injector will deliver fuel to its corresponding intake port. There are three different methods of injector timing used on Toyota engines, depending on application. These methods are Simultaneous, Grouped, and Independent injection.

Simultaneous Injection

All injectors are pulsed simultaneously by a common driver circuit. Injection occurs once per crankshaft revolution just prior to the crankshaft reaching TDC cylinder *1. This means that twice per engine cycle one half of the calculated fuel is delivered by the injectors. This is the simplest and most common injection timing method in use.

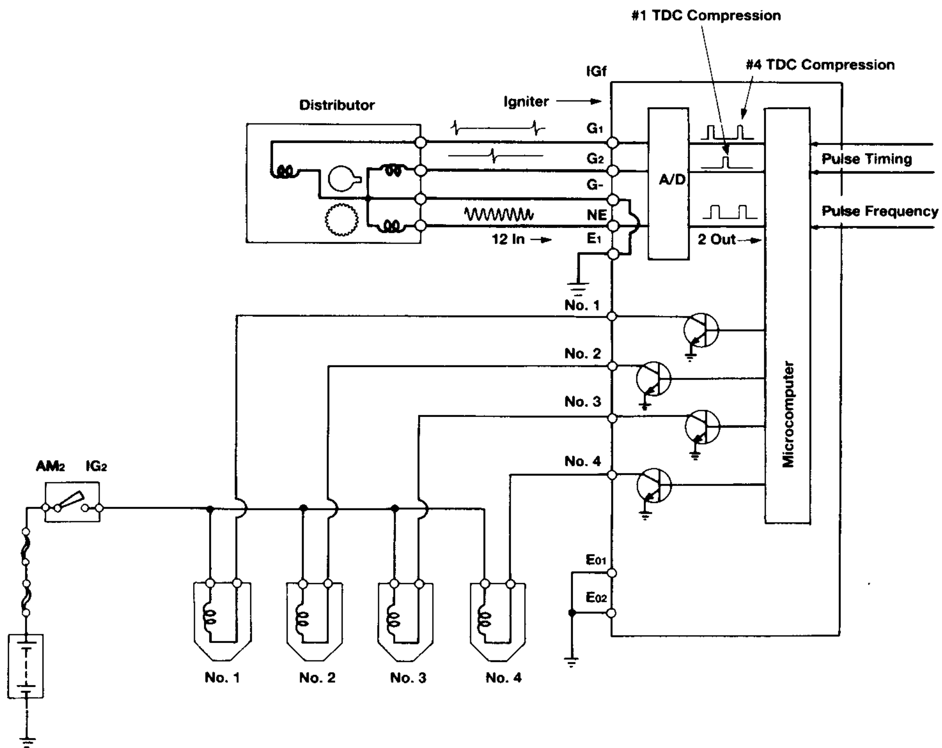
Grouped Injection

Injectors are grouped into pairs. The pairs consist of two consecutive cylinders in the firing order; each pair is driven by a separate driver circuit. Four cylinder engines use two groups, six cylinder engines three groups, and the 1UZ-FE V8 engine uses four groups of injectors.

Injection is timed to deliver fuel immediately preceding the intake stroke for the leading cylinder in the pair. The entire group is pulsed once per engine cycle, delivering the entire calculated charge of fuel. This timing method ensures that fuel does not linger behind the intake valve, thereby, reducing emissions, improving fuel economy and throttle response.

Independent Injection

Injectors are driven independently and sequentially by separate driver circuits. Injection is timed to deliver the entire fuel charge just prior to each intake valve opening. This timing method provides optimum engine performance, emissions, and fuel economy.



Input Signals Required to Pulse Injectors

There are three signals which are necessary to operate the fuel injectors. These are the Ne, G, and IGf signals. Inside the ECU, the Ne Signal is used to produce an injection chive signal. The G signal is used to determine the timing of the injection signals. The IGf signal is monitored for fuel delivery fail-safe. (With Conventional EFI, the IG signal is used to produce the injection drive signal.)

The ECU cannot pulse the injector without an Ne signal and will not start or run if this signal is not present. If the G signal is not present while cranking the engine, the ECU will not be able to identify when to produce the injection signal. The result will be the same, no injection pulse. If the IGf signal is not present, the ECU will go into fuel fail-safe by stopping injection pulses.

If, however, the ECU loses the G signal with the engine running, the engine will continue to run because the timing of injection signals is locked in once the engine starts.

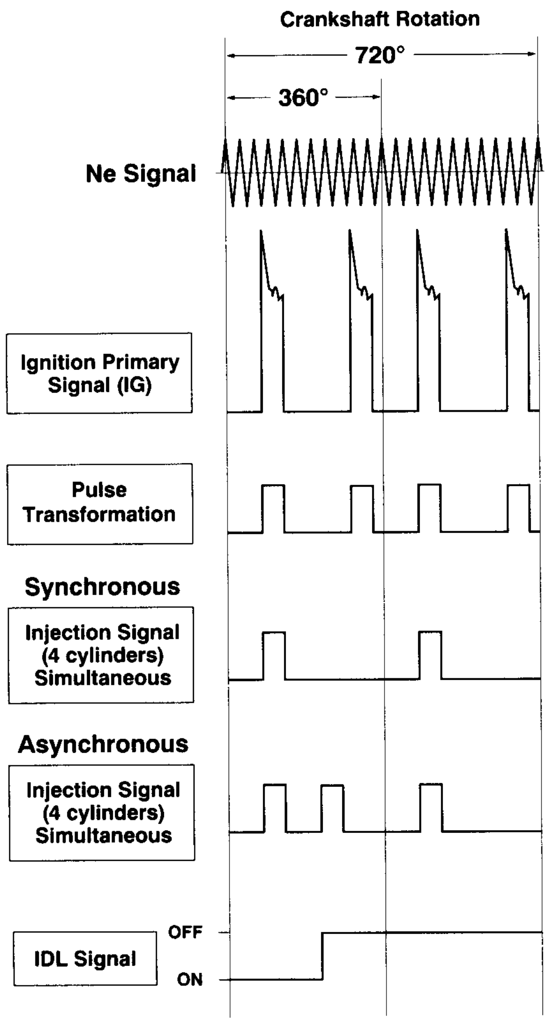
Signal	Engine Condition When Signal Lost	Effect on Injection and Spark
N_e	Cranking	No spark, no injection pulse, engine will not start
N_e	Running	Engine stalls, no spark, and no injection pulse
G_1*	Cranking	Engine will not start, no injection pulse, no spark
G_1*	Running	Engine will continue to run, signal only necessary for starting
IG_f	Running or Cranking	Engine will not start or run, no injection pulse

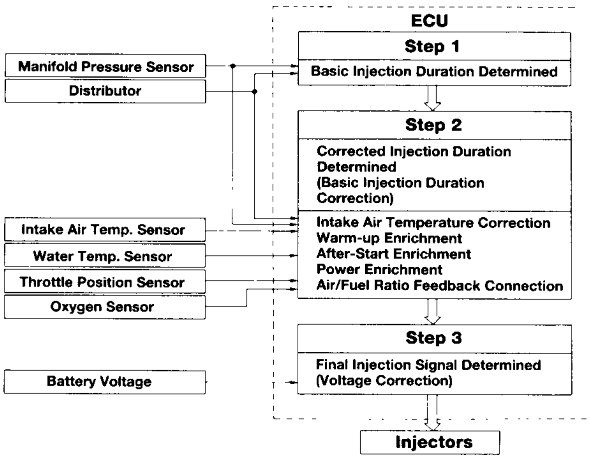
* Applications with G_2 will default to either G sensor if the other sensor fails.

Injector Operating Modes
There are two injection operating modes used by the ECU, depending on engine operating conditions. These modes are called synchronous and asynchronous.

Synchronous Injection
Synchronous injection simply means that injection events are synchronized with ignition events at specific crankshaft angles. Synchronous injection is used a great majority of the time.

Asynchronous Injection
Asynchronous injection is only used during acceleration, deceleration, and starting. It occurs independently of ignition events based on change in idle contact (IDL) or start switch (STA) status without regard to crankshaft angle.





ECU Control of Injector Duration

An Overview of Injection Duration Calculations
Determination of final **injection pulse width** is the function of a three-step process.

Step 1, Basic Injection Duration
The first step involves calculation of basic injection duration. Input sensors used in basic duration calculation are:

- Air Flow Meter (Vs or Ks)
- Manifold Pressure Sensor (PIM)
- Engine rpm (Ne)

The ECU calculates basic injection duration based upon engine speed and air flow volume. These two inputs considered together establish an engine load factor. The ECU monitors the Air Flow Meter signal or Manifold Pressure Sensor for intake air volume information and the Ne signal for engine speed information.

- As either of these parameters increase, injection duration is increased.

Step 2, Injection Duration Correction Factors
The second step involves duration corrections. Input sensors used for injection duration corrections are:

- Engine Water Temperature (THW)
- Intake Air Temperature (THA)
- Throttle Angle (VTA or IDL & PSW)
- Exhaust Oxygen Content (OX)

Once basic injection duration is calculated, the ECU must modify the injection duration based on other changing variables. Variables considered in the correction calculation are coolant and intake air temperature, throttle position and exhaust oxygen sensor feedback (when operating in closed loop).

- As engine and intake air temperatures move from cold to warm, injection duration is reduced.
- As the throttle opens (IDL contact break), injection frequency is momentarily increased.
- Fuel injection duration swings back and forth between longer to shorter durations to correct conditions detected by the exhaust oxygen sensor.

Step 3, Battery Voltage Correction
The final step is a battery voltage correction. The input signal used in battery voltage corrections is: 0 Battery Voltage (+B)

There is an operational delay between the time the ECU sends the injection signal to the driver circuit and the actual opening of the injector. This delay changes with the strength of the magnetic field around the injector coil. The delay increases as battery voltage falls.

To determine final injection duration, the ECU corrects for injector opening delay by using a battery voltage **correction coefficient.**

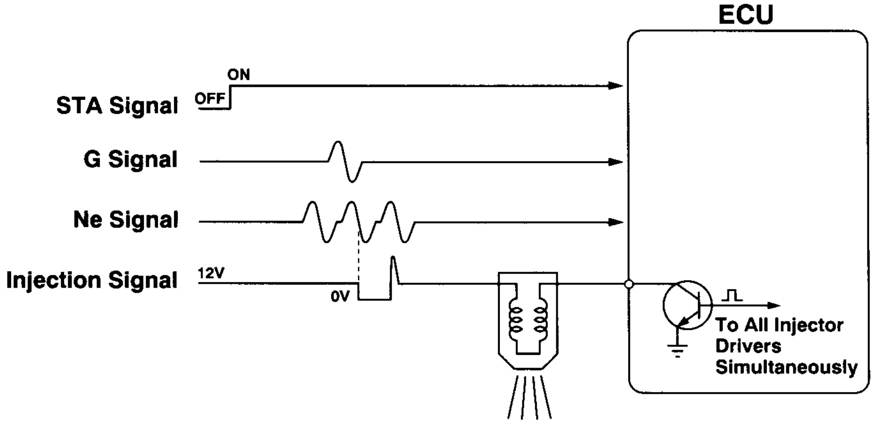
- The battery voltage correction coefficient increases injection duration as sensed battery voltage falls.

ECU Injection Strategy While Starting

Prime Pulse

Because the rpm and intake air volume signals are erratic at cranking speed, injection duration calculation is done differently while the engine is cranking, compared to all other operating conditions.

- To prime the engine upon initial cranking, all injectors are pulsed in an asynchronous mode one time immediately after a G and Ne signal are received.

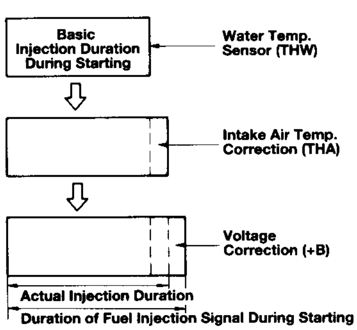


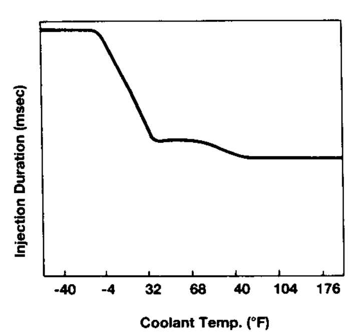
Starting Injection Control

To provide accurate fuel injection duration during cranking periods, the ECU uses a program which determines a basic injection volume based on engine coolant temperature. Once a basic injection duration is calculated, corrections are made for intake air temperature and battery voltage (which is typically low under cranking load).

- Basic injection duration while cranking is increased at low coolant temperatures.
- Injection duration while cranking is corrected for intake air temperature by increasing duration at low intake air temperatures.
- Injection duration while cranking is corrected for battery voltage by increasing injection duration at lower voltage.

The graph represents the basic cranking enrichment strategy used by the ECU. Note that at temperatures below freezing, basic injection duration increases drastically to overcome the poor vaporization characteristics of fuel at these temperatures.





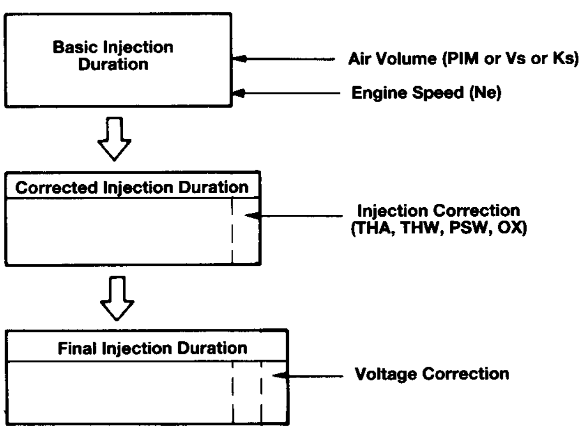
Engine Running Injection Duration Calculation

After Start-up Enrichment
To stabilize the engine immediately after starting, for a short period of time after starting, the ECU supplies extra fuel to the engine to ensure a smooth transition from cranking to running. The maximum enrichment value is determined by the coolant temperature signal, THW.

Basic Injection Calculation
Once the engine has stabilized, engine rpm information and intake air volume measurements are used to determine basic injection duration.

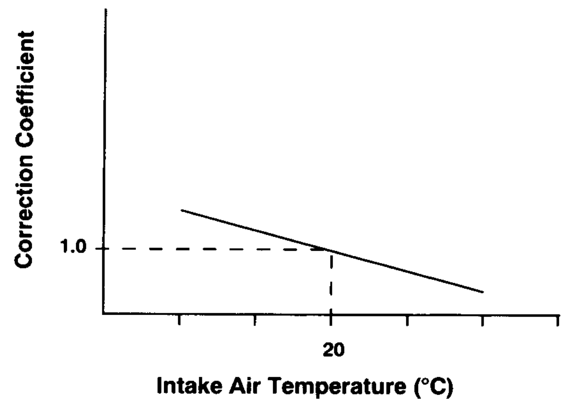
- As intake air volume increases, injector duration increases.

- As engine rpm increases, injector frequency increases.



Injection Corrections
A correction coefficient is calculated by determining the values of the various input sensors. This correction coefficient is used to modify the basic injection duration value to achieve a corrected injection duration value.

Correction For Intake Air Temperature
The density of intake air varies with temperature. The colder the air, the denser it becomes. For this reason, a correction coefficient is used for changes in air temperature.

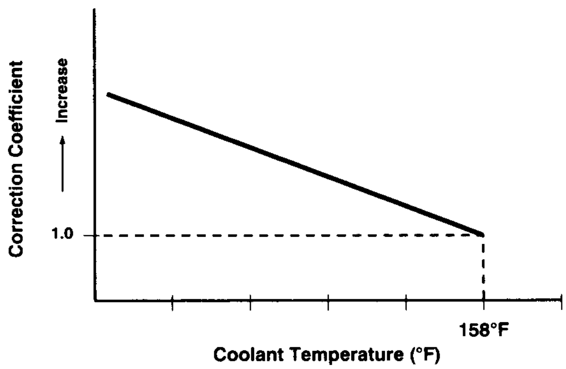


Referring to the coefficient graph, note that a standard air temperature of 68'F (20'C is used. At this temperature, the correction factor is 1.0.

For example, a correction factor of 1.0 means that no correction is made from the basic calculation. A coefficient of 1.1 means that injection duration is being increased by a factor of 10% while a coefficient of 0.9 means that injection duration is being decreased by a factor of 10%.

- As intake air temperature falls below the standard temperature, the correction coefficient increases and injection duration is increased (and vice versa).

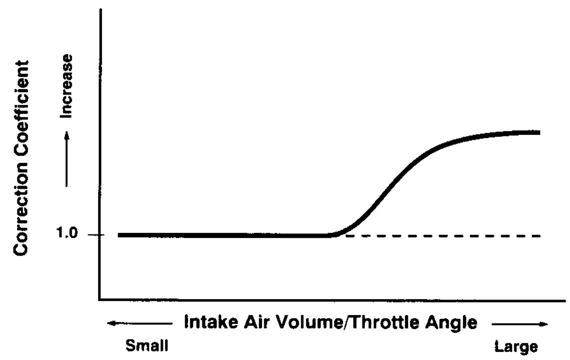
Correction For Coolant Temperature (Warm-up Enrichment)
When the engine is cold, fuel vaporization is relatively poor until the intake manifold warms up. To prevent lean driveability problems associated with this condition, the ECU enriches the air/fuel ratio accordingly based on engine coolant temperature.



The correction coefficient graph above shows a standard value of 158'F (70'C).

- At temperatures below 158'F, basic injection calculations are increased.
- At extremely cold temperatures, injection duration can be increased to almost double normal warm engine values.

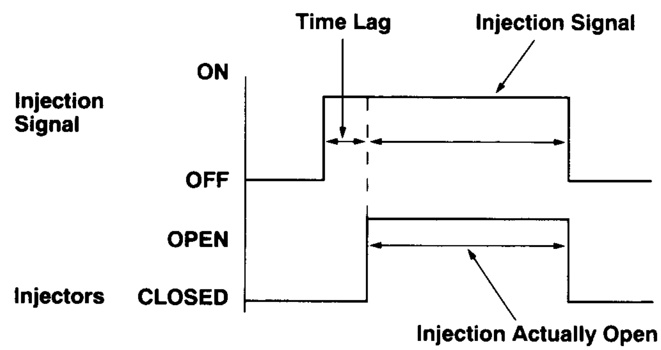
Power Enrichment Correction
When the ECU determines that the engine is being operated under moderate to heavy load, it increases injection duration values by up to 20% to 30%. This power enrichment program is based on information received from the air flow meter or manifold pressure sensor, the throttle position sensor and engine rpm.



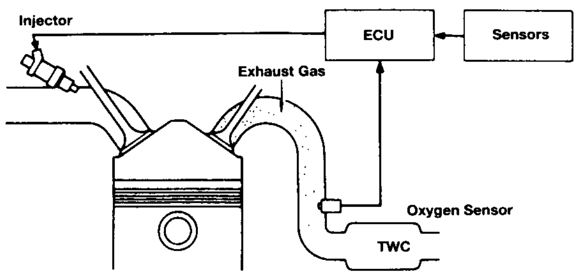
- As engine load increases, injection duration is increased.
- As engine rpm increases, injection frequency increases at the same rate.

Battery Voltage Correction
Because of the injector opening delay which varies with charging system voltage, the ECU must modify the corrected injection duration by a battery voltage correction coefficient to achieve a final injection duration value.

The final injection duration determines the quantity of fuel which is delivered to the engine.



Closed Loop Air/Fuel Ratio Correction
Under certain operating conditions, primarily cruise and idle, the ECU corrects the injection duration value based on signals from the exhaust oxygen sensor. This feedback correction is necessary to promote better vehicle emissions control.

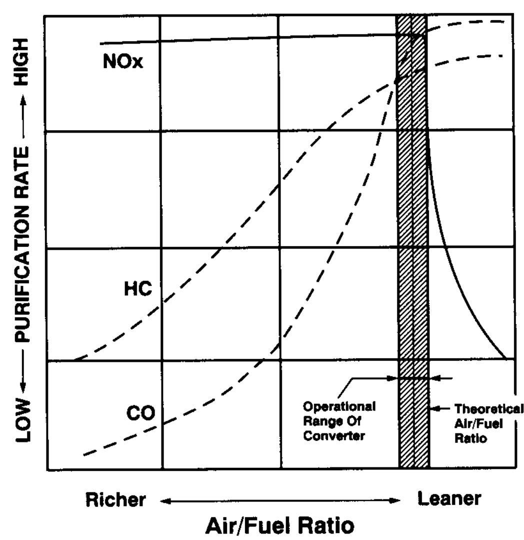


By achieving more accurate fuel metering, the oxygen content of the exhaust stream is held within a very narrow range which supports the most efficient operation of the three-way catalyst (TWC).

Stoichiometry and Catalyst Efficiency
The accompanying graph represents the efficiency of a three-way catalyst system at varying air/fuel ratios. As the graph clearly shows, the catalyst is most efficient in a narrow air/fuel ratio range.

The theoretical or ideal air/fuel ratio at which all tail pipe emissions are best converted is referred to as **stoichiometry**. The stoichiometric air/fuel ratio occurs around 14.7 to 1 (14.7 pounds of air for each pound of fuel).

It is important to note that the primary reason for using a closed loop fuel control system is to satisfy the requirements of the three-way catalyst system.



Closed Loop Operation

Closed loop operation simply means that the ECU is making air/fuel ratio corrections based on oxygen sensor information. Although the ECU can calculate injection duration very accurately without using information from the oxygen sensor, closed loop control brings the air/fuel ratio within the extremely narrow operating parameters of the three-way catalyst (TWC).

The oxygen sensor monitors the oxygen concentrations in the exhaust stream and outputs a voltage signal to the ECU. This signal allows the ECU to determine whether the air/fuel ratio is leaner or richer than the theoretical value necessary for the best catalyst conversion efficiency.

- Exhaust oxygen sensor voltage signal above 1/2 volt indicates an air/fuel ratio richer than stoichiometry. 'Me ECU will reduce fuel injection duration to correct this condition.

- Exhaust oxygen sensor voltage signal below 1/2 volt indicates an air/fuel ratio leaner than stoichiometry. The ECU will increase fuel injection duration to correct this condition.

- During normal closed loop operation, the oxygen sensor signal rapidly switches between these two conditions (at a rate of more than eight times in ten seconds at 2500 rpm). Small injection duration corrections take place each time the signal voltage switches from high to low and back again.

The closed loop correction coefficient ranges from 0.8 to 1.2 (that is, +20% from the basic fuel calculation). If the air/fuel ratio goes out of the ECU's range of correction, the ECU will typically set a diagnostic code and return to open loop operation.

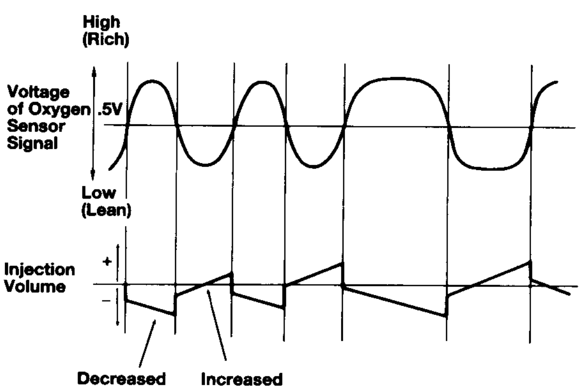
In a closed loop control system, the command corrects the condition.

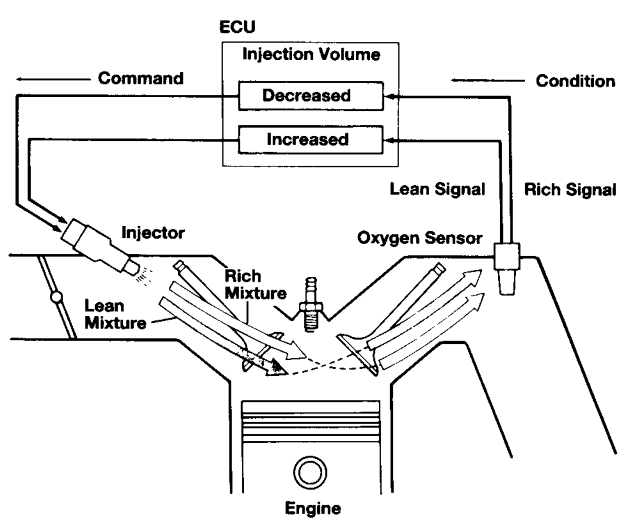
- Oxygen sensor monitors exhaust condition

- ECU commands injectors to correct condition

- Oxygen sensor indicates correction accuracy

- ECU again commands injectors to correct condition





Open Loop Operation

Open loop operation means that the ECU is not correcting the air/fuel ratio based on oxygen sensor information. The ECU ignores exhaust oxygen sensor information even if the sensor is detecting an excessively rich or lean mixture. There are certain operating conditions where it is not desirable to operate the system in closed loop due to risk of catalyst overheating and driveability concerns. These conditions are:

- Engine starting
- Cold engine operation
- Moderate to heavy load operation

In open loop operation, a correction coefficient of 1.0 is used.

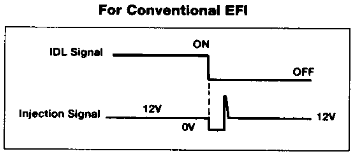
Acceleration and Deceleration Corrections

When the engine operating conditions are in transition, either accelerating or decelerating, the injection volume must be increased or decreased slightly to improve engine performance and fuel economy. The input sensor signals used and the enrichment or enleanment strategies used vary with engine application.

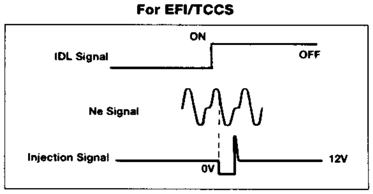
Acceleration Enrichment

As the engine is accelerated, a momentary lean condition exists as the throttle begins to open (this is due to the fact that fuel is more dense than air and cannot move into the cylinder as quickly). To prevent a stumble or hesitation, the ECU uses an acceleration enrichment fuel strategy. When the IDL signal goes from on to off, the ECU delivers an acceleration enrichment fuel pulse.

For Conventional EFI



For EFI/TCCS

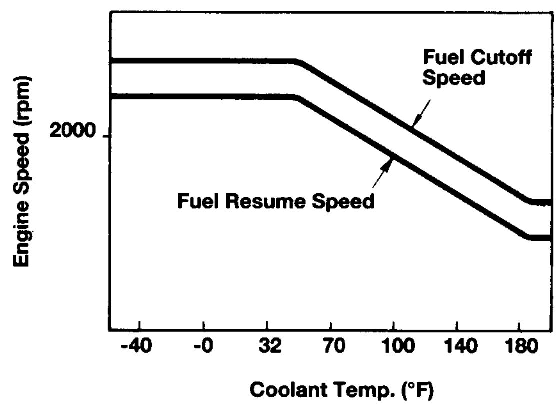


- As the IDL contact opens, the ECU commands all injectors to simultaneously deliver an extra asynchronous injection pulse.

On Conventional EFI engines, this pulse is delivered at the moment the IDL contact breaks. On EFI/TCCS engines, this pulse is delivered synchronous with the Ne signal which follows the IDL contact break.

Deceleration Fuel Cut

During closed throttle deceleration periods from higher engine speeds, fuel delivery is not necessary. In fact, deceleration emissions and fuel economy are adversely affected if fuel is delivered during deceleration.

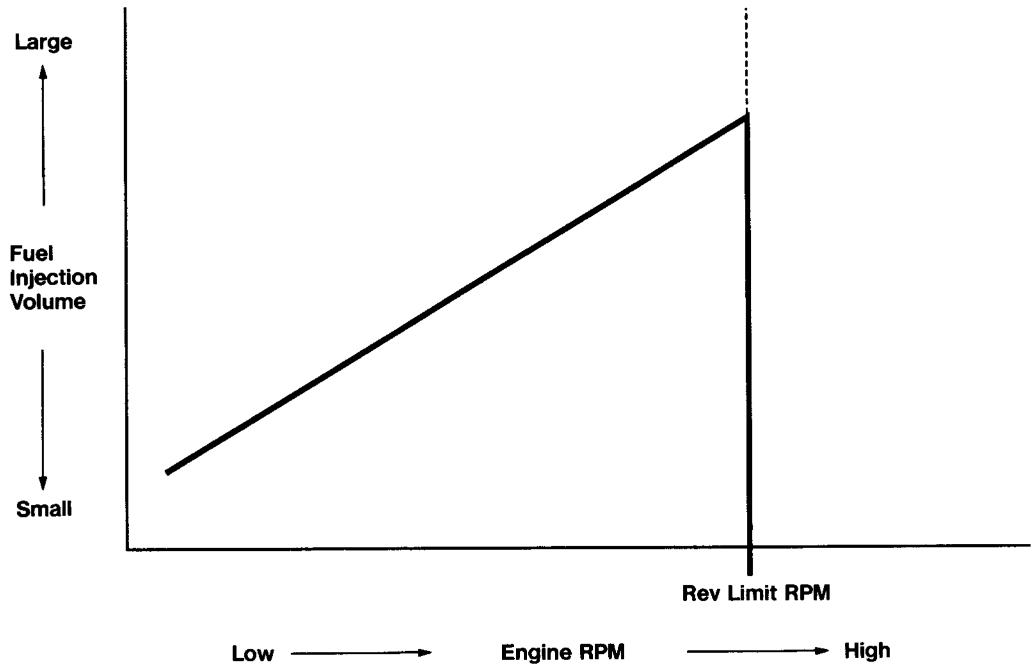


To prevent excessive decel emissions and improve fuel economy, the ECU stops injection pulses completely during certain deceleration conditions.

- When the IDL contacts close with engine rpm above a given speed, the ECU cuts injection operation completely.
- When the engine falls below the threshold rpm, or when the throttle is opened, fuel injection is resumed.

Referring to the graph, fuel cutoff and resumption speeds are variable, depending on coolant temperature, A/C clutch status, and SIT signal.

- With A/C clutch on, fuel cutoff and resumption speeds will be increased.
- With the stop light switch on, fuel cutoff and resumption speeds will be decreased (some applications only).



Engine Over-rev Fuel Cutoff
To prevent potential engine damage, a revlimiter is programmed into the ECU. Any time engine rpm exceeds the pre-programmed threshold, the ECU cuts fuel delivery. Once rpm falls below the threshold, fuel delivery is resumed.

Over-rev rpm threshold varies depending on engine design and application but typically runs in the 6500 to 7500 rpm range, usually cutting fuel slightly above the engine's red line rpm.

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

Spark Advance Control

Electronic Spark Advance (ESA)Variable Advance Spark Timing (VAST)

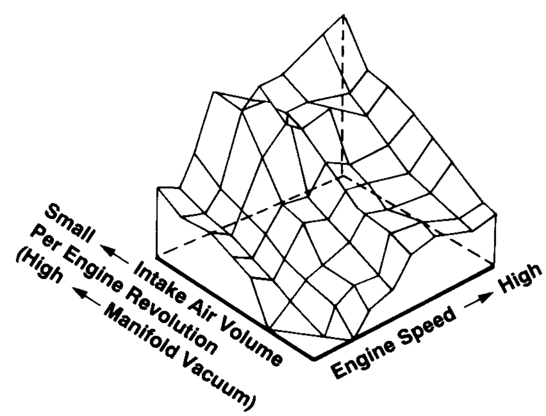
Introduction To ECU
Spark Advance Controls

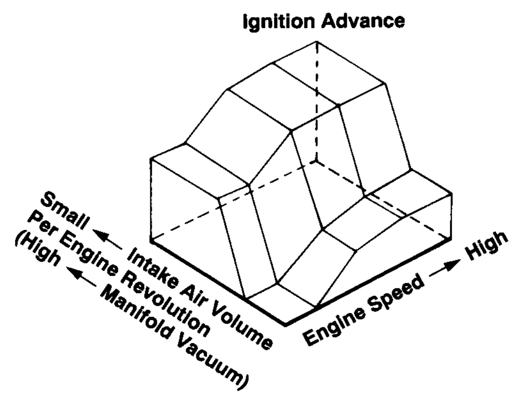
The Advantage of ECU Controlled Spark Timing
To maximize engine output efficiency, the ignition spark must be delivered at the precise moment which will result in maximum combustion chamber pressure occurring at about 100 ATDC. The amount of ignition spark advance, or lead time required to achieve this, will vary depending on many factors.

For example, because fuel bum time remains relatively constant, spark lead time must be increased as engine rpm increases. Because fuel has a tendency to detonate under heavy load conditions, spark lead time must be decreased as manifold pressure and intake air flow increase.

Engines equipped with Conventional and P7/EFI systems use a mechanical advance distributor to accomplish changes in spark lead time. The centrifugal (governor) advance increases spark lead time as engine rpm increases, and the vacuum advance decreases lead time as manifold pressure increases.

When all of the variables which affect optimum timing are considered, there are many more factors which influence required spark lead time. The coolant temperature, quality of fuel, and many other engine operating conditions can significantly impact ideal ignition time.





To provide for optimum spark advance under a wide variety of engine operating conditions, a spark advance map is developed and stored in a look up table in the ECU. This map provides for accurate spark timing during any combination of engine speed, load, coolant temperature, and throttle position while using feedback from a knock sensor to adjust for variations in fuel octane.

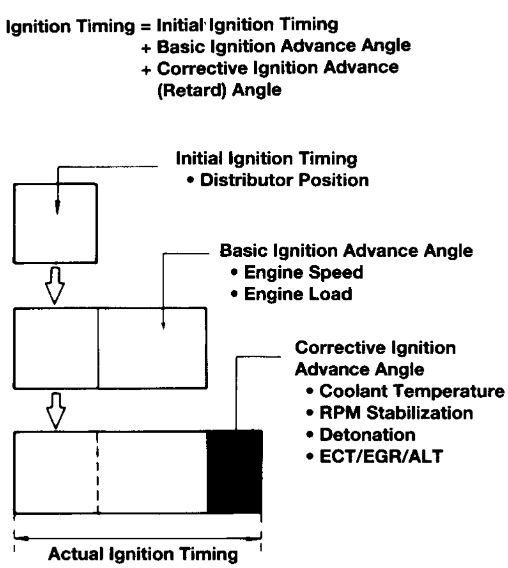
Prior to strict emissions and fuel economy standards, mechanical control of spark advance was adequate to accomplish reasonable engine performance and emissions control. However, in the automotive environment of the '90s, adequate is not good enough.

Two ECU Spark Advance Control Systems Used By Toyota
There are two distinctly different ECU controlled ignition systems in use on TCCS equipped engines. These systems are known as Electronic Spark Advance (ESA) and Variable Advance Spark Timing (VAST). Both systems accomplish the same goal; they provide ideal ignition timing under a wide variety of engine operating conditions.

You also learned the mechanics of how the ESA and VAST systems signal the igniter and fire the ignition coil. You have learned the system hardware. The objective of this lesson is to identify the process the ECU uses to calculate optimum spark advance angle under a wide variety of operating conditions. The ECU program which accomplishes this is the system software.

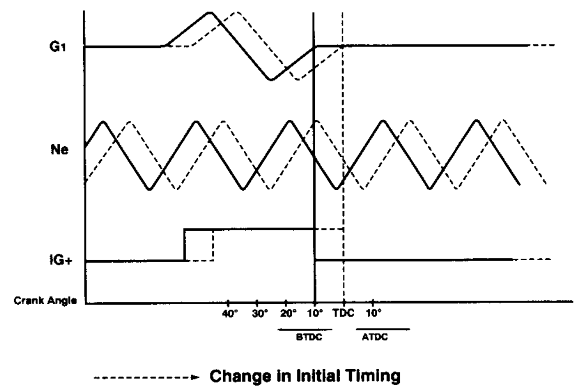
ECU Control Of Spark Advance Angle

Overview Of Advance Angle Calculation
Determination of optimum spark advance angle is the function of a three-step process.



Step 1, Initial Timing Adjustment
The first step involves correct adjustment of initial timing. The input sensor used by the ECU to determine initial timing is: 0 Standard Crankshaft Angle (G1, G2, and Ne)

The initial timing adjustment is critical to proper operation of the ECU controlled spark advance system. Initial timing is a function of the physical position of the distributor in the engine and becomes the base upon which all advance functions are added. Once the initial timing is adjusted properly, it will not change.



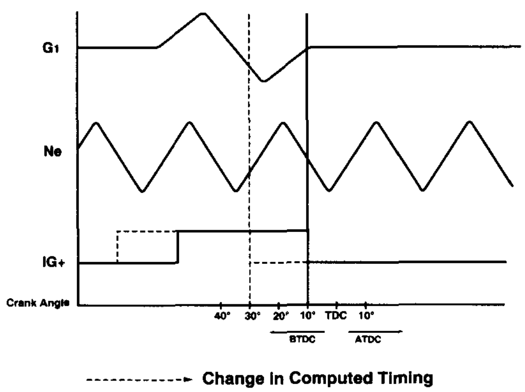
- If distributor position in the engine is changed, the relationship between Ne and G signals to TDC changes.
- Any deviation from specified initial timing will cause an equal amount of error in the final spark advance angle.

Step 2, Basic Advance Angle

The second step involves calculation of the basic advance angle. Input sensors used in basic advance angle calculation are:

- Intake Air Volume (Vs or Ks)
- Intake Manifold Pressure (PIM)
- Engine rpm (Ne)

The basic advance angle is primarily a function of inputs from the engine rpm and intake air volume sensors. This calculation is equivalent to the combined centrifugal and vacuum advance on a mechanical distributor.



- As engine rpm increases, spark angle is advanced.
- As intake air volume (engine load factor) increases, spark angle is retarded.

Step 3, Corrective Advance Angle

The final step in determining optimum or final spark advance angle is calculation of corrective advance angle. Input sensors used in corrective advance angle calculations are:

- Starting Signal (STA)
- Engine Water Temperature (THW)
- Throttle Angle (VTA or IDL & PSW)
- Knock Detection (KNK)
- Altitude (HAC)
- Electronically Controlled Transmission (ECT)

The biggest advantage of ECU controlled spark advance is the system's ability to adjust timing for all possible variables in the ideal advance angle equation. The corrective advance angle calculation accomplishes this by fine tuning the advance angle for changes in coolant temperature, engine detonation, transmission shift status, altitude, accessory status, and other variables.

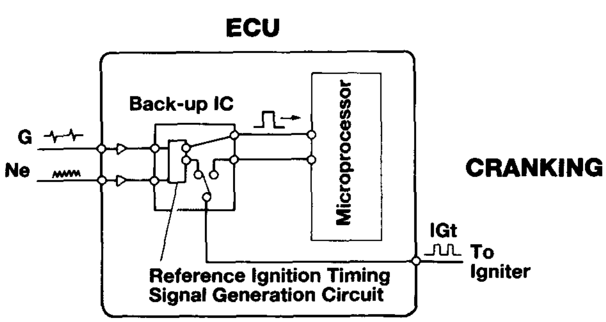
- ECU advances spark angle for cold engine operation and retards for over-temperature conditions.
- ECU retards spark angle when detonation is detected.
- ECU advances spark angle for high altitude operation (models equipped with HAC sensor).

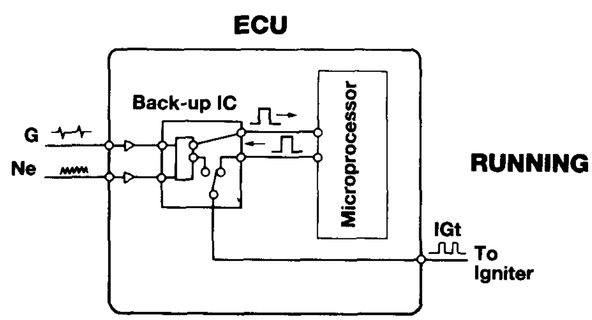
ECU Spark Advance Strategy While Starting

ESA System

Engine starting: During starting, when engine speed is below approximately 500 rpm (or when STA signal is high), spark advance angle (IGt signal) is fixed at initial timing. A Backup IC located in the ECU generates a reference timing signal which is output to the microprocessor and the IGt line to the igniter. The reference signal represents base timing and is calculated based on inputs from the G1 and Ne sensors.

Engine running: Once the engine starts, timing of the IGt signal is controlled by the microprocessor in the ECU. Based on inputs from various sensors, a basic and corrective advance angle are calculated. The final spark advance angle consists of the sum of the initial, basic, and corrective spark advance angles.

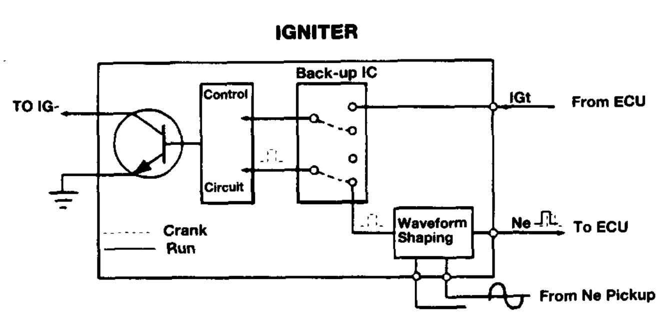


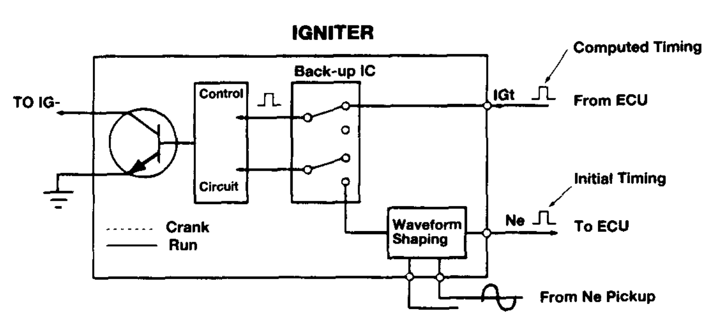


VAST System

Engine starting: During starting, when below a predetermined rpm, no IGt signal is sent from the ECU to the igniter. The ignition coil is driven by the back-up circuit in the igniter at initial timing.

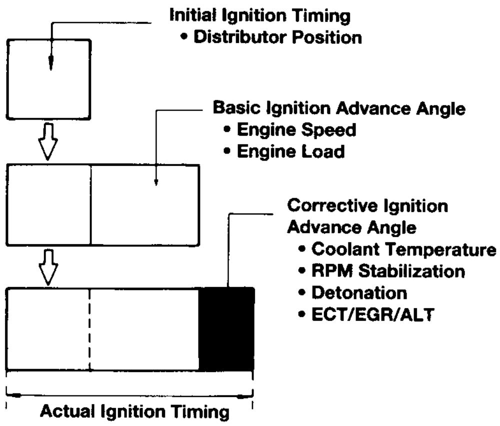
Engine running: Once the engine starts, the ECU sends an IGt signal back to the igniter; the ignition coil is driven by this signal at computed timing.





ECU Spark Advance Strategy While Running

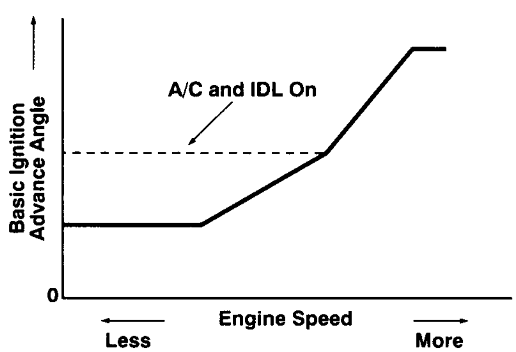
Ignition Timing = Initial Ignition Timing
+ Basic Ignition Advance Angle
+ Corrective Ignition Advance (Retard) Angle



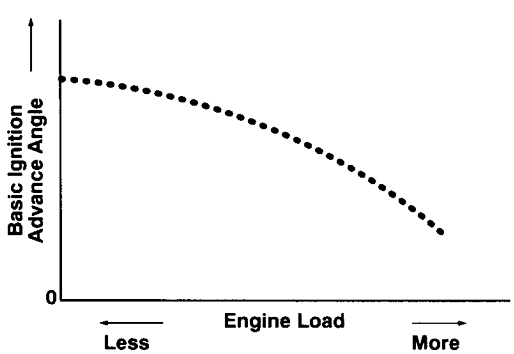
Basic Ignition Advance Angle

The ECU calculates the basic advance angle by evaluating engine rpm and intake air volume signals. These sensors' signals have the most significant effect on basic timing calculation.

ADVANCE FOR ENGINE RPM



ADVANCE FOR ENGINE LOAD



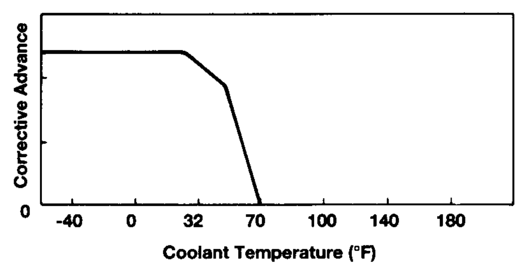
There are other sensor inputs which also affect the basic spark advance angle. The A/C compressor clutch signal advances basic spark angle when the IDL contacts are on (on some engines), and on the 3S-GTE engine, basic advance angle is retarded if the ECU judges that regular fuel is being used, based on signals from the engine knock (KNK) sensor.

Corrective Ignition Advance Angle

Engine Temperature Corrections

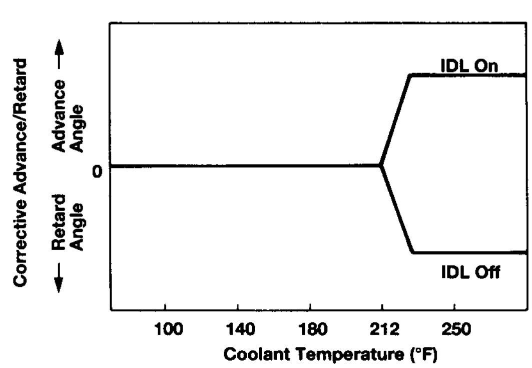
To improve cold driveability, the ECU advances spark angle. The ECU considers intake air volume and the status of the IDL contact to determine how much cold advance to add to the basic spark calculation.

WARM-UP CORRECTION



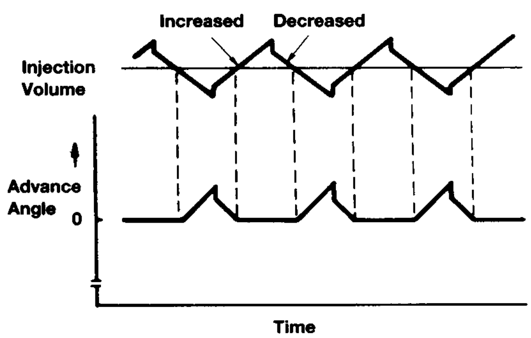
As the engine temperature approaches overtemp, the ECU will advance spark when the IDL contact is on, to prevent overheating. When the IDL contact is off, the ECU will retard spark to prevent detonation. Advance and retard shown on the graph are corrections to the basic advance angle.

OVER TEMPERATURE CORRECTION



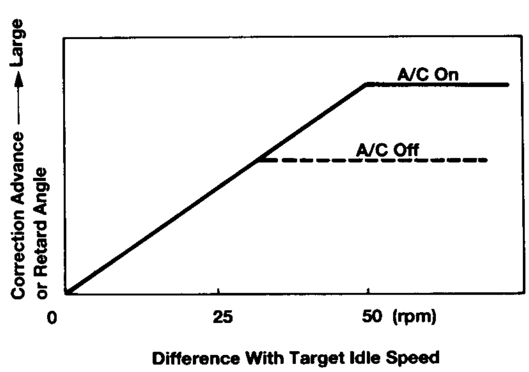
Fuel Feedback Idle Stabilization Correction

To prevent surging due to closed loop air/fuel ratio swings, when the IDL contacts are on, the ECU advances timing as lean commands are sent to the injectors (fuel injection volume decreased). This very small amount of advance added to the basic advance angle serves to stabilize engine idle quality.



Engine Load Idle Stabilization Correction

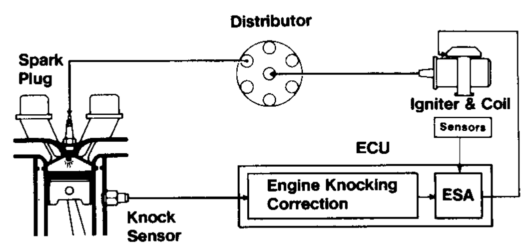
When engine rpm changes at idle due to increased load, the ECU adjusts timing to stabilize idle speed. The ECU constantly monitors and calculates average engine speed. If the average speed is determined to go below a pre-programmed target rpm, the ECU will add advance to the basic spark angle to help re-establish the target idle speed.

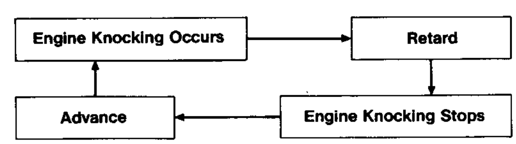


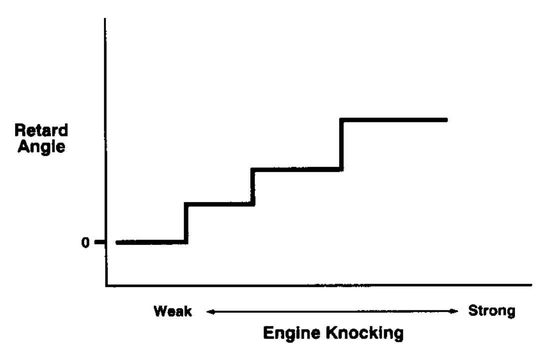
Detonation Correction

The ECU constantly monitors the signal from the knock sensor to determine when detonation occurs. When detonation is sensed, basic advance angle is retarded in varying degrees, depending on the strength of the knock sensor signal. Once detonation stops, the ECU gradually cancels the retard, allowing timing to return to the basic advance angle.

The detonation correction strategy allows the engine to operate at optimum timing regardless of fuel octane, maximizing engine performance when high octane fuel is used. On some engines, this system only operates in a closed loop mode under load (vacuum below approximately 8 inches of mercury). Other engines operate in ignition closed loop under all engine load ranges.

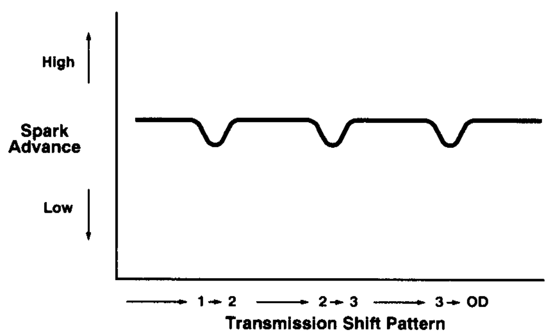






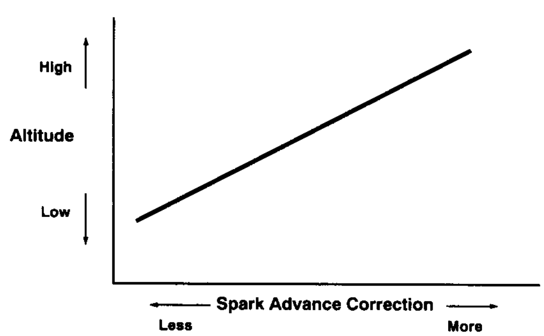
ECT (Transmission) Shift Correction
On some applications with integrated ECT controls, the Engine and Transmission ECU retards the basic advance angle temporarily during gear shifting. This strategy helps reduce shift shock by reducing engine torque momentarily, just as the transmission shifts. The amount of retard varies depending on the status of engine and ECT sensor inputs.

ECT SHIFT CORRECTION



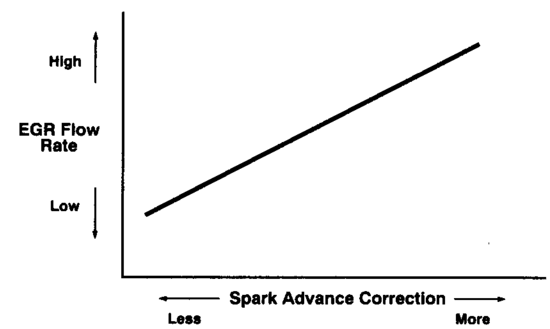
High Altitude Correction
This strategy, which is used only on applications with High Altitude Compensation (HAC) capabilities, improves engine performance and idle quality during high altitude operation by advancing timing over the basic calculated spark angle.

ALTITUDE ADVANCE CORRECTION



EGR Flow Correction
This strategy advances timing from the basic calculation when the IDL contact is off and the ECU is commanding EGR flow. This correction allows the engine to operate more efficiently because it resists detonation when EGR is introduced into the cylinders.

EGR FLOW CORRECTION



Summary
It is possible that minor calibration faults in key system inputs can have a significant effect on calculated spark advance, resulting in degraded driveability. When performance problems arise which appear to be the result of inaccurate timing advance calculation, do not overlook calibration of all relevant input sensors which influence timing during the affected driving mode. The best way to confirm sensor calibration is by becoming familiar with, and performing, the ECU Standard Voltage Check procedures.

Purpose of ECU Controlled Idle Speed Control Systems

The Idle Speed Control (ISC) system regulates engine idle speed by adjusting the volume of air that is allowed to by-pass the closed throttle valve. The ECU controls the Idle Speed Control Valve (ISCV) based on input signals received from various sensors. The system is necessary to provide stabilization of curb idle when loads are applied to the engine and to provide cold fast idle on some applications. The Idle Speed Control system regulates idle speed under at least one or more of the following conditions, depending on application:

- Fast Idle
- Warm Curb Idle
- Air Conditioner Load
- Electrical Load
- Automatic Transmission Load

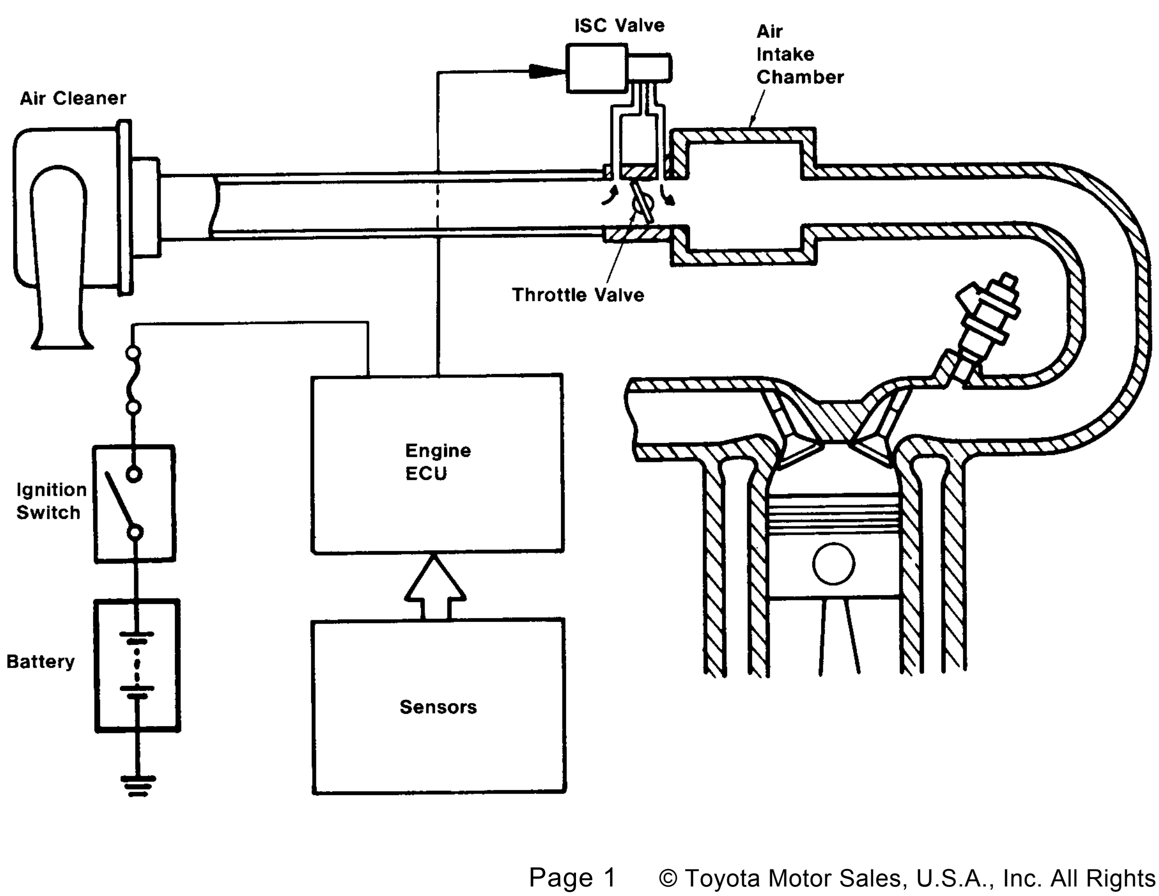
Difference Between Mechanical Air Valves and ECU Controlled ISCV

The ECU controlled ISC systems addressed in this chapter should not be confused with the mechanical air valves which were addressed in Chapter 2, "Air Induction System." The ISC valve is totally controlled by the ECU based on inputs received from the various sensors, and it controls many different idle speed parameters.

The Wax type and Bi-metal mechanical air valves are used only to regulate cold engine fast idle and are not ECU controlled.

There are some engines which utilize a mechanical air valve, for cold fast idle control, in combination with an ECU controlled ISC Vacuum Switching Valve (VSV) to control warm curb idle.

BASIC CONSTRUCTION OF ISC



Four Different ECU Modulated Idle Speed Control Systems (ISC)

There are four different types of ECU controlled ISC systems used on Toyota engines. These systems are referred to as:

• Stepper motor type

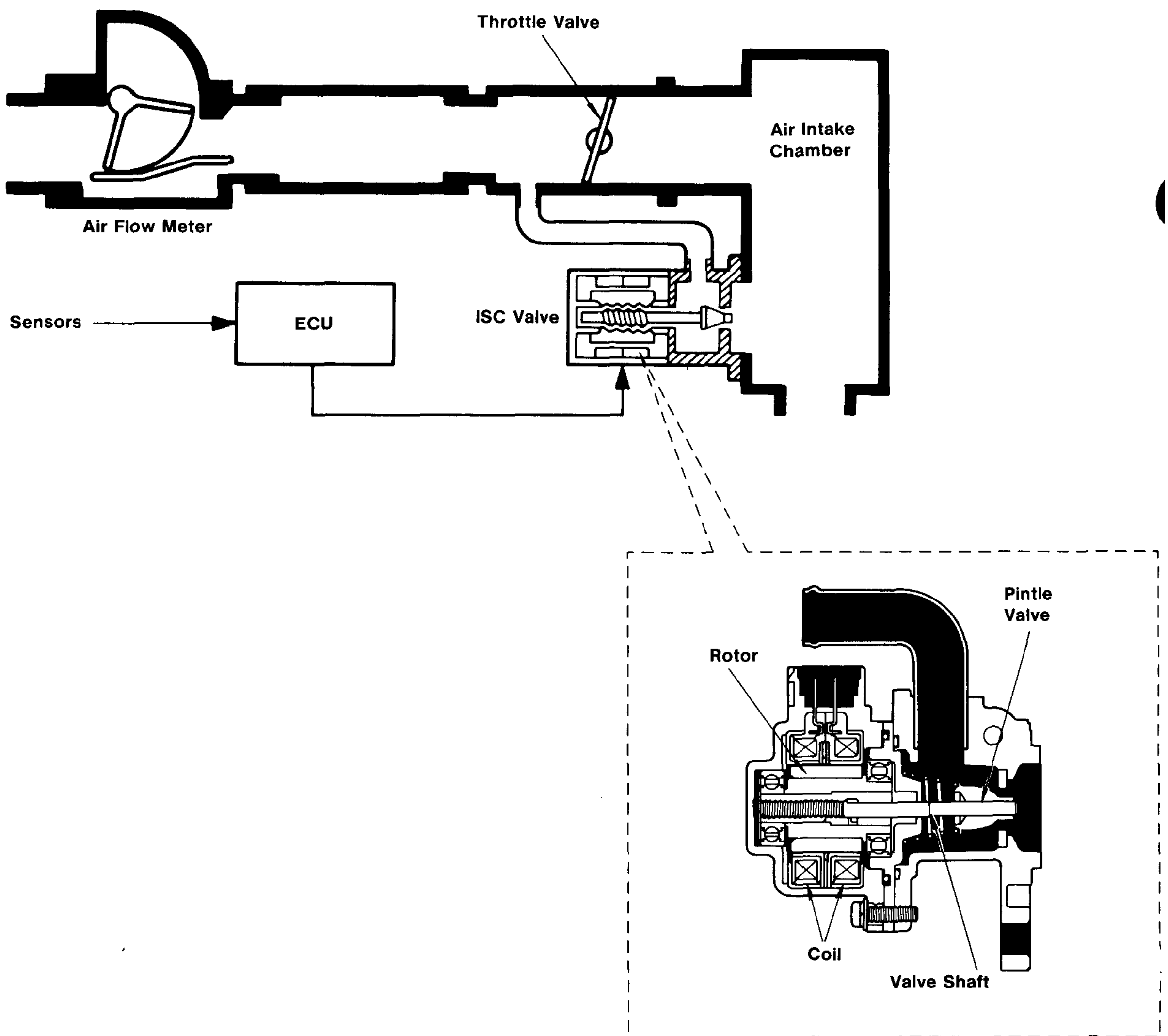
• Rotary solenoid type

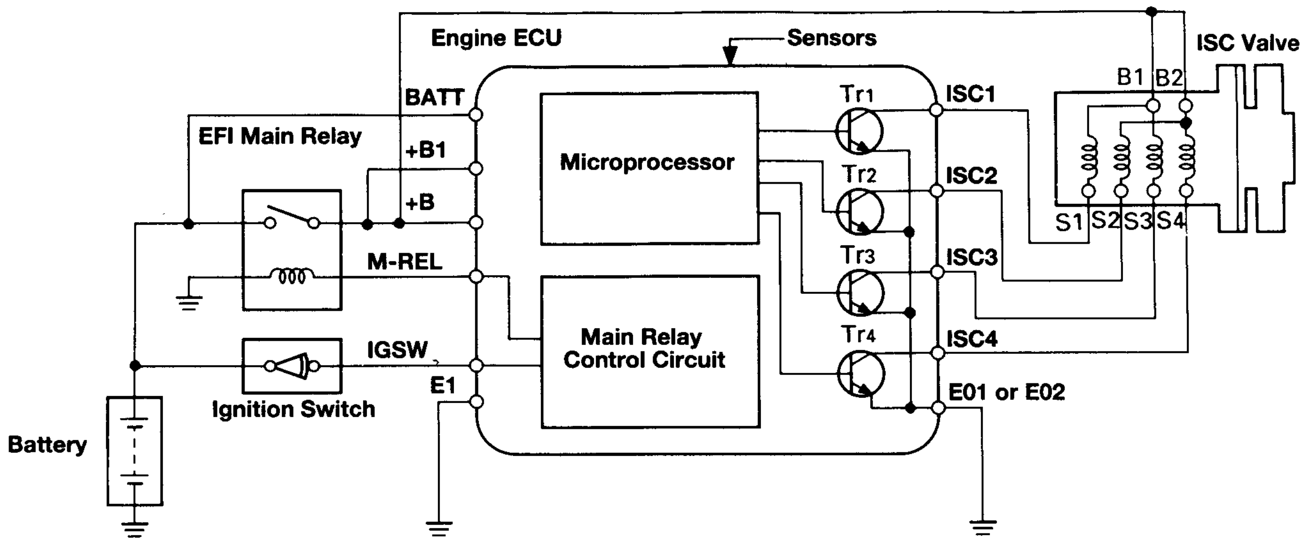
• Duty control ACV type

• On-off control VSV type

Step Motor Type ISC Valve
The Step Motor type ISCV is located on the intake air chamber or throttle body. It regulates engine speed by means of a stepper motor and pintle valve which controls the volume of air by-passing the closed throttle valve. The ISCV throttle air by-pass circuit routes intake air past the throttle valve directly to the intake manifold through a variable opening between the pintle valve and its seat.

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

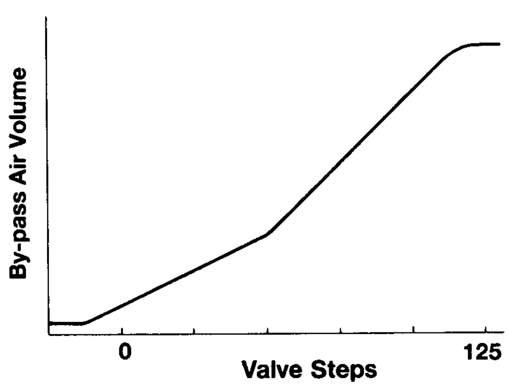




To Extend Valve (Reduce Air By-pass)
Tr1 ⟶ Tr2 ⟶ Tr3 ⟶ Tr4

To Retract Valve (Increase Air By-pass)
Tr4 ⟶ Tr3 ⟶ Tr2 ⟶ Tr1

The ECU controls movement of the pintle valve by sequentially grounding the four electrical stator coils. Each time current is pulsed through the stator coils, the shaft moves one 44 step." Direction of rotation is reversed by reversing the order with which current is passed through the stator coils.



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

Stepper ISC System Applications and Control Parameters

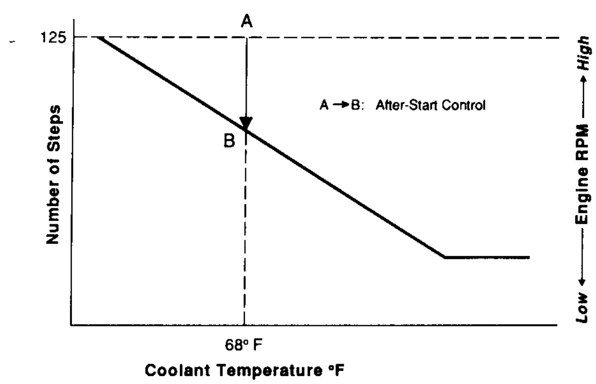
ISC Type/ Engine	Relevant Inputs	Controlled Parameters
Step Motor Type	Engine speed (Ne)	• Warm Curb Idle
	Throttle angle (IDL)	
• 7M-GE/GTE	Vehicle speed (SPD)	• Cold Fast Idle
• 5M-GE	Coolant temp. (THW)	
• 3F-E	Neutral/Start switch (NSW)	• Air Conditioner Idle-up
• 2VZ-FE		
• 3VZ-FE	Ignition switch (STA)	• Electrical Load Idle-up
	Air conditioner clutch (A/C)	
	Electrical load (ELS)	• Automatic Transmission Idle-up
	Battery voltage (+B)	

Primary Controlled Parameters

Initial Set-up

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

INITIAL SET-UP AND AFTER START CONTROL



Engine Starting Control

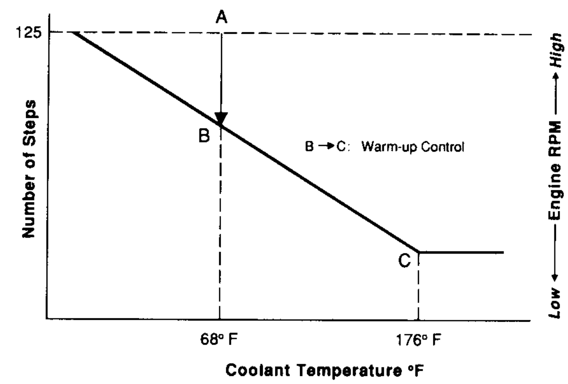
When the engine is started, rpm increases rapidly because the ISCV is fully open. This ISCV position is represented by point A on the graph, 125 steps from seat.

When 500 rpm is reached, the ECU drives the ISCV to a precise number of steps from seat based on the coolant temperature at time of start-up. This information is stored in a look up table in the ECU memory and is represented by point B on the graph.

Engine Warm-up Control

As the engine coolant approaches normal operating temperature, the need for cold fast idle is gradually eliminated. The ECU gradually steps the ISCV toward its seat during warmup. The warm curb idle position is represented by point C on the graph. By the time the coolant temperature reaches 176'F (80'C), the cold fast idle program has ended.

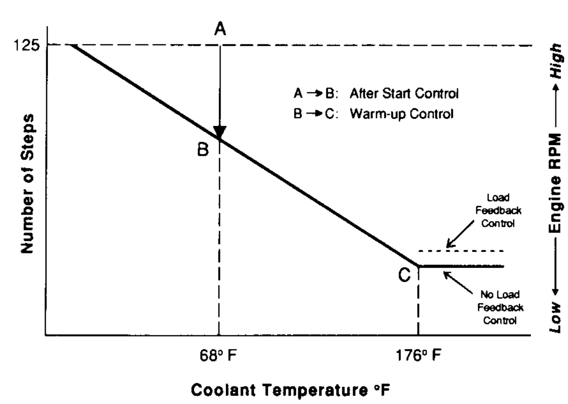
ENGINE WARM-UP CONTROL



Feedback Idle Speed Control

The ECU has a pre-programmed target idle speed which is maintained by the ISCV based on feedback from the Ne signal. Feedback idle speed control occurs any time the throttle is closed and the engine is at normal operating temperature. The target idle speed is programmed in an ECU look up table and varies depending on inputs from the A/C and NSW signals. Any time actual speed varies by greater than 20 rpm from target idle speed, the ECU will adjust the ISC valve position to bring idle speed back on target.

FEEDBACK IDLE SPEED CONTROL



Engine Load/Speed Change Estimate Control

To prevent major loads from changing engine speed significantly, the ECU monitors signals from the Neutral Start Switch (NSW) and the Air Conditioner switch (A/C) and re-establishes target idle speeds accordingly. ISCV position is adjusted very quickly as the status of the A/C or NSW inputs change. Before a change in engine speed can occur, the ECU has moved the ISCV to compensate for the change in engine load. This feature helps to maintain a stable idle speed under changing load conditions.

The following chart shows typical target idle speeds which can be found in New Car Feature books. These speed specifications can be useful when troubleshooting suspected operational problems in the step type idle speed control system or related input sensor circuits.

7M-GE Stepper Type ISC Target Idle Speeds (Warm Engine)

A/C Switch Position	Neutral/Start Switch Position	Target Idle Speed
ON	ON	900 rpm
ON	OFF	750 rpm
ON	M/T	900 rpm
OFF	ON	700 rpm
OFF	OFF	600 rpm
OFF	M/T	700 rpm

Other Controlled Parameters

Electrical Load Idle-up

Whenever a drop in voltage is sensed at the ECU +B or IG S/W terminals, the ECU responds by increasing engine idle speed. This strategy ensures adequate alternator rpm to maintain system voltage at safe operational levels.

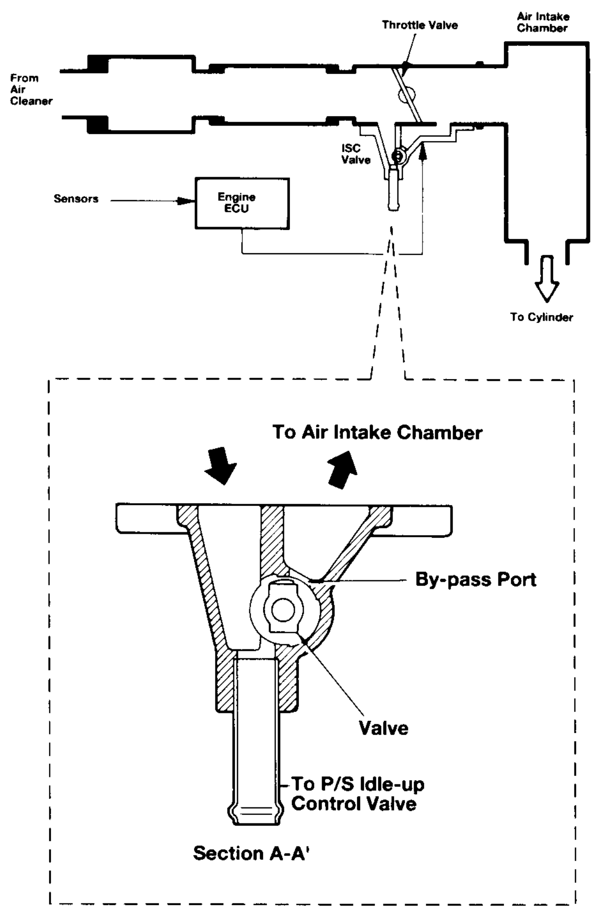
Deceleration Dashpot Control

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

Learned Idle Speed Control

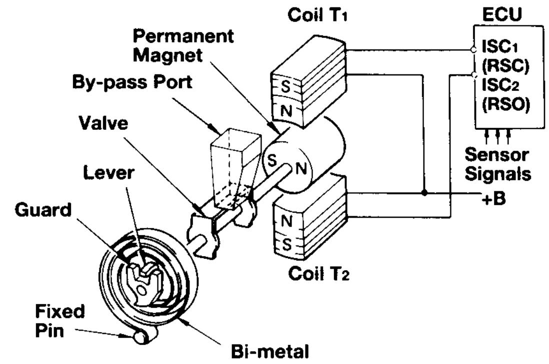
The idle speed control program is based on an ECU stored look up table which lists pintle step positions in relation to specific engine rpm values. Over time, engine wear and other variations tend to change these relationships. Because this system is capable of feedback control, it is also capable of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

Rotary Solenoid Type Idle Speed Control



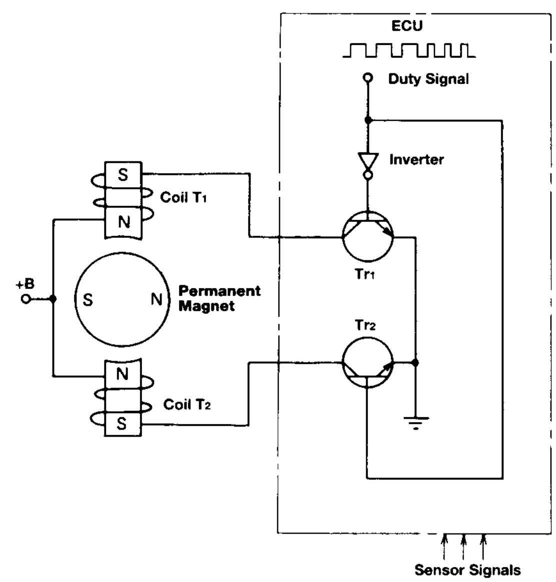
The Rotary Solenoid ISCV is mounted to the throttle body. This small, lightweight and highly reliable valve controls the volume of intake air which is allowed to by-pass the closed throttle valve. Air volume control is accomplished by means of a movable rotary valve which blocks or exposes the air by-pass port based on signals received from the ECU.

Because the Rotary Solenoid ISCV has large air volume capability, it is used to control cold fast idle as well as other idle speed parameters. Although this ISCV is not used in combination with a mechanical air valve, models equipped with air conditioning do require the use of a separate A/C idle-up device.



PRINCIPLE OF ISC VALVE

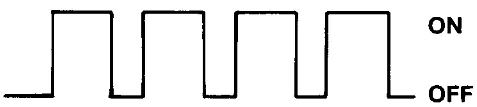
The valve assembly consists of two electrical coils, a permanent magnet, a valve and valve shaft. A fail-safe bi-metallic coil is fitted to the end of the shaft to operate the valve in the event of electrical failure in the ISCV system.



The ECU controls movement of the valve by applying a 250 Hz duty cycle to coils T1 and T2. The electronic circuitry in the ECU is designed to cause current to flow alternately in coil T1 when the duty cycle signal is low and in coil T2 when the signal is high. By varying the the duty ratio (on time compared to off time), the change in magnetic field causes the valve shaft to rotate.

LOW DUTY RATIO
(Closes Air By-Pass)

HIGH DUTY RATIO
(Opens Air By-Pass)



As duty ratio exceeds 50%, the valve shaft moves in a direction that opens the air by-pass passage. At a duty ratio less than 50%, the shaft moves in a direction which closes the passage. If the electrical connector is disconnected or the valve fails electrically, the shaft will rotate to a position which balances the magnetic force of the permanent magnet with the iron core of the coils. This default rpm will be around 1000 to 1200 rpm once the engine has reached normal operating temperature.

Rotary Solenoid ISC System Applications and Control Parameters

ISC Type/ Engine	Relevant Inputs	Controlled Parameters
Rotary Solenoid Type	Engine speed (Ne)	• Warm Curb Idle
	Throttle angle (IDL)	
• 4A-GZE	Vehicle speed (SPD)	• Cold Fast Idle
	Coolant temp. (THW)	
• 2TZ-FE	Neutral/Start switch (NSW)	• Electrical Load Idle-up
• 3S-GTE	Ignition switch (STA)	• Automatic Transmission Idle-up
• 3S-FE	Electrical Load (ELS)	
• 5S-FE	Battery voltage (+B)	

Rotary ISCV Controlled Parameters

Engine Starling, Warm-up and Feedback Control

When the engine is started, the ECU opens the ISCV to a pre-programmed position based on coolant temperature and sensed rpm. The higher the commanded rpm, the longer the duty ratio will be. As the engine approaches normal operating temperature, engine speed is gradually reduced.

Once the engine is fully warmed up, the ECU utilizes a feedback idle speed control strategy which functions identically with the stepper motor ISC system. Different target idle speeds are established depending on the status of load sensor inputs.

Turbo Charger Idle Down Control

On the 3S-GTE engine, the ISCV remains at a higher idle air by-pass rate for a short period of time after high speed or heavy load operation. This strategy prevents damage to the turbocharger center shaft bearings by maintaining an elevated engine oil pressure.

All other controlled parameters for the Rotary Solenoid ISC system are the same as the with the Stepper type ISCV. Idle load stabilization is maintained when input from the neutral safety switch (NSW), headlights or rear window defogger (ELS) indicate additional engine load.

As with the Stepper type ISC system, the Rotary Solenoid system utilizes a learned idle speed control strategy. The ECU memorizes the relationship between engine rpm and duty cycle ratio and periodically updates its look up tables. Both systems utilize current supplied by the BATT terminal of the ECU to retain this learned memory. If the battery is disconnected, the ECU must relearn target step positions and duty cycle ratios.

Duty Control Air Control Valve (ACV) ISC

The Duty Control ACV is typically mounted on the intake manifold. It regulates the volume of air by-passing the closed throttle valve by opening and closing an air by-pass. Valve opening time is a function of a duty cycle signal received from the ECU.

The ACV is incapable of flowing large volumes of air; therefore, a separate mechanical air valve is used for cold fast idle on engines equipped with this system.

The Duty Control ACV consists of an electrical solenoid and a normally closed (N/C) valve which blocks passage of fresh air from the air cleaner to the intake manifold. The ECU controls the valve by applying a 10 Hz variable duty ratio to the solenoid, causing the valve to pass varying amounts of air into the manifold. By increasing the duty ratio, the ECU holds the air by-pass circuit open longer, causing an increase in idle speed.

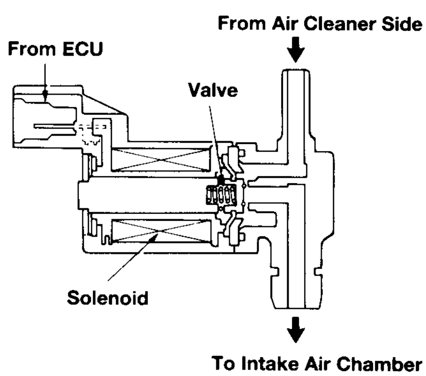
Duty Control ACV ISC Applications and Control Parameters

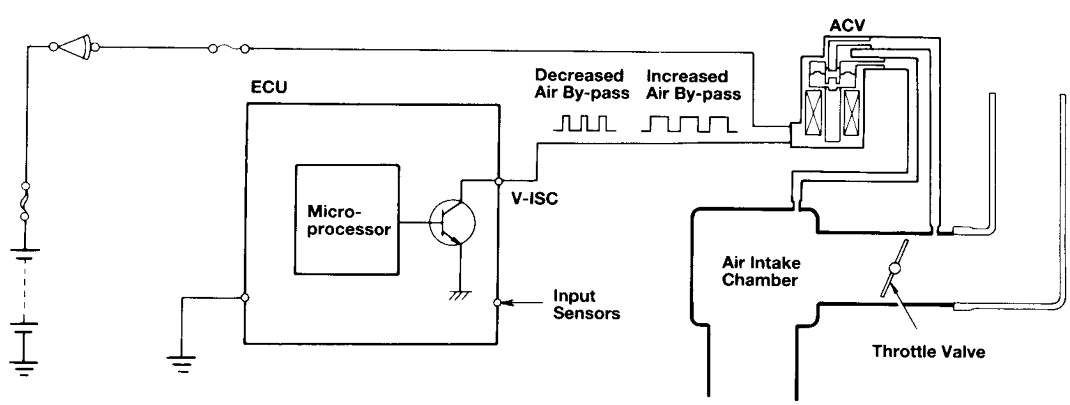
ISC Type/ Engine	Relevant Inputs	Controlled Parameters
Duty Control VSV Type • 4A-FE • 5E-FE	Engine speed (Ne) Coolant temp. (THW) Air conditioner clutch (A/C) Electrical load (ELS) Throttle signal (IDL) Vehicle speed (SPD) Neutral switch (NSW)	• Warm Curb Idle • Engine Starting Stabilization • Automatic Transmission Idle-up • Air Conditioner Idle-up • Electrical Load Idle-up

Duty Control ACV Controlled Parameters

Starting and Warm Curb Idle

When the STA signal to the ECU is on, the ECU cycles the VSV at a 100% duty cycle to improve startability. The ACV does not have any effect on cold fast idle or warm-up fast idle speed.





When the engine has reached normal operating temperature, and the IDL contact is closed, the ECU uses a feedback idle speed control strategy to control warm curb idle speed. When loads are applied to the engine from the automatic transmission or electrical devices, the ECU adjusts target idle speeds accordingly. When the IDL contact is open or any time the Air Conditioning (A/C) signal to the ECU is on, the ECU maintains a constant duty cycle ratio to the ACV, allowing a fixed amount of by-pass air to flow.

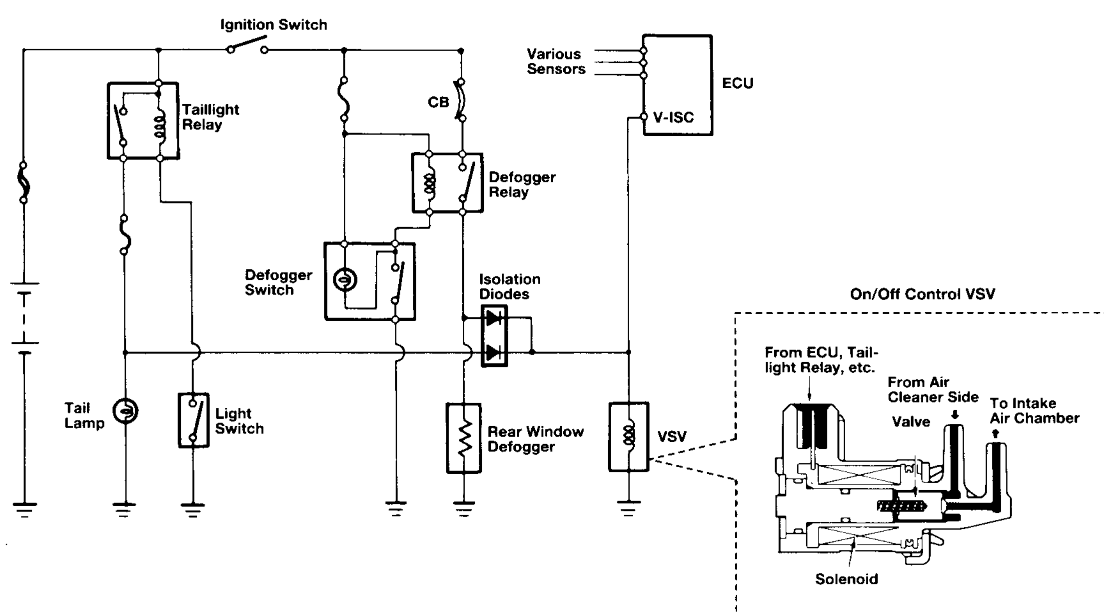
Diagnostic Mode

When the TCCS system enters diagnostic mode (TE1 shorted to E1), the ECU will drive the ACV to a fixed duty cycle ratio regardless of engine operating conditions. Curb idle adjustment on engines equipped with this ISC system is performed in diagnostic mode. For more information on curb idle adjustment procedures, refer to Appendix C.

On-Off Control Vacuum Switching Valve (V-ISC System)

The simple On-Off Vacuum Switching Valve (VSV) ISC system is controlled by signals from the ECU or directly by tail lamp and rear window defogger circuits. The Vacuum Switching Valve (VSV) is typically located on the engine (often under the intake manifold) or in the engine compartment, controlling a fixed air bleed into the intake manifold.

The valve is a normally closed (N/Q design which is opened when current is passed through the solenoid windings. Unlike most ECU controlled circuits which are ground circuit driven, the ECU controls this VSV by supplying current to the solenoid coil when pre-programmed conditions are met. Additionally, current can be supplied to the solenoid from the rear window defogger or taillight circuits by passing through isolation diodes.



The VSV allows only a small amount of air to by-pass the closed throttle valve when it is open, increasing engine speed by about 100 rpm when energized. This ISC system does not control cold fast idle, and engines equipped with the system use a mechanical air valve for cold engine fast idle.

On-Off VSV ISC System Applications and Control Parameters

ISC Type/ Engine	Relevant Inputs	Controlled Parameters
On-Off Control VSV Type	Engine speed (Ne)	• Engine Starting Stabilization
	Coolant temp. (THW)	
	Air conditioner clutch (A/C)	
• 4A-GE	Electrical load (ELS)	• Air Conditioner Idle-up
• 3E-E	Throttle signal (IDL)	
• 4Y-E	Vehicle speed (SPD)	• Electrical Load Idle-up
• 2S-E	Neutral switch (NSW)	
• 3S-GE		• Automatic Transmission Idle-up

On-Off Control VSV Controlled Parameters

Engine Starting and Warm Curb Idle Control
The solenoid is energized by the ECU whenever the STA signal is on and for a short period of time thereafter to improve startability. Additionally, when the IDL contact is closed, the ECU will energize the solenoid whenever engine speed drops below a pre-determined rpm.

Automatic Transmission Idle-up Control
The ECU will energize the VSV for several seconds after shifting the transmission from Park or Neutral to any other gear to stabilize engine speed during the transition from unloaded to loaded conditions.

Electrical Load Idle-up
Referring to the electrical schematic, the VSV receives current directly from the tail lamp and rear window defogger circuits through isolation diodes whenever these circuits are operating.

Diagnostic Mode
Whenever the TE1 circuit is grounded, the ECU is prevented from actuating the V-ISC Vacuum Switching Valve. This inhibit feature is useful during diagnostic and other service procedures. It is important to note that this will not prevent the VSV from energizing when the defogger or tail lamp relays are energized.

Input Sensors Affecting Idle Speed Control Output

Major Impact Sensors

The following input signals to the ECU have a major impact on the output commands sent to the Idle Speed Control Valve.

Engine RPM (Ne)
The Ne signal is one of the most critical inputs for proper operation of the ISC system. This sensor supplies the engine rpm feedback used to determine whether actual rpm equals target rpm.

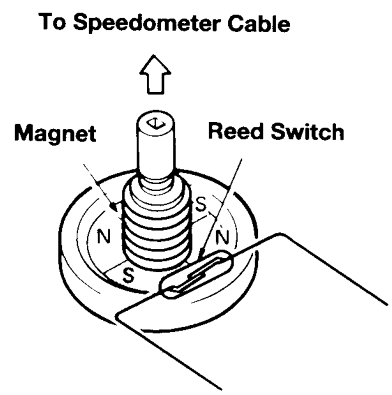
Throttle Position (IDL)
The Idle Speed Control System is functional only when the throttle is closed and the vehicle is not moving. The ECU monitors the IDL signal to determine when to output commands to the ISC actuator. When the IDL contact is closed and the vehicle is not moving, the ECU outputs signals to the ISCV. When the IDL contact is open, the ISC system is not functional. Without an accurate signal from the IDL contact, the ISC system cannot function normally.

Engine Coolant Temperature (THW)
The idle speed control program look up tables list different engine rpm targets depending on coolant temperature for the Step and Rotary ISC systems which control cold fast idle. The ECU uses the THW signal to determine engine coolant temperature for accurate control of idle speed under all engine temperature conditions.

Vehicle Speed (SPD)
The ISC system is not functional when the vehicle is moving. The ECU monitors the SPD signal from the vehicle speed sensor to determine when to operate the ISCV. If the IDL contact is closed and no SPD signal is detected, the ECU will output a signal to the ISCV.

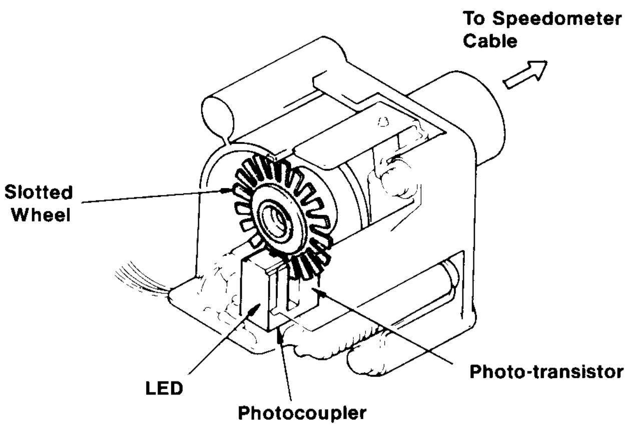
Vehicle Speed Sensor Operation
The ECU expects to see a digital signal of four pulses for each speedometer cable revolution when the vehicle is moving. The vehicle speed sensor (VSS) provides this signal.

There are two different types of vehicle speed sensors used to supply information to the engine ECU. Although these sensors differ in design, the final output signal to the ECU is the same for both, four digital pulses per cable revolution.



Reed Switch Type: The Reed Switch vehicle speed sensor is located in the combination meter assembly and is operated by the speedometer cable. The sensor consists of an electrical reed switch and a multiple pole permanent magnet. As the the speedometer cable turns, the permanent magnet rotates past the reed switch. The magnetic flux lines cause the contacts to open and close as they pass. The magnet is arranged so that the sensor contacts open and close four times for each revolution of the sensor.

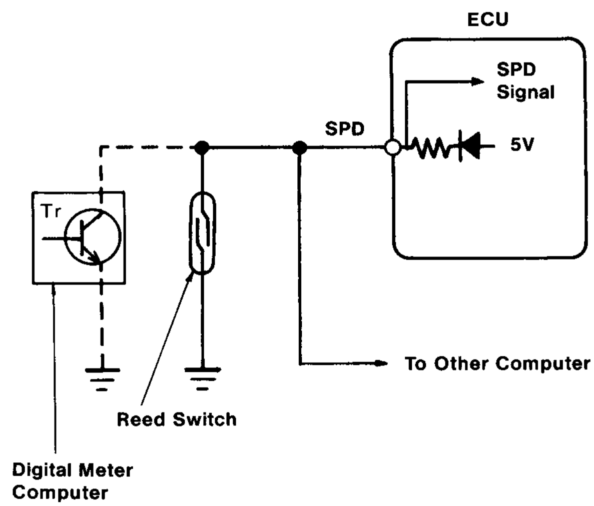
Photocoupler Type: The Photocoupler vehicle speed sensor is also located in the combination meter and operated by the speedometer cable. The sensor consists of a photocoupler circuit and a 20-slot trigger wheel.



The photocoupler circuit is a simple electronic device which uses a photo-transistor and a light emitting diode (LED) to generate a digital electrical signal (see article on Karman vortex air flow meter in Chapter 5 for operation theory of photocoupler circuit). As the slotted trigger wheel moves between the LED and phototransistor, it intermittently blocks and passes light at the photo-transistor. When the wheel blocks the LED, the transistor turns off and when the wheel passes the light, the transistor turns on.

With 20 slots, this sensor generates 20 digital pulses per speedometer revolution. An electronic circuit in the combination meter conditions this signal into four pulses which are sensed by the SPD circuit in the ECU.

Electrically, both the Reed type and Photocoupler type speed sensors work the same. The sensor is, in fact, a switch. By switching on and off, the sensor pulls a reference voltage from the ECU to ground. The resulting voltage drop is monitored by the ECU as the SPD signal.



Minor Impact Sensors

Neutral Start Switch (NSW)
The Neutral Start Switch input to the ECU is used for ISC control as well as having an influence, although minor, on the fuel delivery program. As it relates to the ISC system, this input is used to determine when to increase idle speed for Engine Load/Speed Change Estimate strategy.

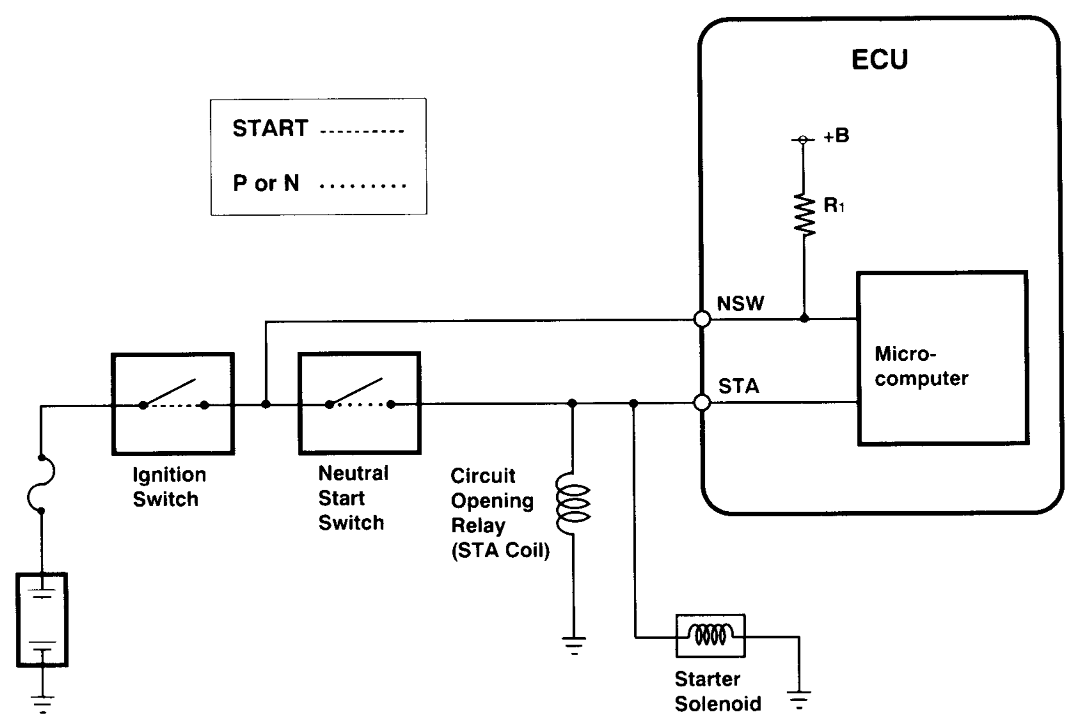
The NSW signal at the ECU will be low (less than 1 volt) as long as the neutral start switch is closed, as it will be with the gear selector in Park or Neutral. This low signal is caused by the voltage drop across R1 which has a relatively high resistance compared to the starter and circuit opening relay coils. When the transmission is shifted into any gear, the neutral start switch opens, causing a halt in current flow through the NSW circuit. This causes an increase in signal voltage at the NSW terminal of the ECU.

In the event this signal malfunctions, the ECU will use the wrong target idle speed for in gear operation and a distinct drop in idle rpm will be noticed as the transmission is shifted from Park or Neutral to any drive gear.

Engine Cranking Signal (STA)
The STA signal is used by the ECU to allow additional air to enter the intake manifold while cranking the engine. Additionally, it is used to determine when to enrich injection for starting and when to operate the Fuel Pressure-Up (FPU) system. In the event that the STA signal malfunctions, the engine may be difficult to start.

The STA signal at the ECU will be low at all times except while the engine is cranking. While cranking, the STA signal goes high (cranking voltage) as current flows through the closed ignition switch and neutral start switch contacts.

NEUTRAL START SWITCH CIRCUIT
STA Circuit



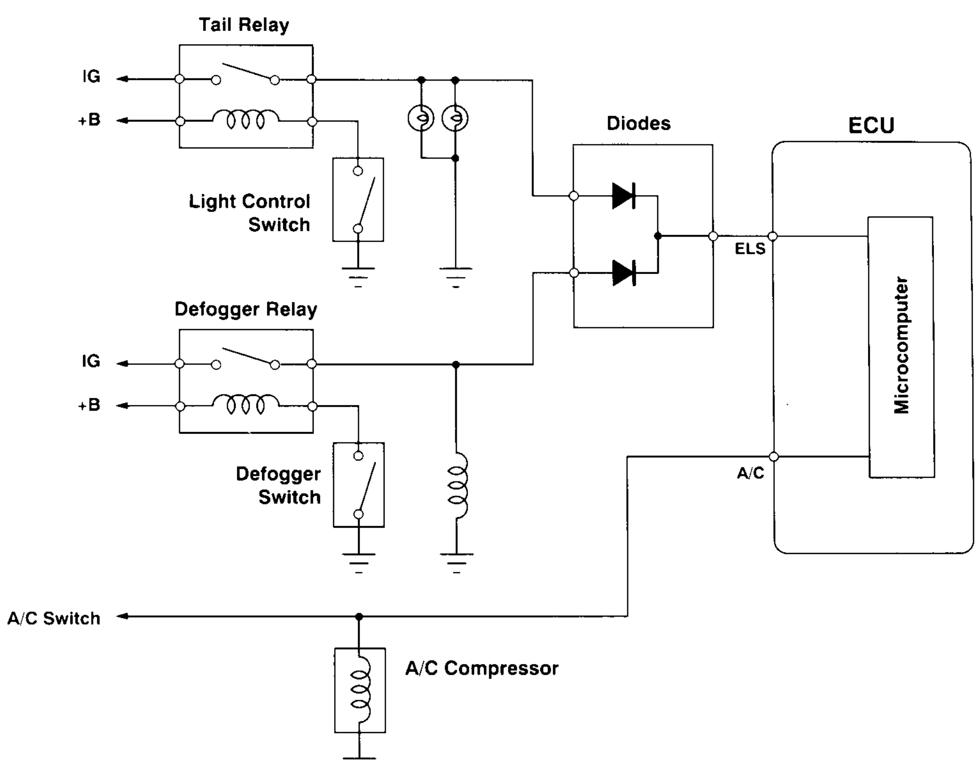
Air Conditioning Compressor Signal (A/C)
The A/C signal to the ECU is used to determine when the air conditioning compressor is loading the engine. The signal is used primarily as an indication to increase ISC air flow to stabilize idle speed. The A/C input is also used by the ECU to modify ignition timing and deceleration fuel cut parameters during compressor operation periods. When the A/C signal is high and the IDL contact is closed, the ECU limits minimum ignition spark advance angle. Additionally, decel fuel cut rpm is increased. In the event that this signal malfunctions, idle quality may suffer and driveability during deceleration could be affected.

The A/C signal at the ECU will be high any time the compressor clutch is energized. When power is removed from the clutch circuit, it is simultaneously removed from the A/C input at the ECU.

Electrical Load Sensor (ELS)
The ELS circuit signals the ECU when significant electrical load has been placed on the charging system from the vehicle lighting or rear window defogger systems. The ECU uses this information to increase the duty cycle ratio on the Rotary ISC Valve, thereby maintaining a stable idle speed.

The ELS signal at the ECU will be low as long as the tail lamps and rear window defogger are off. When either of these accessories are turned on, current flows to the accessory and through an isolation diode to the ECU. When either accessory is on, the signal at the ECU will go to battery voltage.

ELECTRICAL LOAD SIGNAL (ELS)
AIR CONDITIONING COMPRESSOR CLUTCH SIGNAL (A/C)



System Diagnosis and Troubleshooting

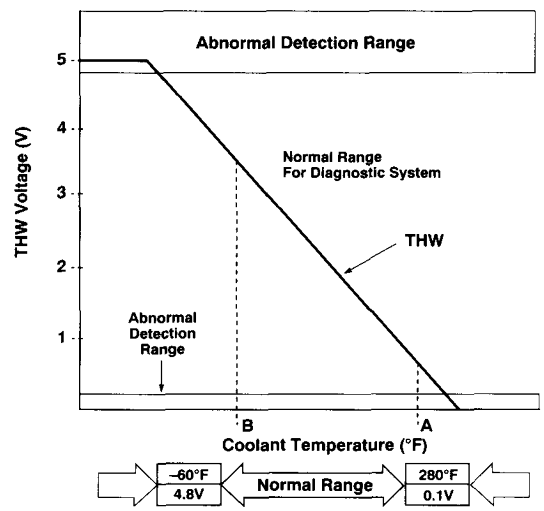
An Overview of the Self Diagnostic System
The ECU on all P7 and TCCS engines has a self diagnostic system which constantly monitors most of the electronic control system's input circuits. When the ECU detects a problem, it can turn on the check engine light to alert the driver that a fault exists in the system. At the same time, the ECU registers a diagnostic code in its **keep alive memory** so that the faulty circuit can be identified by a service technician at a later time.

if the circuit fault goes away, the check engine light will go off. However, the diagnostic code will remain in the ECU memory even after the ignition switch is turned off. For most engines, the contents of the diagnostic memory can be checked by shorting check connector terminals T (or TE1) and E1 together and counting the number of flashes on the check engine light.

After the problem has been repaired, the technician can clear the diagnostic system by removing the power from the ECU BATT feed.

Fault Detection Principles
The ECU fault detection system is programmed to accept sensor signal values within a certain range to be normal, and signals outside of that range to be abnormal. The normal signal range used to diagnose most sensor circuits covers the entire operating range of the sensor signal. As long as the signal value falls within this range, the ECU judges it to be normal. As a result, it is possible for the sensor to generate a signal which does not accurately represent the actual operating condition and not be detected as a problem by the ECU.

FAULT DETECTION RANGE



The fault detection range graph shows typical THW signal parameters. Point A is normal operating temperature and falls within the fault detection normal range. Point B represents the freezing point of water and also falls in the normal range. If the engine is at normal operating temperature but the THW sensor signals the ECU that the coolant temperature is freezing (point B), the engine will operate excessively rich and may not start when hot. Because point B falls within the normal range, the ECU will not recognize this as a problem. No diagnostic code will be set for this problem.

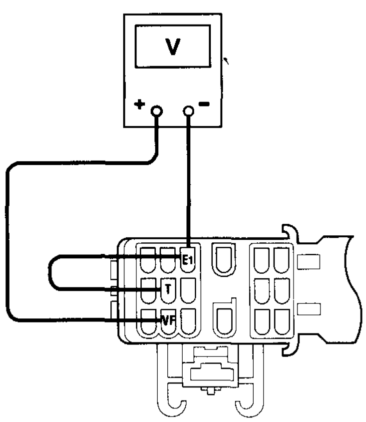
Limitations of the Self Diagnostic System
The self diagnostic system provides an excellent routine to direct the technician to the heart of an electronic control system problem. There are however, several limitations which must be kept in mind when troubleshooting.

- The ECU must see a signal in an abnormal range for more than a given amount of time before it will judge that signal to be faulty. Therefore, many intermittent problems cannot be detected by the ECU.

- When the ECU stores a diagnostic code, the code indicates a problem somewhere in the sensor circuit, not necessarily in the sensor itself Further testing is always required to properly diagnose the circuit.

- Not all circuits are monitored by the ECU. Just because the ECU generates a normal code does not mean that there are no problems within the electronic control system.

- Occasionally, diagnostic codes can be set during routine service procedures or by problems outside the electronic control system. Always clear codes and confirm that they reset prior to circuit troubleshooting.



Check Engine Lamp Functions

The check engine lamp serves two functions in the self diagnostic system, depending on the status of the T terminal. When the T terminal is off (not shorted to E1) the check engine light goes on to warn the driver when a major problem is detected in the electronic control system. When the **T terminal** is on (shorted to E1) the check engine light displays stored diagnostic codes for use by the technician.

VF (Voltage Feedback) Terminal Function

The **VF terminal** also serves two diagnostic functions depending on the status of the T terminal. When the T terminal is off, the VF terminal voltage represents **learned value** correction factor. When the T terminal is on, the VF terminal will either display an emulated oxygen sensor signal (throttle open, IDL contact off) or indicate whether a diagnostic code is stored in the ECU memory (throttle closed, IDL contact on).

CHECK ENGINE LAMP AND VF TERMINAL OUTPUT

T Terminal	IDL Contacts	Check Engine Lamp	VF Terminal Output	
OFF (Open)	N/A	Lamp check function (when engine is stopped)	Air/fuel ratio feedback correction amount or air/fuel ratio learned control value	5V (3.75V) : Increased amount 2.5V : Normal (1.25V) 0V : Decreased amount Some systems have five levels, and other systems have three levels.
		Warning display function (during engine operation)		
ON (Shorted)	OFF	Diagnostic code display function	Results of O_2 sensor signal processing	5V : Rich signal 0V : Lean signal
	ON		Results of diagnosis	5V : Normal 0V : Trouble code stored

Four Systematic Steps In Diagnosis

Simply stated, there are four steps to follow when performing a methodical diagnosis from start to finish. Using this systematic approach will generally lead to reduced diagnostic time and a higher degree of success. The four steps are listed as follows.

- Routine Quick Checks
- Use of the Self Diagnostic System
- Troubleshooting by Symptom
- Quality Control Check

Routine Quick Checks

This step in diagnosis includes confirmation of the problem and routine mechanical and electrical engine checks.

Confirmation of the customer concern is an excellent place to begin any diagnosis. It is important to gather and analyze as much information as the customer can supply and, if the check engine warning lamp is on, to retrieve and record the diagnostic codes.

The conditions of the battery and charging system are critical to the proper operation of the electronic control system. Both should be routinely checked by measuring cranking and engine running battery voltage prior to proceeding with diagnosis.

Depending on the problem or driveability symptom indicated, the following checks should be conducted under the hood:

- Inspection of the engine's mechanical condition (i.e., audible cranking rhythm and visual ignition secondary condition).
- Brief inspection of accessible electrical, vacuum and air induction system duct connections.
- Locate and inspect the condition of the ECU main grounds.
- Inspect for leakage in the EGR and PCV valves.
- Inspect for unwanted fuel entering the intake manifold from the EVAP system.

The entire routine quick check procedure can be performed in less than ten minutes and will often save an hour or more of unnecessary diagnostic time.

Use of the Self Diagnostic System Once you are satisfied that there are no routine problems causing the customer concern, use of the self diagnostic system is in order. This system is available on all P7 and TCCS equipped engines and is capable of indicating if certain faults exist in ECU monitored circuits.

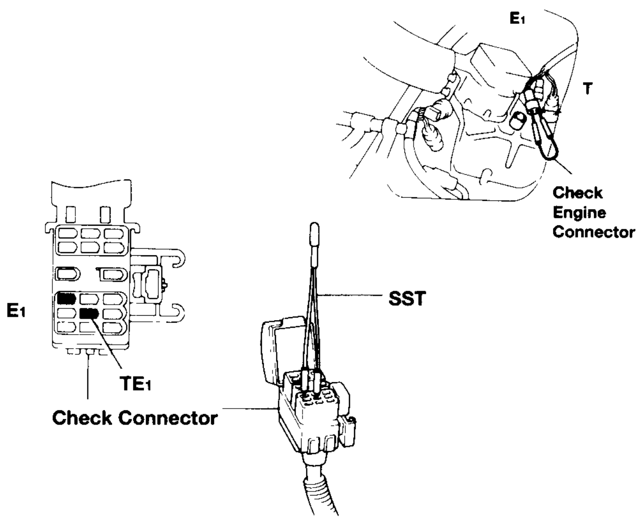
The P7 systems have limited diagnostic capabilities and can only display seven diagnostic codes, including a system normal code. This system will only indicate a fault if the circuit is open or shorted to ground.

Late model TCCS systems have more sophisticated diagnostics which monitor more ECU related circuits with as many as 21 or more diagnostic codes. The latest TCCS ECUs have some special capabilities which make them more useful in diagnosis and prevent the check engine warning light from becoming a source of customer dissatisfaction.

- To allow the diagnostic system to find more system faults, the electrical parameters which the ECU uses to set a diagnostic code are altered to find sensor performance faults like oxygen sensor degradation.
- Some minor TCCS system fault codes will set a diagnostic code in the ECU keep alive memory but will not turn on the check engine light and unnecessarily alarm the customer.
- To prevent false indication of certain system faults, some ECUs are programmed to use a two-trip detection logic which prevents the check engine light from illuminating, or certain codes from setting, until the problem has duplicated itself twice, with a key off cycle in between.
- Some ECUs have a special diagnostic TEST mode which causes the ECU to narrow its diagnostic parameters for the technician, thereby, making troubleshooting intermittent problems easier.

Procedures to Retrieve Trouble Codes

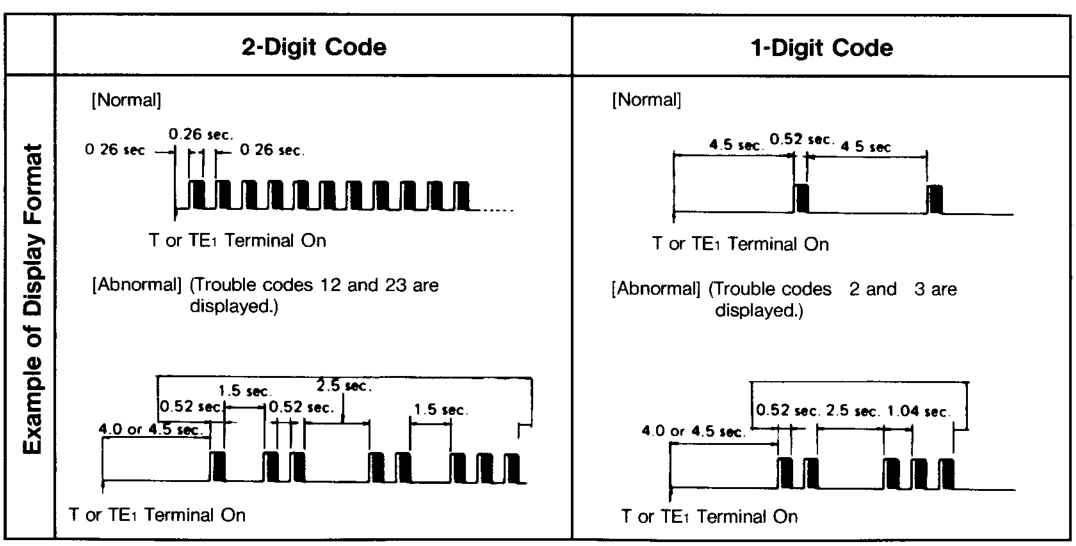
There are several different types and locations of diagnostic connectors which are used to trigger and, in some cases, read diagnostic code output from Toyota EFI engines. All late model TCCS applications, from 1988, use a multiple terminal diagnostic **check connector**. Earlier models use this same multiple terminal or a two-terminal check connector, all located under the hood.



The procedure to examine the ECU memory for diagnostic codes is typically very simple regardless of which vintage engine being diagnosed. All engines equipped with self diagnostic systems have one terminal of the check connector identified as T or TE1. When grounded, this terminal triggers the self diagnostic feature of the ECU. The E1 ground circuit is also located in the check connector.

To enter engine diagnostics:

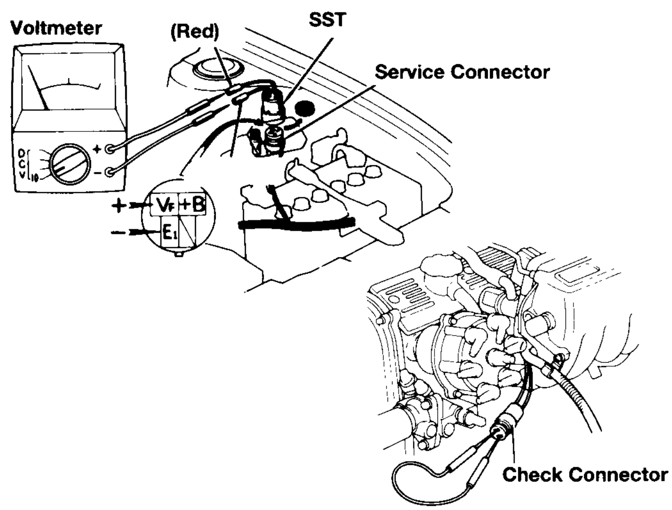
- Locate the check connector under the hood and identify the T (TE1 on late model TCCS) and E1 terminals.
- Turn the ignition switch to the "on" position and make sure that the check engine light is on.
- Confirm that the throttle is closed (IDL contact on).
- Jumper check connector terminals T (TE1) to E1.



When the T terminal is grounded with the ignition switch in the "on" position, the ECU sees the voltage at terminal T go low. Low voltage on T causes the ECU to enter diagnostic mode, producing diagnostic codes on the check engine light. On '83 through '85 Cressida and Supra models, the check engine light does not flash diagnostic codes. An analog voltmeter must be used to read the codes from the VF terminal of the EFI Service Connector.

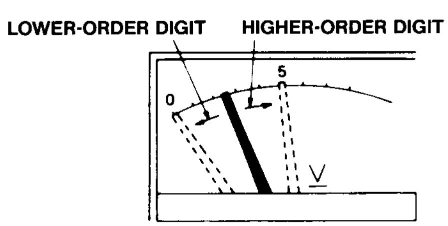
Depending on the vintage of the system being tested, the codes will be displayed in either one or two digit format. It is important to refer to the proper repair manual for specific information about diagnostic connector location, code format, and proper procedures for the vehicle you are troubleshooting.

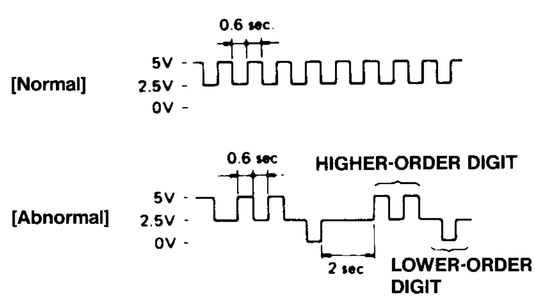
'83 THROUGH '85 CRESSIDA AND SUPRA



2-Digit Code

With 2.5V as the center point, read the number of times the meter needle oscillates to 5V as the higher-order digit, and the number of times it oscillates to 0V as the lower-order digit.

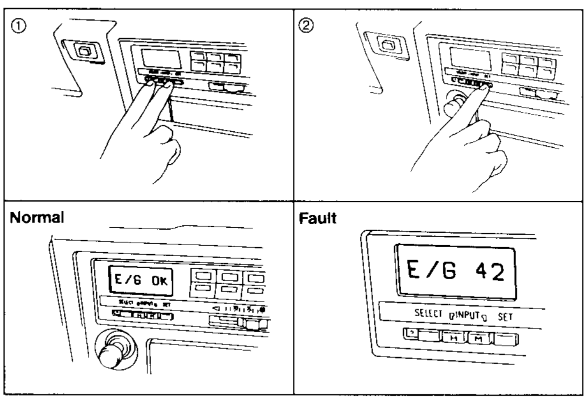




CODE NO. 21

Super Monitor Display: On some 1983 through 1987 Cressida and Supra models, a Super Monitor trip computer was offered as optional equipment. This display can be used to read diagnostic codes by simply pressing and holding the monitor "Select" and "Input M" keys together, for three seconds, with the ignition switch in the "on" position. When the "DIAG" message appears on the display, pressing and holding the "Set" key for three seconds will put the TCCS system into diagnostic mode. The display will indicate any diagnostic codes stored in the ECU's keep alive memory.

Super Monitor Display

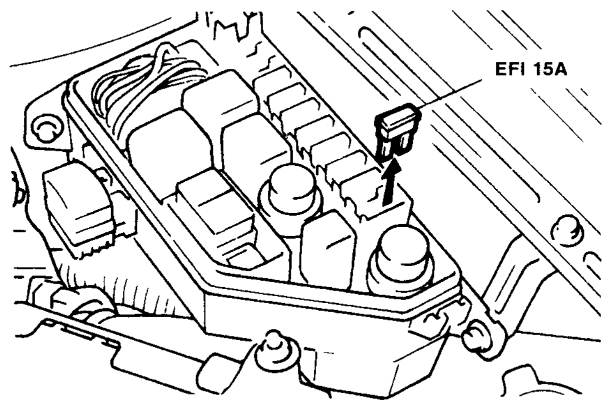


Once Diagnostic Codes Are Retrieved

Once diagnostic codes have been retrieved from the ECU keep alive memory, it is advisable to erase the codes and road test the vehicle. 'Me purpose of this procedure is to confirm that the problem(s) will be present during your diagnosis.

If the diagnostic code re-occurs, the problem can be considered a **hard fault** and troubleshooting will be routine. If the diagnosis code does not re-occur, the problem is either intermittent or was inadvertently stored during a previous service procedure.

If an **intermittent fault** is suspected, a physical check of the indicated circuit must be performed by flexing connectors and harnesses at likely failure points while monitoring the circuit with a multimeter or oscilloscope. If the problem is temperature, vibration, or moisture related, the circuit can be heated, lightly tapped, or sprayed with water to simulate the failure conditions. Attempting to troubleshoot intermittent problems using the normal diagnostic routines will likely result in a misdiagnosis and wasted time.



Erasing Long Term Memory

The procedure to erase stored diagnostic codes is as simple as removing a fuse or disconnecting the battery negative terminal for at least thirty seconds. Fuse removal is the method of choice because it will not disturb any other computer memories in the vehicle (ETR radio stations, trip computer data, etc.)

The proper fuse to remove depends on application but will always be the one which feeds the ECU BATT terminal. The following fuses supply BATT power distribution to the ECU keep alive memory: EFI, STOP, or on some P7 applications, ECU +B.

READING AND CONFIRMING DIAGNOSTIC CODES

(1) Read and record diagnostic code(s).

(2) Code 11, 13, or 42? — YES → Go to relevant Diag. Code Chart.

NO ↓

(3) Code 51? — YES → (7) Check the following:
(a) Air conditioner switch off?
(b) Throttle valve fully closed?
(c) Shift lever in P or A (A/T)?

NO ↓

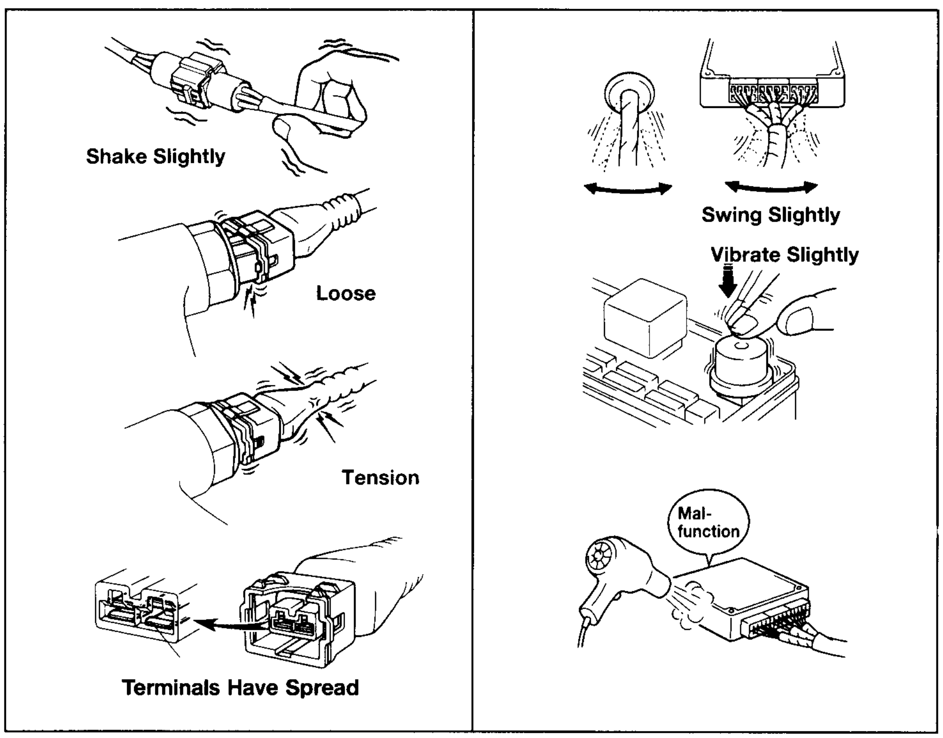
(4) Clear memory; then see whether previously output codes are still being output.

(5) Are previously output codes still being output? — YES → Go to relevant Diag. Code Chart.

NO ↓

(6) Go to "Troubleshooting Intermittent Problems."

RECREATING INTERMITTENTS



Monitored and Non-monitored Circuits

Although the newer TCCS self diagnostic system is getting more sophisticated every model year, there are still many electronic control system circuits which the ECU does not monitor. Generally speaking, most input sensors are monitored for faults, but most output actuators are not. Exceptions to this are the Neutral Start Switch (NSW) and Power Switch (PSW)* input signals which are not monitored. Codes 25 and 26 monitor the air/fuel ratio rather than the status of a particular circuit.

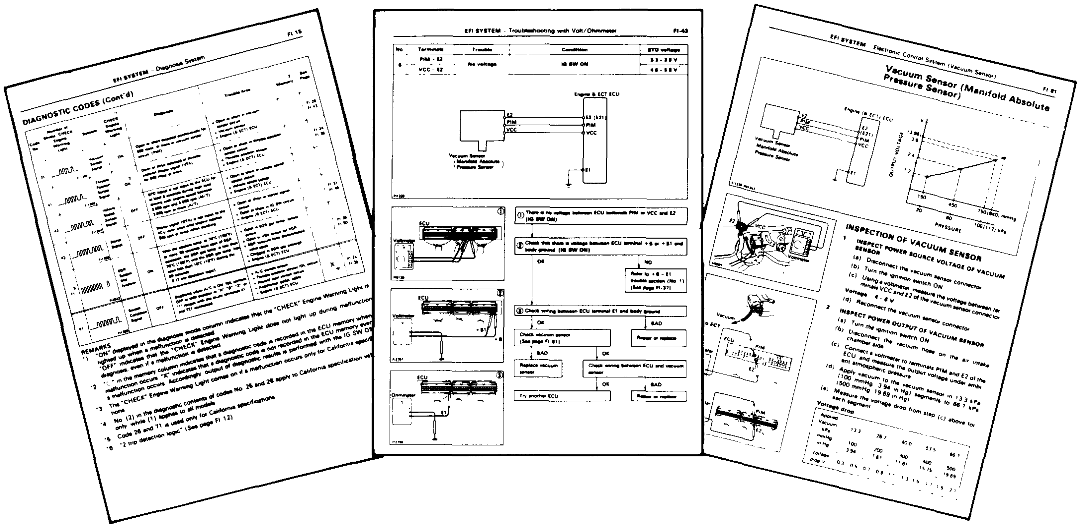
Troubleshooting After Code Retrieval

The diagnostic code leads only to a **circuit level diagnosis**. A pinpoint test of the circuit indicated will be required to isolate the problem down to the component or wiring level.

To find the appropriate diagnostic procedure to follow:

- Refer to the last column of the repair manual "Diagnostic Codes" list.
- This will lead to one or more "Troubleshooting with a Voltmeter/Ohmmeter" diagnostic charts which will facilitate circuit diagnosis.
- This may also lead to an "Inspection of Component" procedure which will facilitate diagnosis of the sensor or actuator in the circuit.

But what if you do not have a diagnostic code to help lead you to the cause of the customer complaint? What do you do next? Before we address the third step in the systematic diagnostic approach, the subject of an inoperative self diagnostic system must be addressed.



- **Retrieve Diagnostic Codes**

↓

- **"Troubleshooting with Volt/Ohmmeter" Chart → EWD**

↓

- **"Inspection of Component" Chart → EWD**

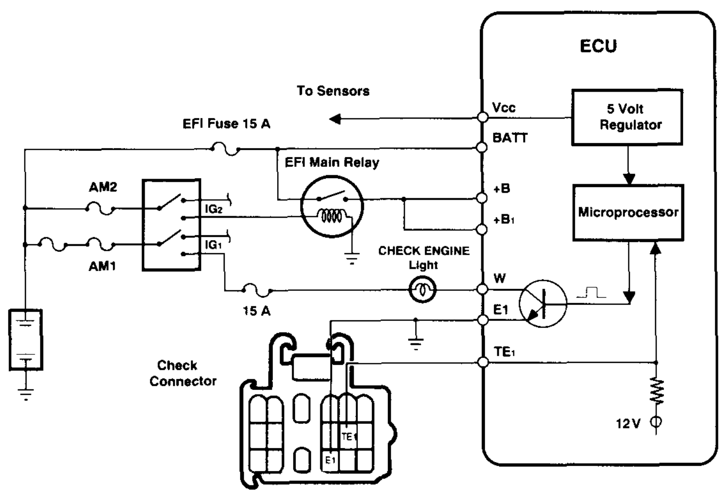
↓

- **Problem Identified**

No Self Diagnostic System Output (Use of Diagnostic Circuit Inspection Schematic)

There are several conditions which could cause the self diagnostic system to malfunction. In the event the check engine light does not work or if the system will not flash diagnostic codes, it will be impossible to make an accurate diagnosis of the electronic control system. Following are some suggestions to help troubleshoot this condition if it is encountered.

DIAGNOSTIC CIRCUIT INSPECTION



Normal Operation

The following sequence of events should occur when diagnostics are functioning normally:

- With the ignition switch in the "on" position, the check engine fight should be on steady.
- When the T circuit is grounded, the check engine light should flash a normal code if all monitored circuits are in proper working order.
- If a fault exists in any monitored circuit, the appropriate diagnostic code should be displayed. If there is more than one code stored in the ECU keep alive memory, codes will be displayed in numerical sequence from lowest to highest.
- Diagnostic codes will continue to repeat until the key is turned off or the T circuit ground is removed.

Abnormal Operation

In the event the self diagnostic system is not functioning normally, it will likely exhibit one of the following symptoms.

1) Check engine light fails to come on at power up (key on, engine off, T circuit open).

2) Check engine light will not flash code when T circuit grounded (T jumpered to E1), check engine lamp stays on or stays off.

These conditions must be corrected before further diagnosis can be performed! The following charts will help to direct you to perform a "Diagnostic Circuit Inspection."

Check Engine Light Fails to Come On At Bulb Check

Possible Cause	Action to Take/Items To Inspect
Faulty fuse or wiring in BATT or +B circuit(s) to ECU	• Repair cause and replace fuse. • Repair open in BATT circuit. • Repair EFI Main Relay to ECU +B terminal.
Faulty fuse or wiring in IG_1 feed to check engine lamp	• Repair cause of burned fuse and replace fuse. • Repair open in wiring to check engine lamp.
Burned out check engine bulb	• Replace bulb.
Faulty wiring in W circuit between fuse and ECU (including ECU connection at terminal W)	• Isolate circuit fault using multimeter starting at ECU terminal W. – With ignition off, disconnect ECU connector, turn ignition on; there should be battery voltage at ECU harness terminal W. – Grounding harness terminal W should turn on check engine light if circuit is good.
Faulty E_1 ground circuit	• Isolate fault using multimeter and repair as necessary.
Grounded Vcc circuit in wiring or sensor	• With ECU connected and ignition on, measure voltage at V_{cc} terminal. – A grounded Vcc will pull this voltage low. – Start disconnecting sensors fed by Vcc one at a time until the voltage goes up to 5 volts; this identifies the offending sensor. • If all sensors are disconnected and voltage is still low at Vcc, turn off the ignition and disconnect the ECU. – Use ohmmeter to measure harness for continuity to ground on the Vcc circuit. – If no fault is found in sensors or harness, the ECU is at fault.
Faulty ECU	• Make sure that connections at the ECU are good (use terminal contact gauge on harness to confirm). • Check +B, W, and E_1 circuit connections. If these connections are good, replace ECU.

Check Engine Light Does Not Flash Codes (Stays On or Off)

Possible Cause	Action to Take/Items To Inspect
Faulty wiring in T circuit (including ECU connection at terminal T)	• With T circuit open and ignition switch in "on" position, there should be 12 volts at the T terminal of the check connector. – If voltage is zero, re-check voltage at ECU under same condition. – If voltage is still zero, turn ignition switch off and disconnect ECU. • Check connection at terminal T in harness connector using a terminal contact gauge. – If connection checks O.K., replace ECU.
Grounded W circuit between check engine bulb and ECU	• Turn off ignition switch, disconnect ECU connector. – Turn ignition on, if check engine light comes on, W circuit is grounded. – Disconnect connector at combination meter and isolate unwanted ground.
Faulty E_1 ground circuit	• Isolate fault using multimeter and repair as necessary.
Faulty ECU	• Make sure that connections at the ECU are good (use terminal contact gauge on harness to confirm). – Re-confirm T connection. – If this connection is good, replace ECU.

At this stage in your diagnosis, you may have already diagnosed the problem and are ready for repair and a quality control check. If the problem has not yet been identified, you are ready for the next diagnostic step.

Troubleshooting By Symptom

When the self diagnostic system fails to indicate a problem with the electronic control system (normal code displayed), there are two possibilities left. Either there is a problem in the electronic control system which the ECU is not capable of detecting or the problem lies outside of the electronic control system entirely. In either case, the "Troubleshooting" section of the repair manual will help you locate the appropriate diagnostic routine to quickly isolate the problem cause.

The third step in a systematic diagnosis requires use of the "Troubleshooting" and cc Voltage at ECU Wiring Connectors" sections of the repair manual. Based on the symptom the vehicle exhibits, these manual sections will lead you to the diagnostic routine which will assist in solving the problem.

Voltage at ECU Connector Checks

The self diagnostic system is not capable of detecting sensor circuits which are feeding out of range information to the ECU. By using the Voltage at ECU Wiring Connectors chart, measured voltage signals at the ECU can be compared to **standard voltage values** listed in the repair manual. Signals which are out of the normal range can be identified and the cause diagnosed by referring to the far right column of the chart; this will lead to the appropriate pinpoint test to perform.

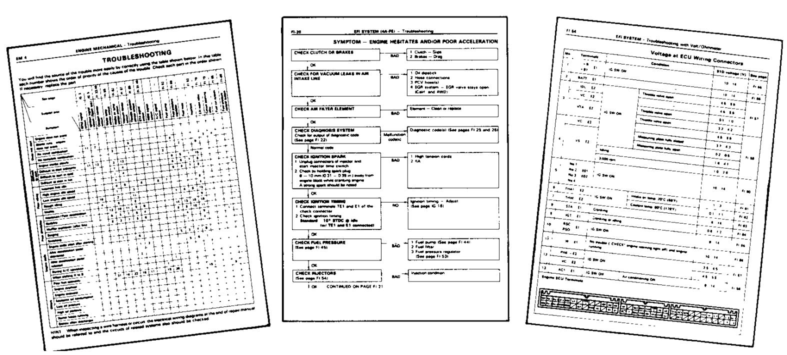
In the event that all listed values fall within a normal range, the symptom charts in the repair manual should be consulted. Starting with new models introduced after '90, repair manuals include a comprehensive troubleshooting matrix that replaces the symptoms charts. Beginning with '92 repair manuals, this matrix is located at the beginning of the Emissions (EM) section of the repair manual.

Using the Symptom Charts and Troubleshooting Matrix

The most important part of troubleshooting by symptom is to identify the symptom accurately. An accurate description of the problem will ensure that the appropriate diagnostic routines will be selected. Based on the symptom chosen, a series of testing routines are available to assist in pinpointing the problem area.

These test routines address items within the electronic control system as well as areas outside the system which could cause the symptom chosen. The technician's knowledge and experience will be his guide to which tests to perform first and which tests to disregard in any particular situation.

TROUBLESHOOTING BY SYMPTOM



Quality Control Check and Confirmation of Closed Loop

The final step in any diagnosis and repair is a quality control check to confirm that the original customer complaint has been corrected and that the system is functioning normally. In the case of the engine electronic control system, the Quality Control Check should consist of the following items:

• Clear any stored diagnostic codes.

• Confirm closed loop operation.

• Confirm normal air/fuel ratio calibration.

• Confirm codes do not reset.

Three of these confirmations can be performed using the VF terminal of the check connector.

Using the VF Terminal As A Closed Loop and Air/Fuel Ratio Monitor

The VF terminal serves as a closed loop monitor, allowing the technician to track the oxygen sensor activity and confirm closed loop operation.

To Use the VF Terminal as a Closed Loop Monitor

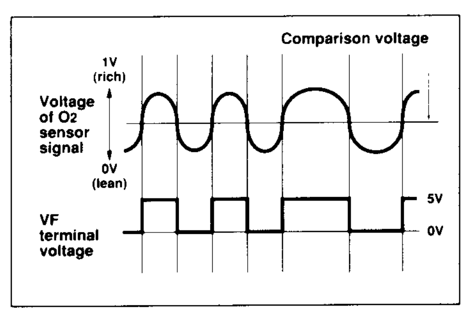
• T terminal must be on (shorted to E1).

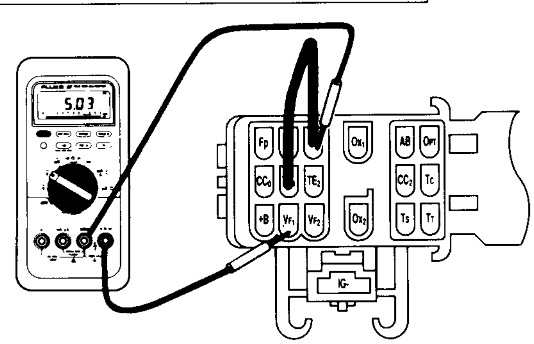
• IDL contacts must be off (throttle open).

When these conditions have been satisfied, the voltage signal on the VF terminal will imitate the oxygen sensor signal. Whenever the oxygen sensor signal is high, indicating a rich exhaust condition, the VF terminal voltage will be 5 volts. When the oxygen sensor signal is low, indicating a lean exhaust condition, the VF terminal voltage will be 0 volts.

At 2500 rpm, oxygen sensor switching should occur a minimum of eight times in ten seconds if the closed loop system is operating normally. To test, the engine must be fully warmed up and run at 2500 rpm for one minute to ensure the oxygen sensor has reached operating temperature.

VF VOLTAGE (TE1 GROUNDED)
Closed Loop Monitor

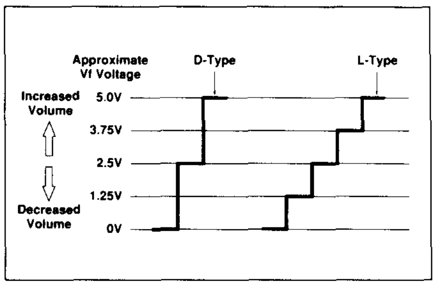


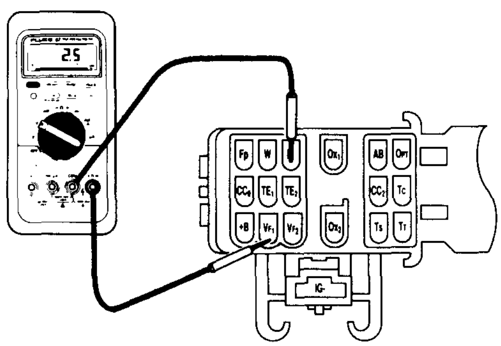


To Use the VF Terminal to Confirm Air/Fuel Ratio

• T terminal must be off (not grounded).

VF VOLTAGE (TE1 OPEN)
LEARNED VALUE





Under this condition, the VF voltage represents the learned value correction factor to fuel injection duration. As you learned in Chapter 5, final injection duration is the sum of basic injection plus injection corrections. Learned value is simply another correction factor which is used to bring the corrected air/fuel ratio as close to the stoichiometric air/fuel ratio as possible.

The ECU fuel injection duration program is the same for every engine; however, each engine is a little bit different from the next. The purpose of the learned value correction is to tailor the standard fuel injection duration program to each individual engine. The injection duration calculation, before oxygen sensor correction, is the ECU's best guess at a stoichiometric air/fuel ratio. The oxygen sensor correction fine-tunes injection duration precisely to 14.7 to 1. The learned value correction factor ensures that oxygen sensor corrections do not become too large to manage.

In this mode, the VF voltage signal will be at one of five different steps (three steps on D type EFI) depending on how close the calculated air/fuel ratio (before oxygen sensor correction) is to stoichiometry. With the engine operating in closed loop, learned value VF should be somewhere in the 1.25 to 3.75 volt range with a nominal value of 2.5 volts.

Generally speaking, a lower voltage indicates the ECU is decreasing fuel to correct for some long term rich condition. Examples of conditions which could cause low learned value VF:

• Crankcase diluted with fuel
• Loaded evaporative canister
• High fuel pressure

A higher voltage indicates that the ECU is increasing fuel to correct for some long term lean condition. Examples of conditions which could cause high learned value VF:

• Atmospheric leaks into intake system
• Worn throttle shaft
• Low fuel pressure

Toyota Diagnostic Communications Link (TDCL)

The TDCL is an enhanced diagnostic check connector which adds a special diagnostic TEST mode to the self diagnostic system. It is only used on '89 and later Cressida, '92 and later Camry, and all Lexus models. It is located under the left side of the instrument panel.

The TDCL uses a TE2 test terminal, which when grounded, triggers the special TEST mode. In TEST mode, the ECU is capable of detecting intermittent electrical faults which are difficult to detect in a normal diagnostic mode. The ECU eliminates most code setting conditions when TEST mode is entered, allowing it to immediately detect a malfunction in many of the monitored circuits.

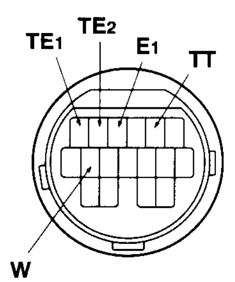
Using the Diagnostic TEST Mode Procedure

With the ignition switch off, connect terminals TE2 and E1 using SST #09842-18020 (TEST mode will not start if TE2 is grounded after the ignition switch is already on).

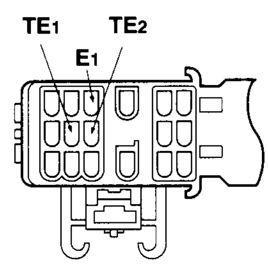
- Turn the ignition switch on; then start the engine and drive the vehicle at least 6 mph or higher (code 42, vehicle speed sensor will set if vehicle speed does not exceed 6 mph).
- Simulate driving conditions that problem occurs under.
- When the check engine lamp comes on, jumper TE1 to El without disconnecting TE2.
- Note and record diagnostic codes (codes display in same manner as in normal diagnostic mode).
- Exit diagnostic TEST mode by disconnecting TE2 and turning the ignition switch off.

Diagnostic TEST mode is also available on the > '92 Celica 5S-FE and 3S-GTE applications through the check connector TE2 terminal. For more information on using the VF terminal and the TE2 TEST mode diagnostics, refer to Course #872, TCCS Diagnosis.

TDCL



CHECK CONNECTOR



TE1 and E1 Terminals	TE2 and E1 Terminals	Diagnostic Mode	Output of Check Engine Lamp
Open	Open	Normal	Lamp lights if malfunction occurs and warns the driver.
	Connected	Test	Lamp lights if malfunction occurs and informs the technician.
Connected	Open	Normal	Output of diagnostic results (content of malfunction), in normal mode indicated by the number of times the lamp blinks.
	Connected	Test	Output of diagnostic results (content of malfunction), in test mode indicated by the number of times the lamp blinks.

