

ENGINE CONTROLS PART #3 - IDLE SPEED CONTROL

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:

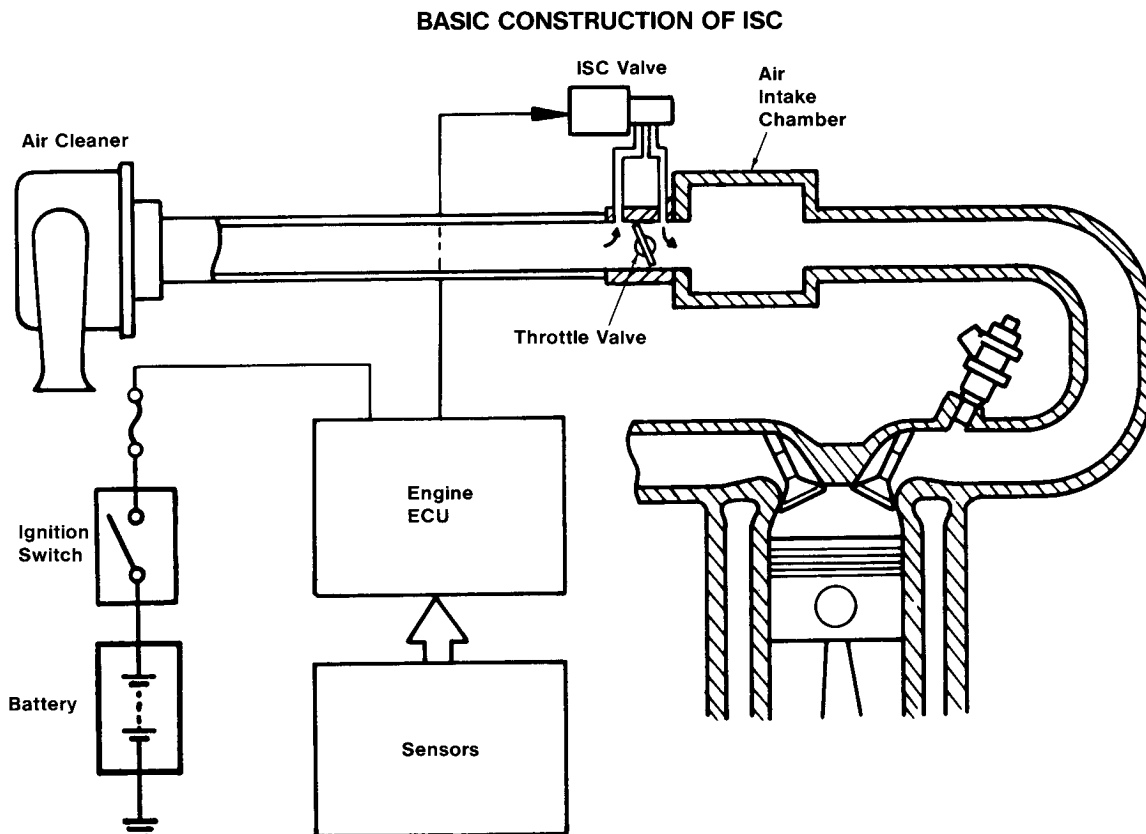
- Fast Idle
- Warm Curb Idle
- Air Conditioner Load
- Electrical Load
- Automatic Transmission Load

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.



Four Different ECU Modulated Idle Speed Control Systems (ISC)

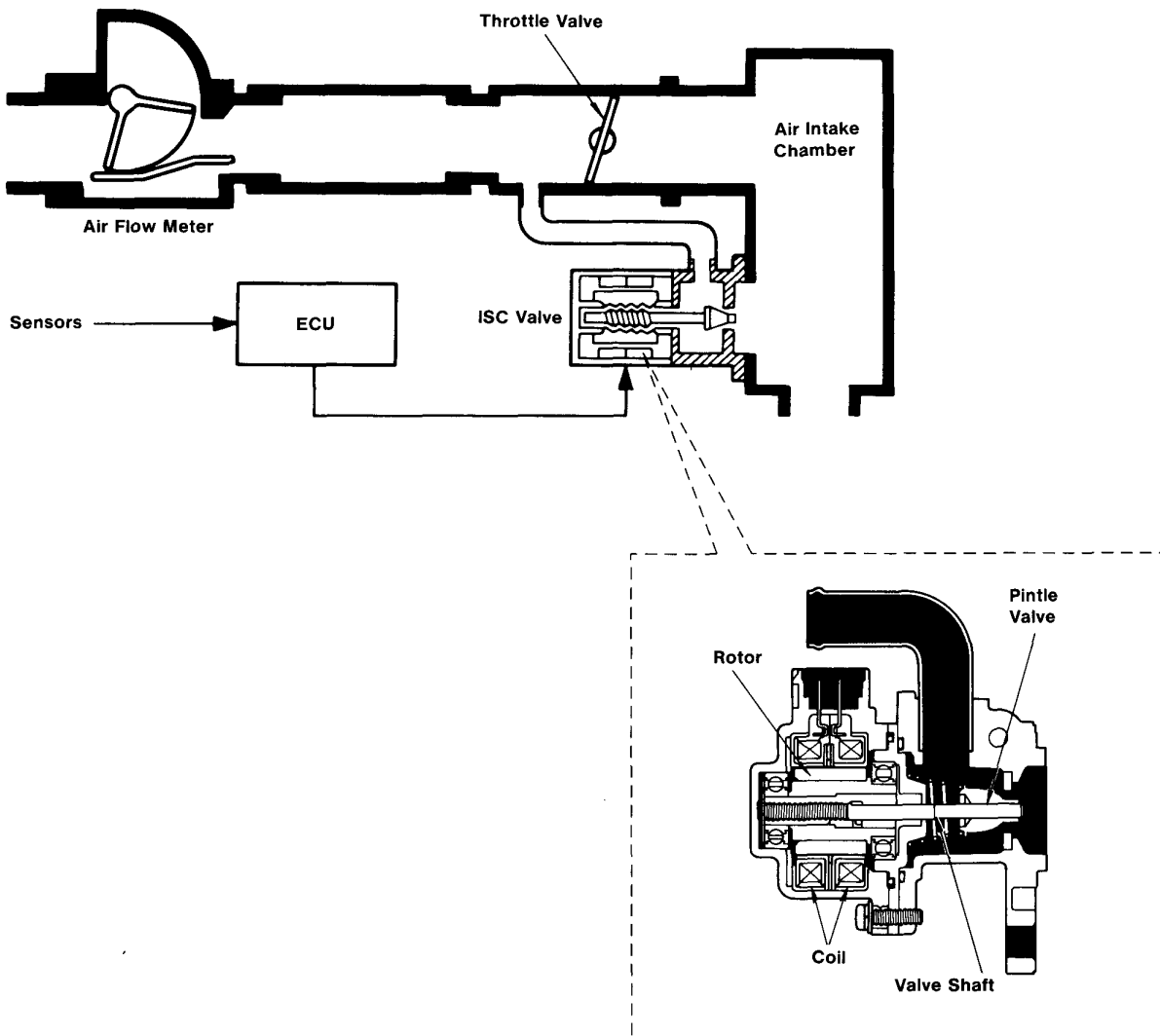
There are four different types of ECU controlled ISC systems used on Toyota engines. These systems are referred to as:

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

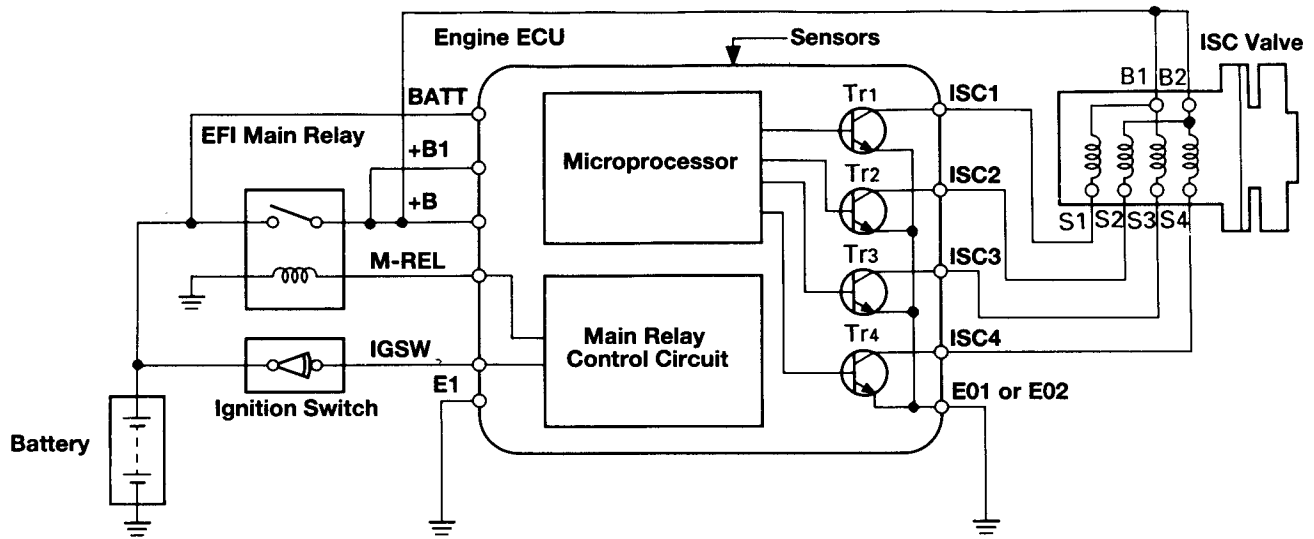
Step Motor Type ISC Valve

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.



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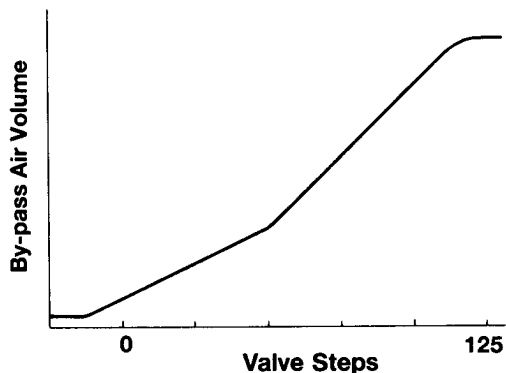


To Extend Valve (Reduce Air By-pass)
Tr1 → Tr2 → Tr3 → Tr4

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

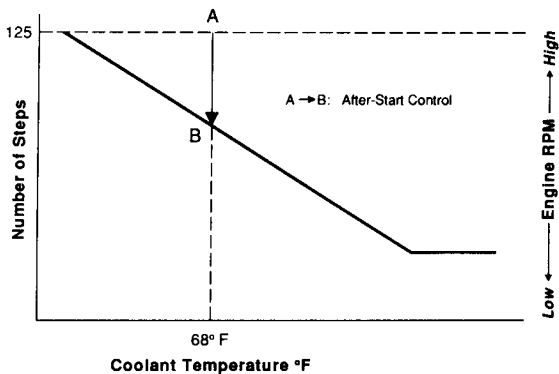
| ISC Type/ Engine | Relevant Inputs | Controlled Parameters |
|---------------------|---|----------------------------------|
| Step Motor Type | Engine speed (Ne) Throttle angle (IDL) | • Warm Curb Idle |
| • 7M-GE/GTE | Vehicle speed (SPD) | • Cold Fast Idle |
| • 5M-GE | Coolant temp. (THW) | • Air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

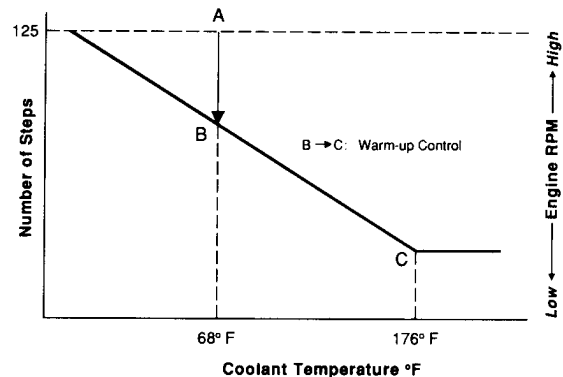
When 500 rpm is reached, the ECU drives the ISCV to a precise number of steps from seat based on the coolant temperature at time of start-up. This information is stored in a look up table in the ECU memory and is represented by point B on the graph.

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.

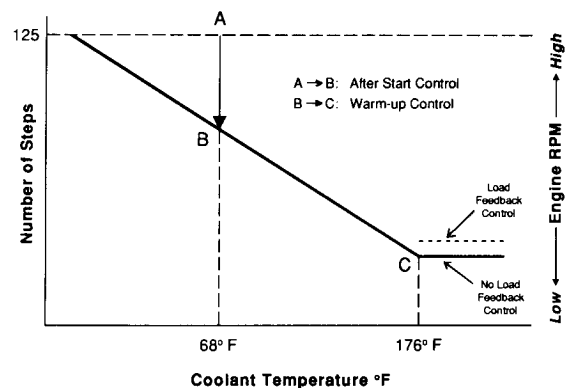
ENGINE WARM-UP CONTROL



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 ISCV 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.

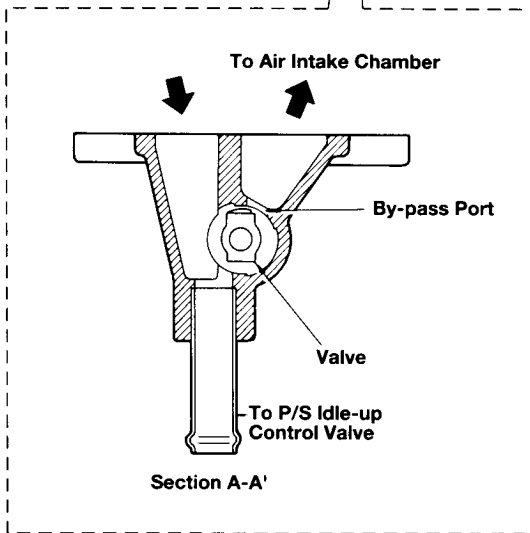
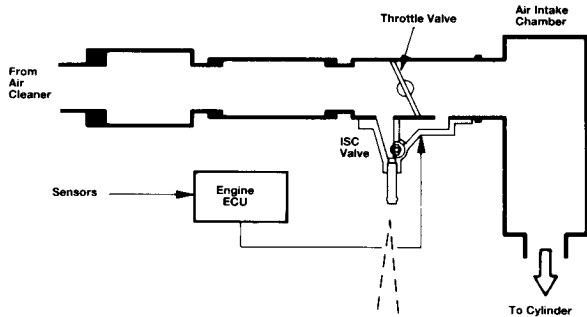
Deceleration Dashpot Control

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

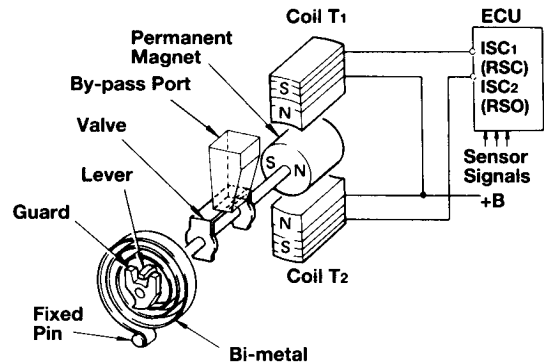
The idle speed control program is based on an ECU stored look up table which lists pintle step positions in relation to specific engine rpm values. Over time, engine wear and other variations tend to change these relationships. Because this system is capable of feedback control, it is also capable of 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



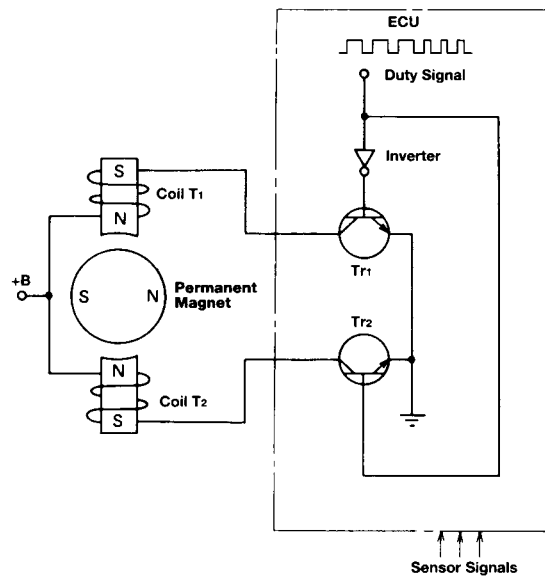
The Rotary Solenoid ISCV is mounted to the throttle body. This small, lightweight and highly reliable valve controls the volume of intake air which is allowed to by-pass the closed throttle valve. Air volume control is accomplished by means of a movable rotary valve which blocks or exposes the air by-pass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



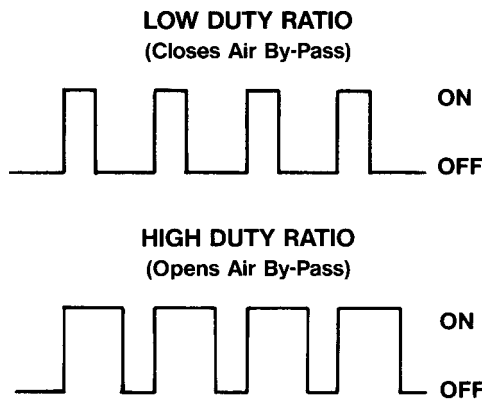
PRINCIPLE OF ISC VALVE

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.



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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.



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) Throttle angle (IDL) | • Warm Curb Idle |
| • 4A-GZE | Vehicle speed (SPD) Coolant temp. (THW) | • Cold Fast Idle |
| • 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 Startling, 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.

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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.

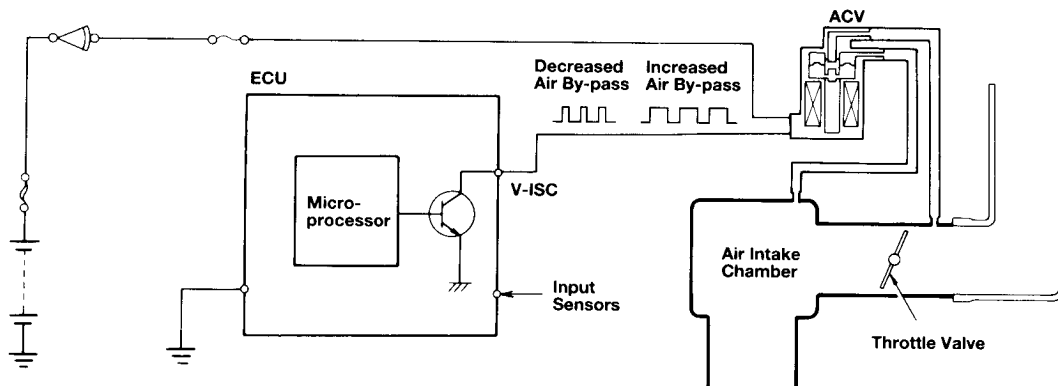
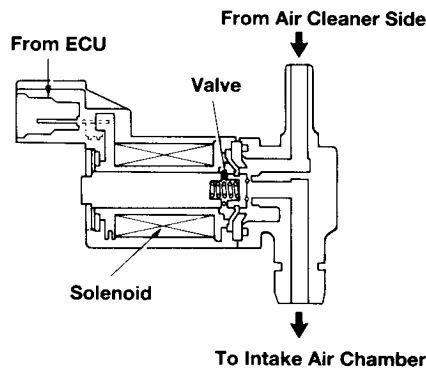
Duty Control ACV ISC Applications and Control Parameters

| ISC Type/Engine | Relevant Inputs | Controlled Parameters |
|-----------------------|---|---|
| Duty Control VSV Type | Engine speed (Ne) Coolant temp. (THW) Air conditioner clutch (A/C) Electrical load (ELS) Throttle signal (IDL) Vehicle speed (SPD) Neutral switch (NSW) | <ul style="list-style-type: none"> • 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.



ENGINE CONTROLS PART #3 - IDLE SPEED CONTROL

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.

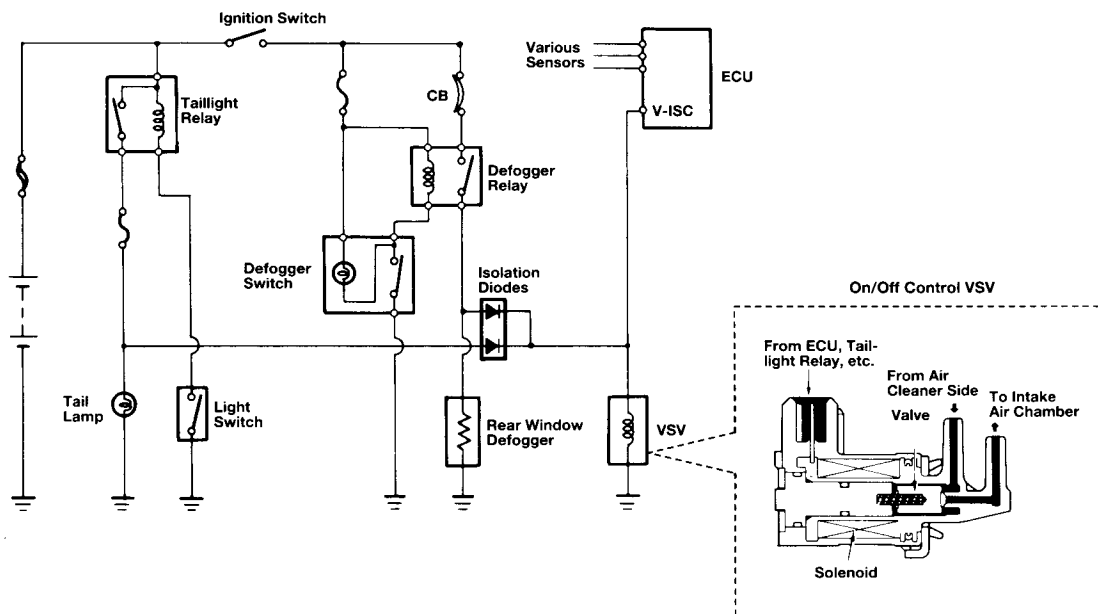
Diagnostic Mode

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.



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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) Coolant temp. (THW) Air conditioner clutch (A/C) | <ul style="list-style-type: none"> • Engine Starting Stabilization |
| <ul style="list-style-type: none"> • 4A-GE • 3E-E • 4Y-E • 2S-E • 3S-GE | <ul style="list-style-type: none"> Electrical load (ELS) Throttle signal (IDL) Vehicle speed (SPD) Neutral switch (NSW) | <ul style="list-style-type: none"> • Air Conditioner Idle-up • Electrical Load Idle-up • 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.

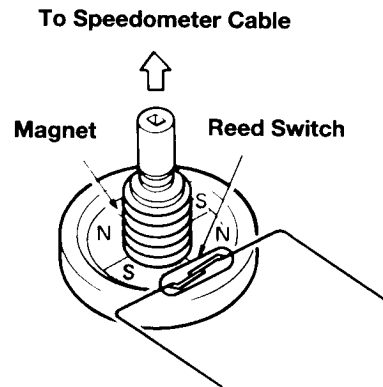
Vehicle Speed (SPD)

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

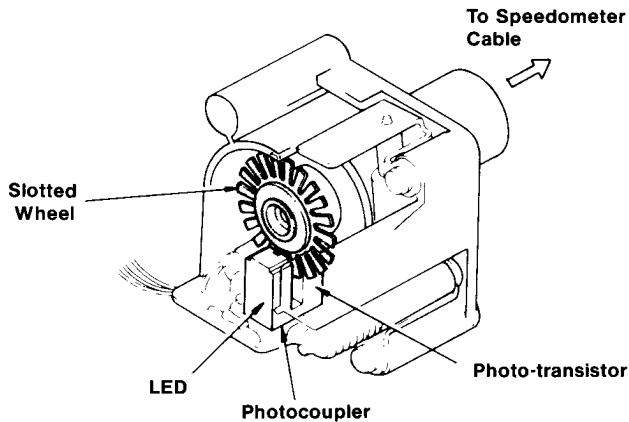
The ECU expects to see a digital signal of four pulses for each speedometer cable revolution when the vehicle is moving. The vehicle speed sensor (VSS) provides this signal.

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.

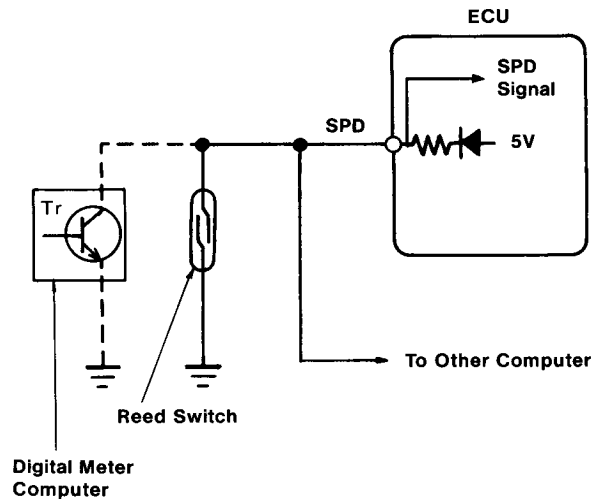
Photocoupler Type: The Photocoupler vehicle speed sensor is also located in the combination meter and operated by the speedometer cable. The sensor consists of a photocoupler circuit and a 20-slot trigger wheel.



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.

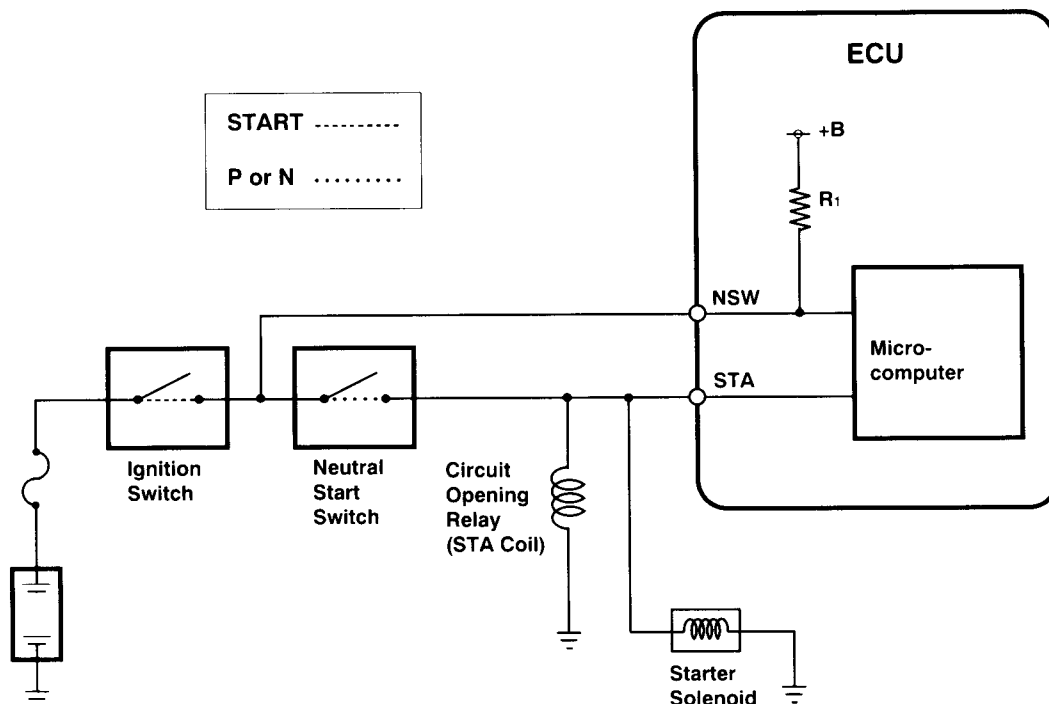
In the event this signal malfunctions, the ECU will use the wrong target idle speed for in gear operation and a distinct drop in idle rpm will be noticed as the transmission is shifted from Park or Neutral to any drive gear.

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



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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.

