Chapter 6

Actuators—Implementing Control Strategies

Contents

1. INTRODUCTION

Actuators are what it's all about—the reason we have sensors and computers is to control actuators for air-fuel ratio, spark timing, idle rpm (bypass air), and emissions. See Fig. 1-1.

When you finish this chapter, you'll be able to tell what happens to each actuator as it receives output signals from the control module. Another term for actuators is "control". As you'll remember from Chapter 5, outputs to the actuators are generally digital:

- Yes/no, or simply timing control modified in the control module
- Solenoid operation, controlling flow
- Grounding an actuator that is on battery power
- Readout to a solid-state display such as scan tool or dashboard indicator

Table a lists the EEC-IV, MECS-I and MECS-II actuators controlled by the control module. These are the familiar terms used up through 1992.

Table a. Control Module Outputs to Actuators

Air-Fuel Control	Fuel Injectors Intake Air Control (IAC) Intake Manifold Runner Control (IMRC) High Speed Inlet Air (HSIA) Variable Resonance Induction (VRIS) Turbo Boost Control (TBC)
Timing/Spark Control	Thick Film Integrated-IV (TFI-IV) Ignition Distributorless Ignition (DIS) Electronic Distributorless Ignition (EDIS) Electronic Spark Advance (ESA)
Throttle Bypass Air	Idle-Speed Control—Bypass Air (ISC-BPA) Idle-Up solenoids
Emission Control	Exhaust Gas Recirculation (EGR): Pressure Feedback (PFE) Electronic (EEGR) Thermactor (TAB/TAD) Canister Purge (CANP)
Relay/Information	Shift Indicator Light Data Output (DOL) Check engine light (MIL) Self-Test Output (STO) Fuel Pump Relay (FPR) Controller Modules A/C & Fan (WAC, EDF, HEDF) Lock-Up Solenoid (LUS)

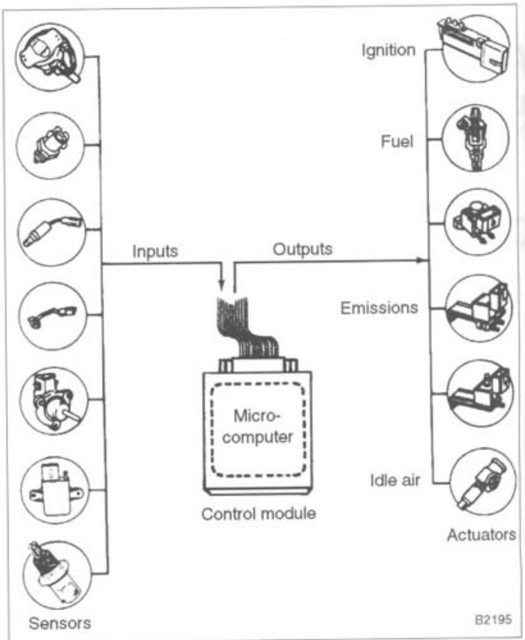


Fig. 1-1. Sensor inputs to control module are for control of air-fuel ratio, spark timing, throttle Bypass Air (BPA), emissions.

1.1 Terminology

Beginning in 1993, a number of the names for the actuators were changed to comply with the SAE standard J1930 to provide common terms for the same general part throughout the automotive industry. For more information on terminology changes, see Chapter 1. This chapter uses the terminology applicable for the years 1988–1992. For reference, **Table b** lists those terms and their equivalents that changed in 1993. Especially note the changes of Intake Air Control and Idle Speed Control.

Refresh your memory about the different Ford fuel injection systems, as they were applied in time sequence:

- 1980, Central Fuel Injection (CFI)
- 1983, first MultiPort Fuel Injection (MFI); Ford called it EFI. By 1988, virtually all Ford engines are MultiPort
- 1986, the first Sequential (MultiPort) Fuel Injection (SFI), Ford-speak = SEFI. I'll use the term "port injectors" when I mean both MFI and SFI
- 1989, Mass Air Flow (MAF-SFI). By 1992, MAF is almost universal in EEC systems
- 1988, MECS MultiPort applied to 1.6L Tracer, 2.2L Probe; later to 1.3L Festiva and 1.8L Escort/Tracer
- *1993 MECS-II SFI with MAF and SC-VAF applied* to Probe

Table b. 1993 and Later J1930 Terminology

1988–1992 Term	1993 Equivalent
Converter Clutch Control (CCC)	Torque Converter Clutch (TCC)
Distributorless Ignition System (DIS)	Electronic Ignition (EI)—Low Data Rate
DIS / EDIS / TFI Module	Ignition Control Module (ICM)
Electronic Distributorless Ignition (EDIS)	Electronic Ignition (EI)—High Data Rate
Electro-Drive Fan (EDF)	Low Fan Control (LFC)
High-Speed Fan (HEDF)	High Fan Control (HFC)
Idle Speed Control (ISC)	Idle Air Control (IAC)
Inertia Switch (IS)	Inertia Fuel Shut-Off Switch (IFS)
Intake Air Control (IAC)	Intake Manifold Runner Control (IMRC)
Integrated Relay Control Module (IRCM)	Constant Control Relay Module (CCRM)
Lock-Up Solenoid (LUS)	Torque Converter Clutch Solenoid (TCC)
Self-Test Connector (STC)	Data Output Line (DOL)
Self-Test Output (STO)	Data Link Connector (DLC)
Spark Angle Word (SAW)	Spark Output (SPOUT)
TFI-IV/DIS/EDIS Module	Ignition Control Module (ICM)
Thermactor Air–Bypass (TAB)	Air Injection Reaction Bypass (AIRB)
Thermactor Air–Diverter (TAD)	Air Injection Reaction Diverter (AIRD)
Thick Film Integrated-IV (TFI-IV) Ignition	Distributor Ignition (DI)

2. Actuators for Air-Fuel Ratio

2.1 Injectors

The actuators that control the air-fuel ratio are the injectors. Injectors are solenoid valves. They are electrically-hot all the time the fuel-pump relay is closed. For fuel delivery, the final stage of the control module grounds the injectors. The grounding in the control module completes the circuit, signalling the injector to open.

Each injector opens as a result of the electrical signal from the control module, and closes by spring force when that signal stops. See Fig. 2-1. When current flows through the winding, electromagnetic force lifts the solenoid, and the injector delivers fuel. When the needle valve is closed by the spring, no fuel flows.

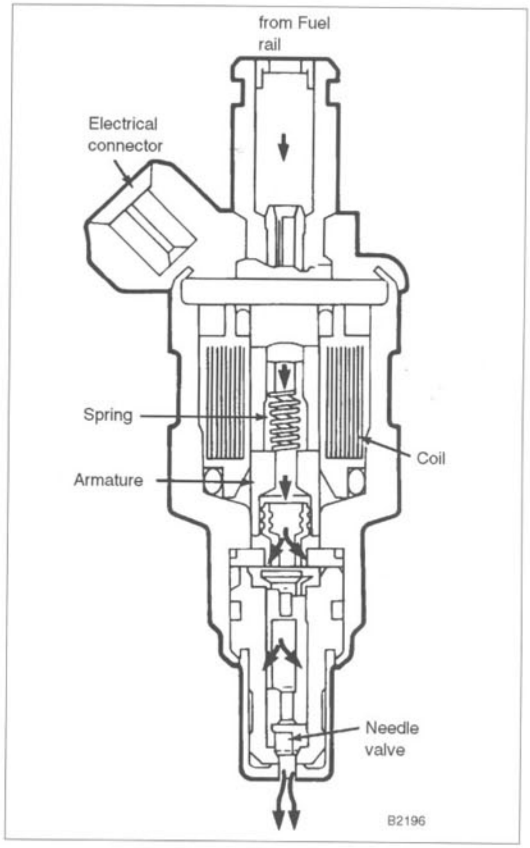


Fig. 2-1. High-pressure injector is about size and shape of a spark plug.

Looking at the cross-section of the high-pressure injector you can see the main parts:

- Top feed, with an integral filter
- Electrical connector, both VPWR and ground
- Coil and armature of the solenoid
- Stainless-steel body
- Stainless-steel needle, lifted by the solenoid
- Needle valve with pintle (See Fig. 2-2)

Since 1988, Ford has standardized on high-pressure injectors located in the intake ports, one for each cylinder. See Fig. 2-3. Note that the 1988–89 2.5L Taurus uses low-pressure injectors located in the central charging assembly.

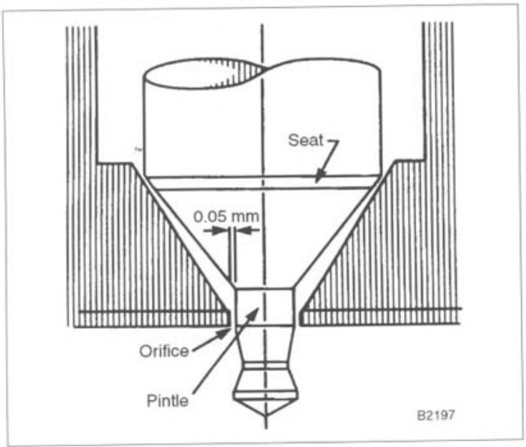


Fig. 2-2. Valve seats on conical body. Pintle has very small precise clearances to body. Pintle tip shape atomizes and distributes fuel.

Most Ford high-pressure injectors operate at relative fuel pressures of about 270 kPa (39 psi). Remember, port injectors operate downstream of the throttle in the changing pressures of the intake manifold so the regulator needs to keep the relative pressure the same.

Port injectors are held in the intake manifold ports with O-rings that tend to insulate the injectors from engine heat and vibration. If the O-rings crack, false air enters, leans the mixture and may increase idle rpm.

Fig. 2-3. Port injectors are mounted in manifolds at intake ports.

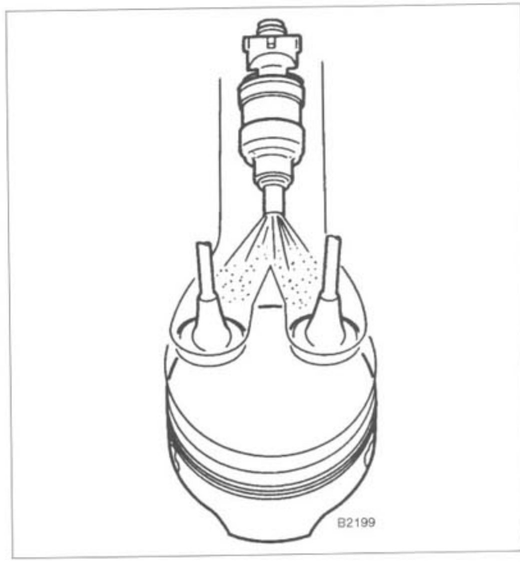


Fig. 2-4. Divided-spray injector delivers separate spray of fuel into each intake port of DOHC engines.

Metering Fuel Injection

Two factors affect the amount of fuel delivered by the electronic fuel injectors:

- Pressure—the greater the pressure, the greater the delivery
- Time—*the longer the injector is open, the greater the* fuel delivery

That may seem obvious, but variations in those two factors, pressure and time are important to your understanding of electronic fuel injection.

In electronic fuel injection, metering takes place at the tip of each injector as a needle lifts a tiny amount, for a short time, and delivers a small amount of fuel. The amount of lift is about 0.15mm (0.006 in.), about the thickness of two pieces of paper. The lift is fixed, the same every time. The amount of fuel injected depends on the time the injector is open. It also depends on the fuel pressure. For port injection, actual fuel pressure in the system depends on the fuel-pressure *differential between the injector tip and the manifold.*

Suppose you want to add more fuel than the original engine. Perhaps you've cleaned up the intakes to admit more air. Remember, the engine is measuring the air flow and injecting fuel to match. So, for street cars, the control module will usually increase fuel injection with no modification on your part.

Perhaps you want to run richer for off-road. Then you increase the fuel-pressure, or you increase the injector-open times. You must consider the injection time—how long the injectors are open under different conditions, and the pulse-period—how much time is available in the engine cycle for injector delivery.

Time Factors

I said that the signal from the control module to the injectors is a pulse that changes to vary the amount of fuel injected. Injection time—the pulse time that delivers the amount of fuel required—may be as short as one millisecond or as long as 15 milliseconds. A millisecond, that's one-thousandth part of a second, written ms. Some wit has defined a millisecond: "That's the time between the light changing green and the guy behind honking." We'll say it's a very short piece of time.

Injection Time, sometimes called pulse-width, is the open time of each injector, from the instant it receives the open signal until it receives the close signal. The injector is delivering fuel the whole time. It takes about 1ms to open, that is counted in the injection time. The closing time is not counted, but it averages out: pulse-width is effective injector-open time.

Operation

MFI injectors are grounded by the control module in banks. See Fig. 2-5.

- V-6 and V-8 by separate left and right banks
- In-line 4- and 6-cylinder engines in two groups (referred to in circuit diagrams as "bank 1" and "bank 2", even though the cylinders are in line, all in one bank)

Sequential Fuel Injection (SFI) controls each injector individually in firing order for better control of individual cylinders. See Fig. 2-6. This requires more computing power, but extra computing power was designed into EEC-IV from the beginning. By 1992, most Ford engines are SFI.

Does each sequential injector fire at the time its intake valve is open? That easy assumption is not always true.

- In some engines, depending on the intake porting, injectors are timed to fire through the open valve
- In other engines, firing through the intake valve can produce undesirable variations in the in-cylinder mixture. In these engines, firing the injector against the closed, hot intake valve just before it opens improves fuel vaporization and reduces emissions.

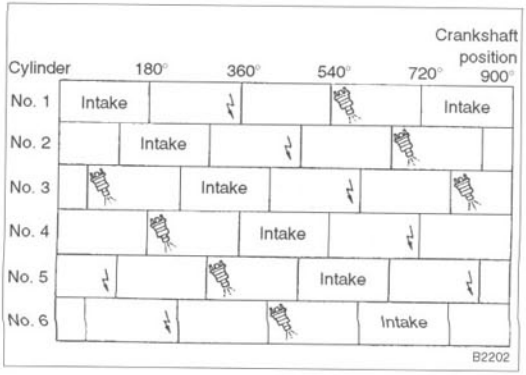


Fig. 2-6. Sequential injection timing on 1993 and later Probe 2.5L V-6 shows delivery during exhaust stroke, before intake valve opens.

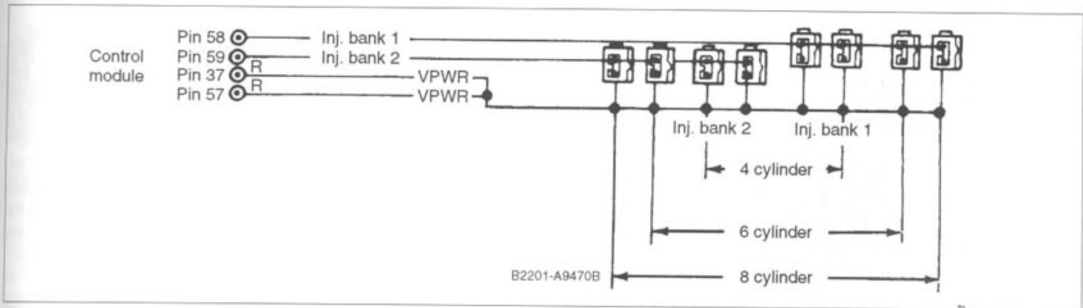


Fig. 2-5. MFI injectors (shown) are grounded in banks, L-R for V-type, and two cylinders at a time for 4 and 6-cylinder engines. SFI injectors are grounded by control module individually in firing order. V-6 and V-8 are similar.

Deposit-Resistant Injectors (DRI)

Port injectors are more prone to deposits than Central Fuel injectors because port injectors meter at the injector tip near the hot intake valve, where the temperatures are higher.

Beginning in 1990 models, look for Deposit-Resistant Injectors (DRI) in most engines. DRI resist the tendency of injectors to clog with deposits from certain fuels under certain operating conditions. See Chapter 11 for information on un-clogging earlier injectors.

Injectors identified as DRI resist deposits in two ways:

- Some have a director/metering plate to shield the tip from excess temperatures
- Others meter most of the fuel in the center of the injector, away from the heat at the tip

On the 1993 and later 2.5L V-6 Probe, side-feed injectors mount in the fuel distributor or rail. See Fig. 2-7. As fuel flows through the injector, some fuel is delivered to the intake passage during injector open-time. But other fuel flowing through carries away fuel vapor that might interfere with hot starting.

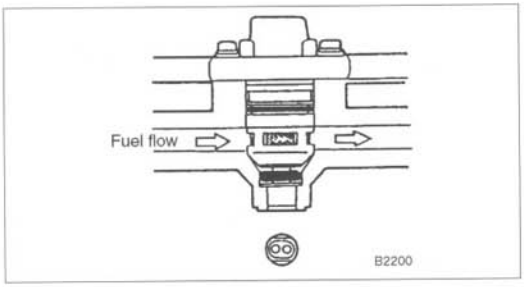


Fig. 2-7. Side-feed injector on 2.5L V-6 circulates fuel through injector. Fuel flow carries away vapor caused by engine heat, improving hot starting.

2.2 Inlet Air Control

Remember the discussion in Chapter 2, where intake runner length is a factor affecting engine performance. I'll describe several inlet air controls, all designed to get more air into the cylinders for more power. These include: Intake Air Control (IAC) on SHO 3.0L/3.2L engines, Intake Manifold Runner Control (IMRC) on 4.6L-4V engines, Variable Resonance Induction System (VRIS) in the MECS 2.5L V-6, and turbo control on MECS 2.2L turbo engines.

Intake Air Control (IAC)

Intake Air Control (IAC) on SHO 3.0L/3.2L engines varies the length of the air intake passages to increase power output over a greater range of rpm. See Fig. 2-8. IAC controls valves in the variable-intake manifolding. When you look at a SHO engine, the long tuned runners seem to overwhelm the entire engine, but they are important to that 220 hp. at 6200 rpm.

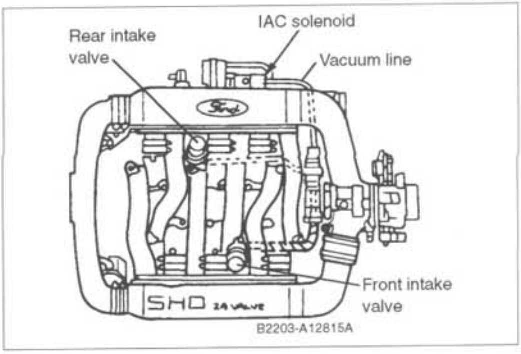


Fig. 2-8. Intake Air Control (IAC) valves on SHO 3.0/3.2L intake manifolds are operated by vacuum from IAC solenoid valve controlled by control module. IAC valves change intake passages for increased power over greater range of rpm.

IAC changes the air intake flow so the air passages are longer at lower rpm, and shorter at higher rpm. Do not confuse the manifold intake valves with the traditional cylinder-head intake valves. The manifold valves are like throttle-valve plates.

In the manifolds, the front Intake Valve and the rear Intake Valve are vacuum-operated. The control module controls operation of the IAC solenoid actuator. At higher rpm, control-module signal voltage to the solenoid closes the IAC valves by vacuum operation. This has the effect of shortening the intake manifold runners and increasing the ram effect.

Intake Manifold Runner Control (IMRC)

Intake Manifold Runner Control (IMRC) manages air delivered to the dual intake valves of the 4.6L-4V V-8. See Fig. 2-9. IMRC differs from the IAC "resonance" control in the SHO engines and the other Ford DOHC engines. In the 4.6L-4V, IMRC closes off one set of intake manifold runners at low rpm (below about 3,000). So, even though all intake valves open, the engine operates through the primary intake runners as a single-valve (per cylinder) engine. With no air delivered to the secondary intake vales, economy and emissions are improved at low speed, low load.

> "Resonance" is the term describing the back and forth movement of air in the short and long intake runners of the SHO engine, and some MECS engines. The purpose is to increase power over a broad band of engine speeds. Do not confuse this resonance with the passive resonance chambers of the intake system. Their purpose is to reduce intake noise. They are not part of engine control.

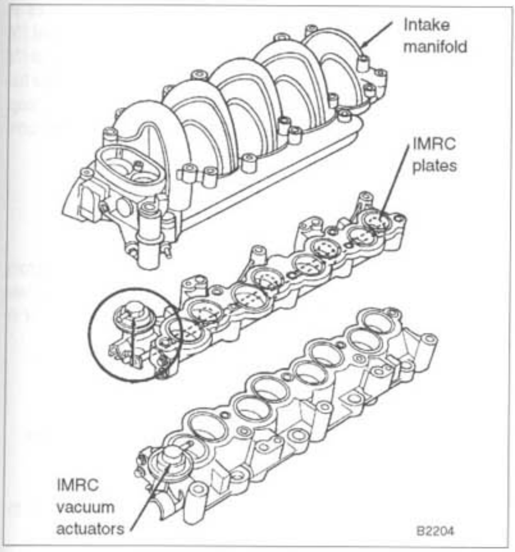


Fig. 2-9. Intake Manifold Runner Control (IMRC) on 4.6L-4V delivers intake air to one manifold runner (primary) and intake valve for each cylinder. Above about 3,000 rpm, IMRC valves open to deliver air to both intake valves.

As rpm rises, the control module signals the IMRC vacuum solenoid to vent the two IMRC Vacuum Actuators (one for each cylinder bank). The eight spring-loaded secondary valve plates (one for each cylinder secondary-intake-runner) open. With intake air delivered to both intake valves of each cylinder, more power is available on demand. On the camshafts, each secondary intake-cam lobe opens the secondary intake valve slightly later than the primary intake valve, promoting swirl in each cylinder.

The driver's foot (or cruise control) controls power of this 4.6L-4V engine by the mechanical throttle in the throttle body. In contrast, electronic control (IMRC) of the valve plates in the secondary intake runners improves power output in the higher ranges.

MECS High Speed Inlet Air (HSIA) Control

In High-Speed Inlet Air (HSIA), different kinds of manifold valves control the length of the intake runners in 1991 and later 1.8L DOHC engines. See Fig. 2-10. The HSIA control operates for the same purpose as the Intake Air Control (IAC) of the SHO engines. You'll also find the nomenclature Variable Inertia Charging System (VICS), and Variable Resonance Induction System (VRIS).

Below 5,000 rpm, the HSIA solenoid is actuated by a signal from the control module. The solenoid applies vacuum to actuate the four Shutter Valves, closing the shorter inlet air passages. Intake air must flow through the longer passages that have a longer-time inertia or "ram" effect to match the lower range of rpms. (See Chapter 2 for more discussion of the inertia effect.)

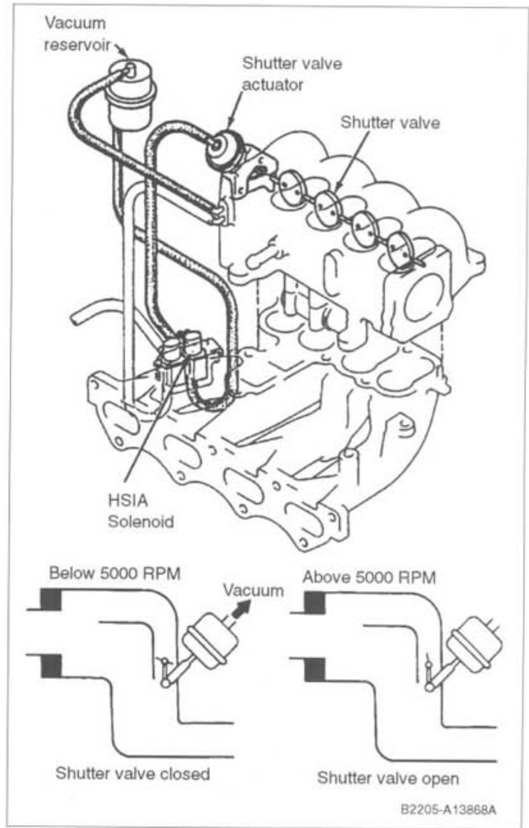


Fig. 2-10. Above 5,000 rpm, HSIA solenoid opens shutter valve actuator to atmosphere, opening four shutter valves to shorter passages. Vacuum reservoir insures power to actuate even at full-throttle.

Above 5,000 rpm, the control module signals the solenoid to vent the actuator, opening the four Shutter Valves to the shorter high speed ports for the faster inertia "ram" effects. There's no need to close the longer paths. When both sets of passages are open, the intake air naturally flows through the shorter, easier passages. The Vacuum Reservoir insures that the actuator will operate even at low-rpm full-throttle conditions.

Variable Resonance Induction System (VRIS)

The Variable Resonance Induction System (VRIS) in the 2.5L V-6 of the 1993 and later Probe improves the ram effect of the intake air at low rpm, through medium rpm, and to higher rpm. Three shutter valves are vacuum operated according to engine rpm and throttle opening angle (TPS). See Fig. 2-11.

- Shutter valve 1 (VRIS-1) opens at about 3,000 rpm, changing the resonance path from long to medium
- Two shutter valves (VRIS-2) on a shaft near the main throttle open at about 4,000 rpm. With VRIS-1 and VRIS-2 open, the resonance paths are shortest, directly to the cylinders
- Above about 6,000 rpm, VRIS-1 and VRIS-2 close again, providing best resonance path for high rpm

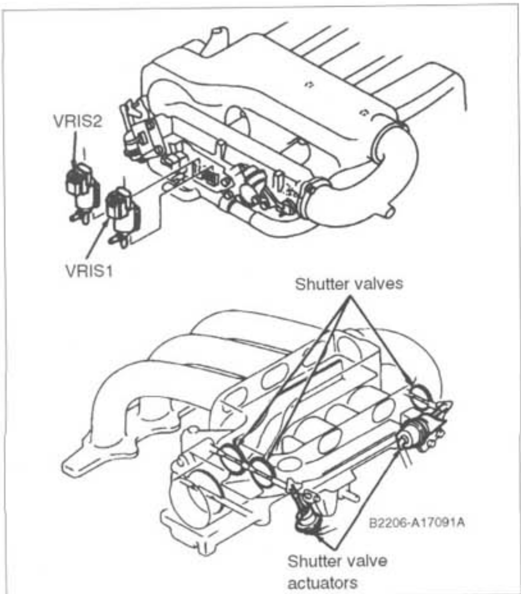


Fig. 2-11. Variable Resonance Induction System (VRIS) in 1993 and later Probe 2.5L V-6 operates similar to the IAC of Taurus SHO V-6.

MECS Turbo Boost Control (TBC)

MECS Turbo Boost Control (TBC) controls the wastegate to protect the engine from overboost, and from engine damage due to knocking.

In 2.2L engines, TBC operates the same as in EEC, with the control module controlling the wastegate. The control module limits boost to a maximum pressure of 8.7 psi (60 kPa). In overboost condition, the wide-open VAF switch will signal the control module, sounding a warning chime for the driver and cutting off fuel injection. If the KS indicates knocking even after spark timing retard, the control module will control boost to 6.5 psi (45 kPa).

In 1.6L engines, wastegate control is mechanical, based on boost pressure. Boost is limited to a maximum of 8.1 psi (56 kPa). If the Boost Pressure Switch (BPS) indicates 11 psi (76 kPa) boost, the control module cuts off fuel injection. Your turbo-boost gauge will be in the red. If the KS indicates knocking, the control retards spark timing up to 15 degrees, but the control module cannot reduce boost.

2.3 Summary

So the actuators controlling air-fuel ratio are the injectors, and, in multi-valve engines (4-valves per cylinder), the intake manifold air controls. Some engines use the resonance or inertia effect to pack in more air:

- In SHO engines, IAC solenoid controls intake air passages
- In 1.8L DOHC, HSIA controls intake air passages
- In 2.5L V-6, VRIS controls intake air passages
- In the 4.6L-4V, IMRC electronically controls secondary throttles to increase intake air delivery to engine secondary-intake valves.

3. Spark Timing

All Ford EEC systems handle spark timing electronically in the control module, and therefore need no centrifugal weights or vacuum diaphragms. Through the 1980s most EEC systems use distributors. Through the 90s, the control module handles both timing and distribution, eliminating distributors.

3.1 Thick-Film Integrated-IV (TFI-IV) Ignition

Thick-Film Integrated-IV (TFI-IV) is an electronic distributor-type system using an integrated ignition module. "Thick film" refers to the manufacture of the solid-state trigger and power units in the module. It has no service meaning except that TFI is different from Duraspark. TFI-IV ignition systems began with the first EEC-IV systems in 1983.

The EEC control module uses the Profile Ignition Pickup (PIP) and Cylinder Identification (CID) signals to determine the proper point to fire the coil. See Fig 3-1. The control module sends the Spark Output (SPOUT) signal to the TFI module to turn the coil on and off. The TFI module also generates the Ignition Diagnostic Monitor (IDM) signal so that the EEC module can check TFI operation. Operation of the PIP and CID sensors is covered in Chapter 4.

TFI Module

The TFI module acts as an electrical switch controlling the flow of electricity to the coil. See Fig. 3-2. TFI circuits calculate the best coil-charging time between SPOUT pulses. The TFI module is usually mounted on the distributor, except on models with Closed Bowl distributor, as described below.

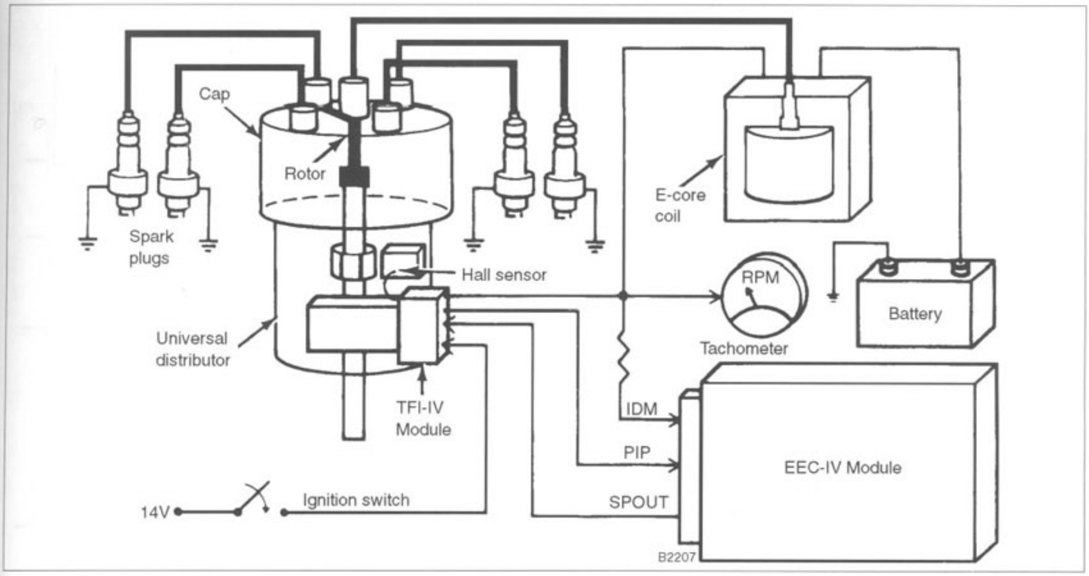


Fig. 3-1. EEC-IV ignition system is slightly different from other makers' systems. Thick Film Ignition (TFI) module is switch for spark timing, as controlled by EEC module.

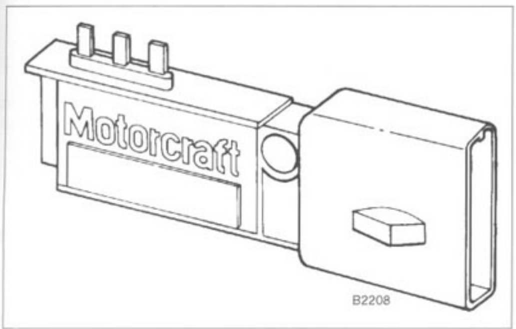


Fig. 3-2. TFI Module is solid-state unit that calculates timing and switches flow of electricity through ignition coil.

Spark Output (SPOUT)

The signal controlling ignition is the Spark Output (SPOUT) from the control module to the TFI module. The SPOUT signal determines the ignition timing of the next plug in firing order. It differs slightly according to the type of ignition. As shown in Fig. 3-3, spark timing goes through TFI Module twice:

- The PIP signal goes through the TFI module to the control module for advance or retard adjustments
- The SPOUT signal from the control module goes back to the TFI module
- The TFI module opens the primary circuit to control spark timing, and switches primary closed
- If the TFI module does not receive a SPOUT signal, it times the ignition directly from the PIP signal

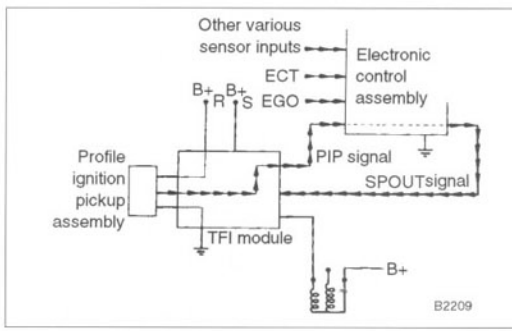


Fig. 3-3. Control module modifies PIP signal to change ignition timing according to other sensor inputs. Control module sends SPOUT signal to TFI Module. TFI module uses SPOUT or PIP to fire ignition coil at proper timing.

In Chapter 5, you saw a typical Look-Up Table for spark advance. The control module determines that for certain conditions, say 33 kPa Manifold Absolute Pressure and 2000 rpm, spark advance should be 32 deg. before TDC.

The PIP input signals the control module about rpm and the basic crankshaft position of 10 deg. BTDC. Using other sensor inputs, such as ECT and EGO, the control module calculates the timing for 32 deg. BTDC, and sends an output signal to the TFI. TFI compares SPOUT and PIP for timing to open the primary circuit for the coil, causing firing of one plug as selected by the distributor rotor.

Ignition Diagnostic Monitor (IDM)

Ignition Diagnostic Monitor (IDM) signal is sent from the TFI Module to the control module as a check of ignition function. This uses the same pin that sends the signal to the coil and to the tachometer. The control module compares the IDM with the SPOUT to verify that the coil signal from the TFI module matches the SPOUT signal from the control module. If they are not the same, the ignition system probably has some fault.

The control module will turn on the "Check Engine" Light and store the proper trouble code in its memory. If the fault is serious, *the control module will switch over to Failure Mode Effects Management* (FMEM) so you can drive home or to the shop. Ford has described this checking as "SPOUT is the shout, IDM is the echo."

Push Starting

For push starting, output of the control module is modified for stronger spark under conditions of low battery. The control module recognizes push-starting condition as a relatively low rpm signal, as if cranking, but no START signal, as if cranking with the starter. Push starting mode provides longer dwell for greater coil ON time. See Fig. 3-4.

Compare the waveforms of the Ignition Control Module (ICM), the upper showing push-start mode, and the lower, regular Computer-Controlled Dwell (CCD). In each set of waveforms, the top set of lines shows the spark firing lines as you would see them on the scope.

- Push start: the coil is fired (turned off) by the rising edge of a SPOUT signal. This provides the longest coil ON time for maximum charging of the coil Charging time is not controlled by SPOUT signal.
- CCD: SPOUT signal rising edge fires the coil. Falling edge turns coil ON, just long enough to charge coil

TFI-IV With Closed-Bowl Distributor (CBD)

TFI-IV Closed Bowl identifies a distributor design in 1988–90 3.8L engines. The distributor bowl is closed, and the TFI module is remotely mounted. One PIP signal (PIP-B) is sent to the TFI module. A second PIP signal (PIP-A) is sent to the control module, along with the ignition ground, along with the

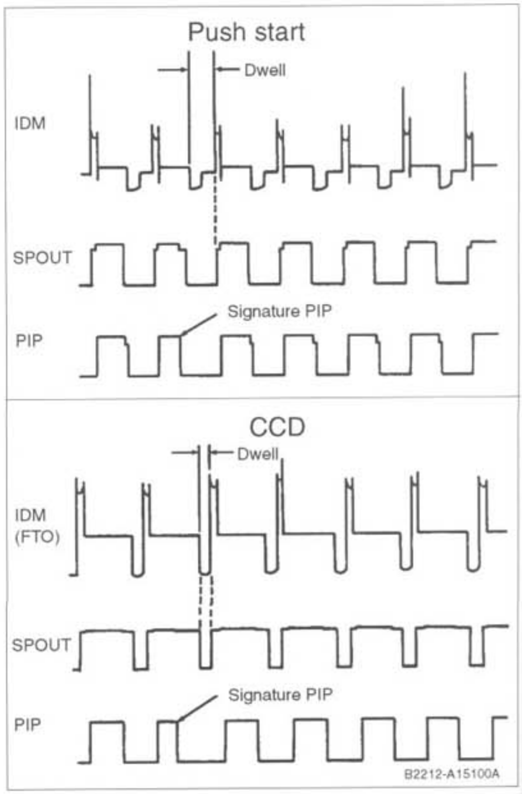


Fig. 3-4. Push-start spark signals, upper, fire plugs when ignition is ON, PIP signals are low rate, and START signal is missing. Compare to Computer-Controlled Dwell (CCD), lower.

SPOUT signal from the TFI. See Fig. 3-5. These show in the wiring diagram *as passing through a grounded shield.*

TFI With Computer-Controlled Dwell (TFI-CCD)

TFI Computer-Controlled Dwell (TFI-CCD) is used on some Ford engines, beginning with the 1989 3.0L in California. By 1992, most Ford systems control dwell, the minimum time necessary to charge the coil before the next firing, either TFI or DIS/EDIS (see following).

CCD computes the timing of closing the primary circuit. See Fig. 3-6. In effect, CCD answers the question, "When must TFI close the primary circuit for the next firing (which keeps changing its timing) so the coil primary current can rise to the proper level just at the moment of opening the primary circuit?" For example, the higher the rpm, the sooner the primary circuit must close to allow enough time to charge the coil, so CCD includes inputs from PIP. CCD delivers less energy into the coil to reduce overheating.

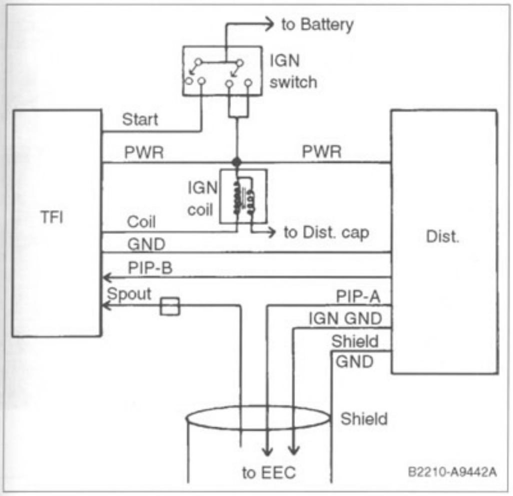


Fig. 3-5. TFI-IV Closed Bowl Distributor mounts TFI module remote from distributor. PIP-B signals go to TFI, while PIP-A signals go to control module.

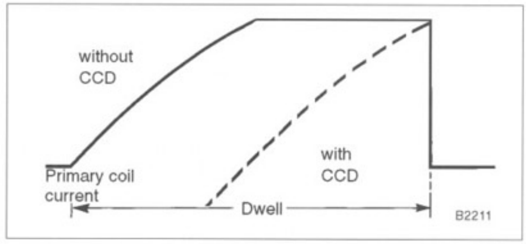


Fig. 3-6. Without CCD, primary coil current must be turned on well before firing timing. With CCD, primary coil current is turned on so primary coil current reaches proper level just at turn-off for spark timing.

3.2 Distributorless Ignition System (DIS)

You already know how computer-controlled ignition systems eliminated points to switch the coil current. Distributorless Ignition Systems (DIS) eliminate the rotor and cap to distribute the high-voltage current directly from the coils to each plug.

The DIS module, Fig. 3-7, uses the Profile Ignition Pickup (PIP) sensor signal, Cylinder Identification (CID) sensor signal, and the Spark Output (SPOUT) signal from the EEC mod-

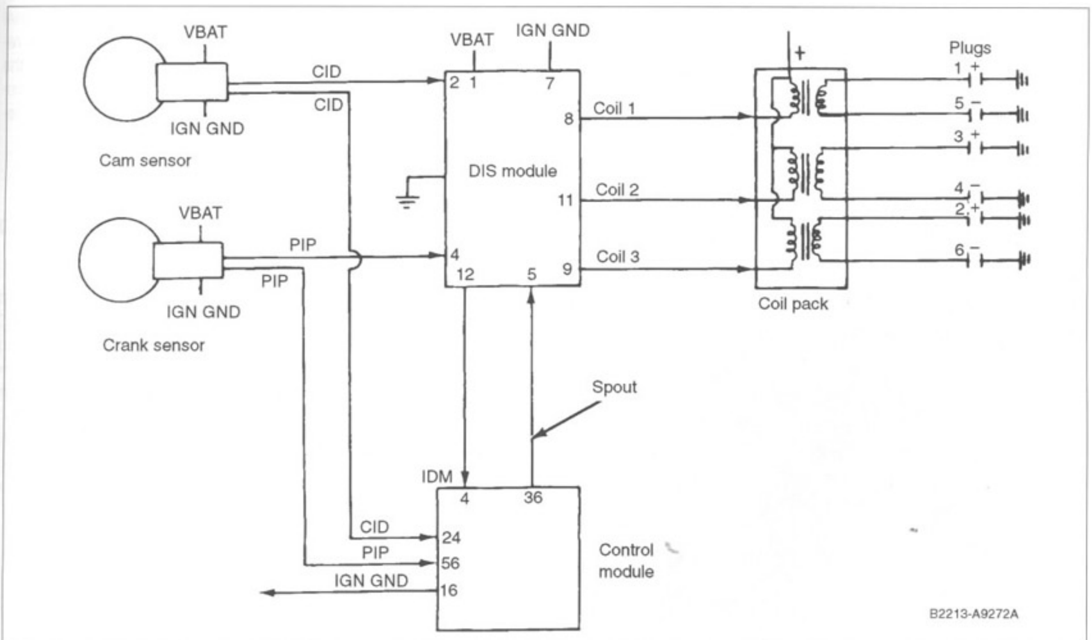


Fig. 3-7. DIS module receives SPOUT signal from control module. Comparing it to PIP and CID, module calculates timing and determines which coil to fire.

ule to determine coil turn on and turn off. PIP and CID sensors used on different DIS models are covered in Chapter 4.

In place of the distributor and coil, look for one or two box-shaped coil-packs. See Fig. 3-8.

- For most 4-cylinder engines, the coil pack handles two pairs of 2 cylinders. (Exception: Dual-Plug DIS uses two coil packs
- For a 6-cylinder, the coil pack handles three pairs of two cylinders
- In the 4.6L V-8, two four-cylinder coil packs handle the four pairs—8 cylinders

DIS Module

The DIS module replaces the TFI module. See Fig. 3-9. DIS receives input from both PIP and CID Hall-effect sensors. Most DIS engines use a single set of plugs, while Dual-Plug DIS (DPDIS) on some 2.3L engines uses dual plugs. I'll concentrate in single-plug DIS, first used on 3.0L engines including SHO, and 3.8L engines.

SPOUT signals are sent by the control module to the DIS module. Comparing SPOUT to PIP and CID, the DIS module determines when to fire a coil, and decides which coil to fire. During cranking, CID determines which coil to fire. During running, CID also determines sequential fuel injection (SFI).

DIS includes CCD—Computer Controlled Dwell. In Fig. 3-10, you can see the SPOUT signals, a series of digital pulses.

- The first signal, SPOUT off, closes the primary of 1 coil so the current increases, charging the coil
- The second signal, SPOUT on, opens the primary of 1 coil so the current falls, firing two plugs, Power and Waste

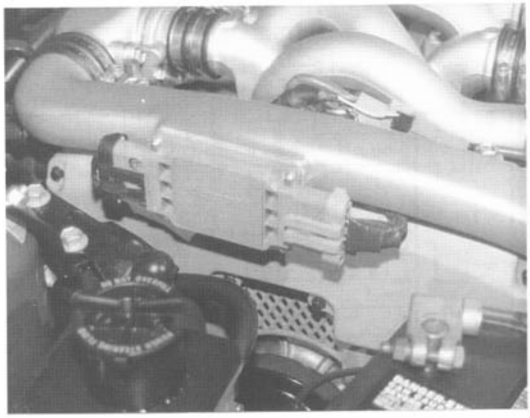


Fig. 3-9. DIS module on 3.0L SHO engine.

The difference between the first (on) and the second (off) signals is dwell. By changing the on-time to be just right for the off-time, the DIS module uses the length of the SPOUT signal to control the dwell. See Fig. 3-11.

At engine start, coil 2 always fires first. In the V-6, cylinder 3 is rising on compression stroke while cylinder 4 is rising on the exhaust stroke. Coil 2 fires two sparks at the same time. In cranking, during the next crankshaft revolution, the CID signal causes 3 and 4 to exchange. Cyl 4 on compression stroke receives the power spark; Cyl 3 on exhaust stroke receives the waste spark. Each coil fires in the order 2-3-1, firing synchronized with compression strokes. The coils continue in this relation to the firing order.

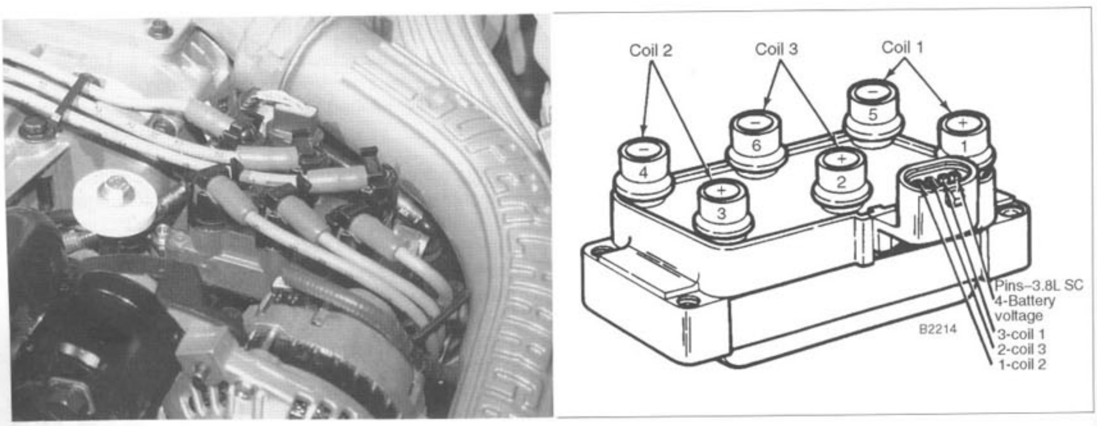


Fig. 3-8. DIS coil pack replaces distributor and coil. Three coils fire six cylinders of 3.0L and 3.8L engines.

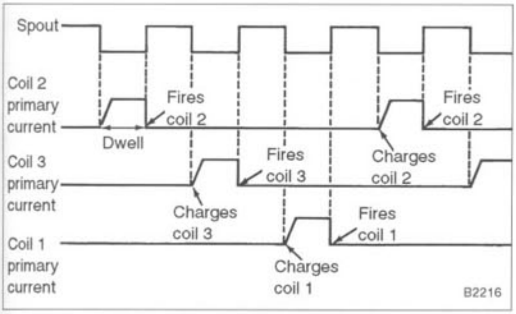


Fig. 3-10. When SPOUT signals on, DIS module closes primary—current increases. When SPOUT signals off, primary opens, firing coil, determined by timing needs. Dwell is difference between off and on.

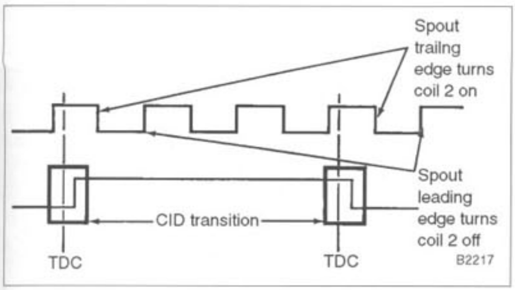


Fig. 3-11. SPOUT signals and CID signals combine to choose which coil to fire. They control coil turn-on and turn-off, firing two plugs.

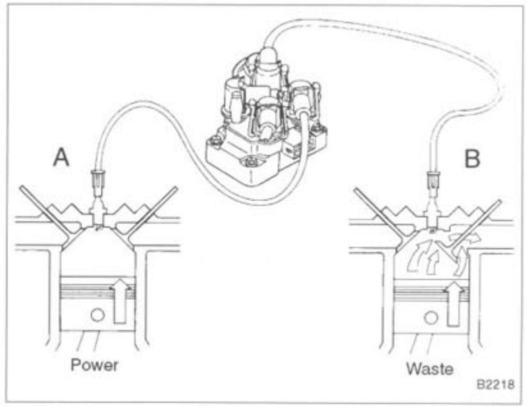


Fig. 3-12. Two plugs fire in pairs from each coil. When plug A is on its compression stroke, A gets power spark, most of coil energy. Plug B is on its exhaust stroke, so it gets waste spark. On next rotation of crankshaft, B gets power spark and A gets waste spark.

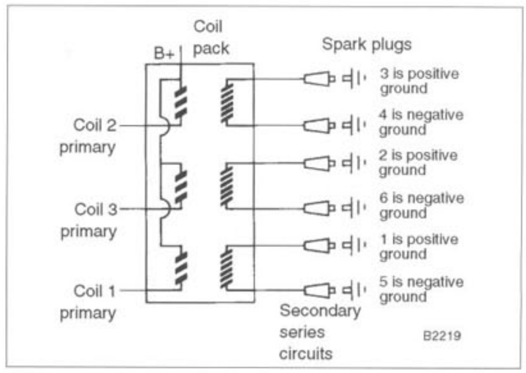


Fig. 3-13. Each coil fires a pair of plugs. Coil 2 fires both plugs 3, positive ground, and 4, negative ground.

Cylinder Pairs

Each coil fires a pair of two cylinders at the same time, the two cylinders that rise toward TDC at the same time. See Fig. 3-12. I'll call them "A" and "B." Cylinder A is rising on the compression stroke, ready to fire. A gets most of the coil energy in what is called the "power spark." As B is rising on its exhaust stroke, B gets a little of the coil energy in what is called the "waste spark." On the next rotation of the crankshaft, when B rises on its compression stroke, B gets the power spark and A gets the waste spark. The big question is: "how does the coil know?" (See sidebar, page 126.)

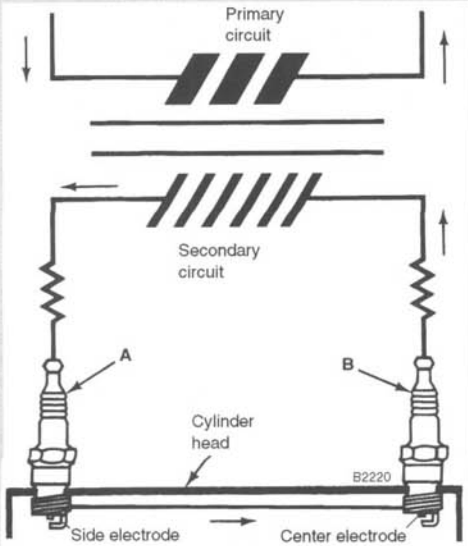
At first, it may seem impossible to fire two cylinders with one coil. In fact, a few engines (not Ford) provide a separate coil for each cylinder, four for the Saab 4, and 8 for the Lexus V-8. If you don't care how Ford fires two plugs with one coil so the proper cylinder gets the proper spark, skip the side-bar on the next page.

On the 4.6L V-8s, you see one DIS coil pack at the end of each cylinder bank. See Fig. 3-14. You may wonder why each pack doesn't just handle the plugs in that bank. Why do the plug wires cross-over to the other bank? Then you realize that each coil handles two cylinders in pairs depending on their sequence in the firing order. An "A" cylinder in one bank pairs with a "B" cylinder in the opposite bank.

6

How does the coil know?

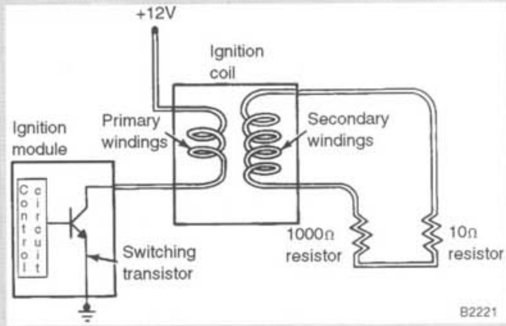
I will tell you, beware of misinformation about why the power spark delivers high voltage to the cylinder on the compression stroke. Even some Ford factory manuals are confused about this. Let's see if we can figure it out.



Each end of secondary connects in series to one plug, with circuit completed through cylinder head.

From the coil secondary, current flows through the plug cable to plug A and jumps from the center electrode to the side electrode. Crossing through the head to plug B, the current jumps from the side electrode to the center electrode, completing the series circuit through the plug cable to the coil. The amount of current flow is the same throughout the series circuit. What differs between the two plugs is voltage.

- In A, on its compression stroke, the cylinder pressure is high, requiring higher voltage to overcome the resistance of the air-fuel mixture to fire the spark.



Consider two spark plugs as resistors with same current flowing through a series circuit. Plug with lower resistance (~10Ω) (exhaust stroke) has lower voltage drop, and lower energy (waste spark). Plug with higher resistance (compression stroke) gets power spark.

- In B, on its exhaust stroke, the cylinder pressure is low so the waste spark fires at low voltage.

The power spark goes to the proper cylinder (under compression) and the waste spark goes to the cylinder during exhaust based on cylinder pressure and the associated resistance. *With two cylinder pairs connected in series to each coil, the current flow must be the same.*

- When A is beginning its power stroke with high compression pressure, it will require high voltage to jump the spark gap, say 10 kv. Power is proportional to voltage, so A gets the power spark
- B gets the low voltage waste spark, say less than 2-3 kv., because it is firing into the exhaust gases at low cylinder pressure. The waste spark has no effect on emissions or power

To see DIS on the engine analyzer scope, select secondary display for a two-cylinder engine, and place the secondary pick-up on each plug lead one at a time. Look for the high voltage of the power spark in cylinder A, plus the alternate firing of the high voltage of the power spark in cylinder B. The usual display adds them on the screen—A, then B, then A, until they appear to be simultaneous. In between, you'll see a little noise from another coil for another cylinder pair.

Dual Plug DIS (DPDIS)

Dual Plug DIS (DPDIS) provides dual ignition in each cylinder to improve the burning of the air-fuel mixture, increasing power and reducing emissions. See Fig. 3-15. DPDIS operates on PIP and CID signals from the Dual Hall sensor described in Chapter 4. On the left side of the engine, you'll find the DIS Module, the four left-side plugs, and the left coil pack. On the right side, you'll find another set of four plugs and another coil pack.

Dual-Plug Inhibit (DPI)

Both left and right-side plugs fire at the same time when the engine is running. When it is cranking, however, only the right set of plugs fires. During cranking, the control module signals the DIS Module through the Dual-Plug Inhibit (DPI) circuit to inhibit or restrict the left set of plugs from firing.

Fig. 3-14. Coil pack on each cylinder bank of 4.6L V-8 shows plug wires crossing to other bank, necessary to fire cylinders in proper pairs.

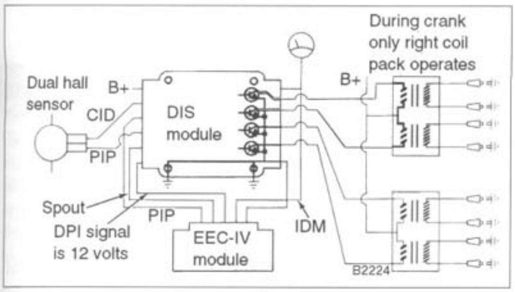


Fig. 3-15. DPDIS module fires two coils under control of control module. During crank, DPI signal from control module to DIS module acts to inhibit (shut off) left set of plugs.

3.3 Electronic Distributorless Ignition System (EDIS)

The Electronic Distributorless Ignition System (EDIS) simplifies the earlier DIS by using a single crankshaft-mounted Variable Reluctance Sensor (VRS) in place of the PIP and CID sensors. VRS generates a more complex signal, and provides more accurate spark timing, both steady state and transient (acceleration).

EDIS uses dual coil packs similar to DIS coils, and also uses two plugs, one firing on the power stroke while the other fires on the exhaust (waste) stroke. See Fig. 3-12 above. The EDIS module (Fig. 3-16) uses the PIP and CID signals from the

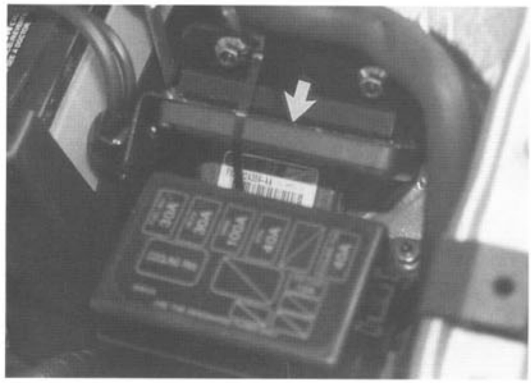


Fig. 3-16. EDIS Module calculates spark timing and coil firing. It selects proper coil and turns it on and off with a coil driver. It is usually located on a fender apron.

VRS, and the Spark Angle Word (SAW) signal from the EEC module, to determine coil turn on and turn off. See Fig. 3-17. See Chapter 4 for more information on VRS operation.

Electronic Distributorless Ignition Systems (EDIS) first appeared in:

- 1990 1.9L 4-cylinder engine in Escort/Tracer
- 1990 4.0L V-6 engine in Ranger, Bronco II, and Aerostar
- 1991 4.6L V-8 engine in Lincoln Town Car

Spark Angle Word (SAW)

Spark Angle Word (SAW) is the response by the control module to the EDIS module after the control module does its usual job of calculating the advance or retard of spark timing. In EDIS, SAW is the same kind of signal as SPOUT is to TFI-IV and DIS.

In the EDIS Module, the microprocessor decides which coil to fire at what millisecond—coil selection and spark timing. In addition to the coil-driver outputs, the EDIS Module confirms its timing by sending the IDM signal to the control module, a signal that also operates the tachometer.

Repetitive Spark (1.8L Escort/Tracer)

Repetitive Spark fires each plug with a series of sparks for each ignition during operation under 1,000 rpm. This tends to smooth the idle. You'd never know the difference except:

- Your external tach will probably misread actual rpm
- You can see the extra spark pulses on a scope

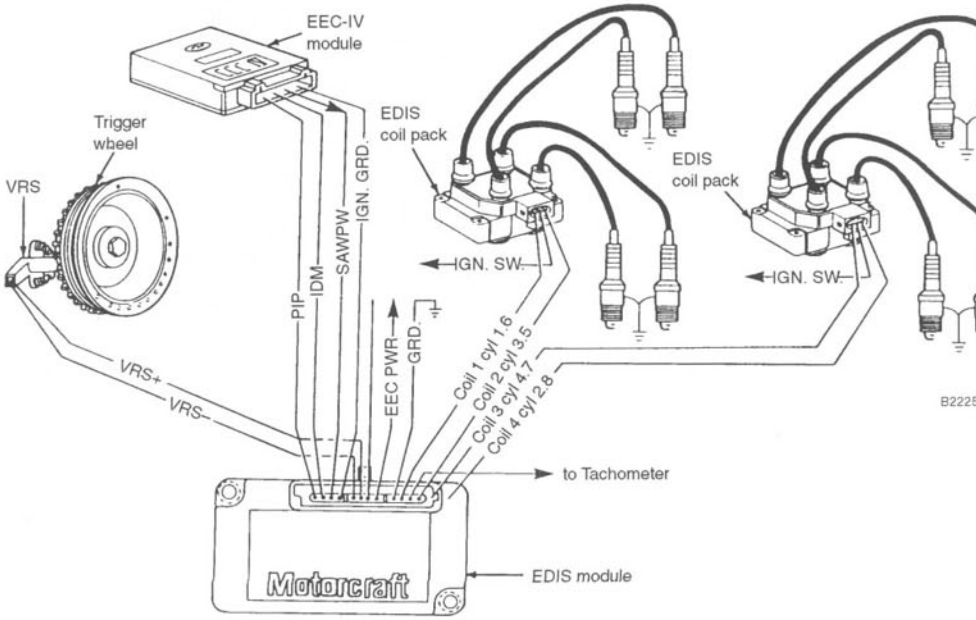


Fig. 3-17. EDIS on 4.6L engine uses two sets of two EDIS coil-packs, each firing two cylinders. Firing cylinder-pairs, two wires cross over from each set of coil packs to opposite bank of cylinders. EDIS Module has own ground to the battery negative post.

Delay Start

On some EDIS engines, Delay Start allows crank without ignition for about half a second. The purposes:

- Insure oil flow to the bearings before starting loads
- Insure full revolution of the crankshaft for better timing signals from the VRS

3.4 MECS Spark Timing

As of 1993, all MECS ignition systems operate with a distributor; none are DIS. Several operate with mechanical-advance flyweights and vacuum-operated diaphragms! Mazda-speak: "Distributor-Mounted Ignition Module with Vacuum Advance (DMIVA)". Forget it—I'm talking primitive electronic ignition as we knew it in 1975. The engines include the 2.2 L non-turbo, 1.6L turbo and non-turbo. Look for the vacuum hoses running to the distributor.

Other MECS engines are more modern, controlling spark timing as determined by the engine-control module, similar to EEC systems.

MECS Electronic Spark Advance (ESA) controls spark timing based on input signals from many sensors, as shown in Fig 3-18. The control module calculates timing and signals the igniter to generate the high voltage for the coil.

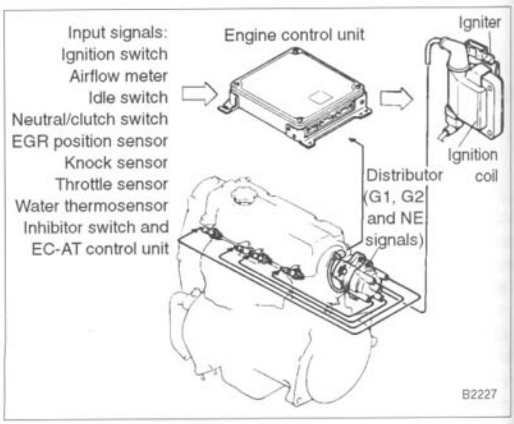


Fig. 3-18. MECS Electronic Spark Advance (ESA) operates in similar manner to Ford EEC systems. Igniter generates high voltage to coil.

4. Throttle Bypass Air—Idle Speed Control (ISC)

The Throttle Bypass Air—ISC performs three functions:

- Controls idle speed according to a variety of engine loads and conditions
- Acts as an electronic dashpot during deceleration, preventing engine stalling, and preventing too-low manifold pressure that causes excess emissions
- Provides additional air during starting, bypassing the closed throttle

These roles are reflected in the new terminology under SAE J1930 in 1993, with the term "Idle Air Control." This throttle bypass does more than most people realize since the functions of deceleration control and emission control are hidden by the name. I'm talking about the amount of air that enters the engine when the driver's foot is off the accelerator. In engineering terms, an engine operating at "no-load" is at idle, regardless of the rpm. So the name change helps us understand this control.

Beginning with 1988 models, all Ford EEC systems use Idle Speed Control—ByPass-Air (ISC-BPA) Valve Assembly. ISC-BPA bypasses air around the closed throttle plate(s). Although they are sometimes described by the same name, the EEC ISC-BPA is quite different from the MECS-I ISC-BPA described below. The EEC unit uses only electronic control, while most MECS units use a combination of electronic control and mechanical coolant-control. Exception: 1993 and later Probe 2.5L V-6 idle air is controlled by Powertrain Control Module as in EEC, but not the '93 and later Probe 2.0L.

4.1 Bypass Air Valve Assembly (ISC-BPA)

The Throttle-Bypass Air valve is usually mounted on the throttle body. See Fig. 4-1. In normal operation, it allows controlled air to bypass the closed throttle plate(s). This bypass air must not lean the air/fuel ratio of the mixture. The air flowing through the bypass usually comes from directly upstream of the throttle so it is measured air.

- For VAF or MAF systems, the increased bypass air flow increases the air flow signal, automatically adding fuel to compensate
- For the MAP systems, the bypass air increases the measured MAP. The calculated increased air flow signal automatically adds fuel to compensate

A few Ford engines draw bypass air from the air cleaner. This is unmeasured air. The control module calculates the increased air flow according to the bypass air signal, and adds fuel to compensate. You can tell those engines by the air hose from the air cleaner to the Bypass Air valve.

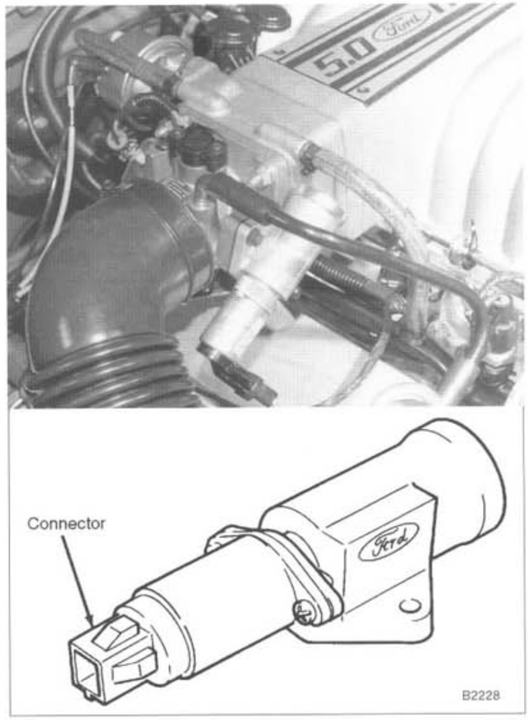


Fig. 4-1. Throttle-Bypass Air (ISC) valve usually mounts on throttle body to provide a passage around throttle plate.

Duty Cycle

The Throttle-Bypass Air valve is positioned by a solenoid, controlled by output ISC signals from the control module. Supplied with Vehicle Power (VPWR), the solenoid is grounded in the control module. The solenoid receives a series of digital pulses. The more pulses, the greater the opening. See Fig. 4-3.

- With 100% duty cycle pulses, the solenoid receives maximum current and opens the valve fully.
- With 0% duty cycle (no pulses), the valve is closed

In normal engine-idle operation, the valve is held partly open, allowing some air to bypass the throttle. It closes as necessary to reduce idle speed, and opens to increase idle speed.

In "dashpot" mode, it allows bypass air to flow during deceleration to prevent engine stall. Of course, as the engine speed reduces, bypass air must be cut off to allow engine braking and to prevent fast idle.

100% duty cycle is the normal setting for CRANK, providing what Ford calls "no-touch" starting.

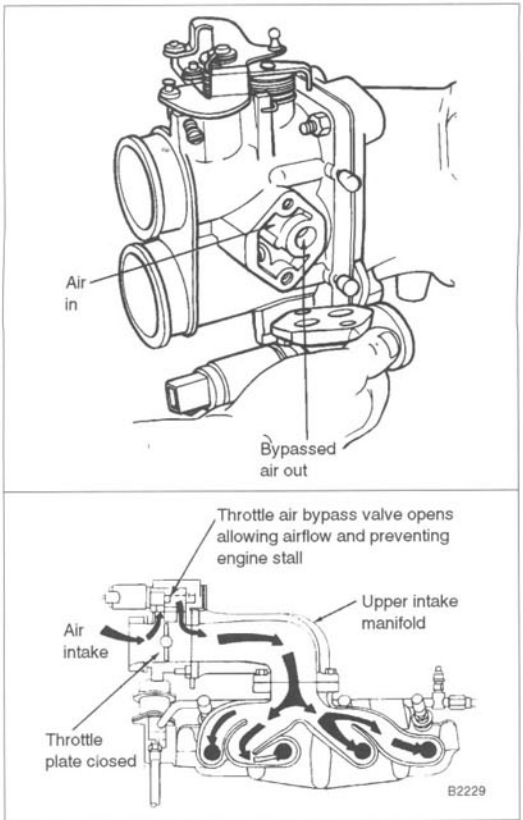


Fig. 4-2. Throttle Bypass Air is normally part way open allowing barometric air to bypass a closed throttle into the area of reduced MAP.

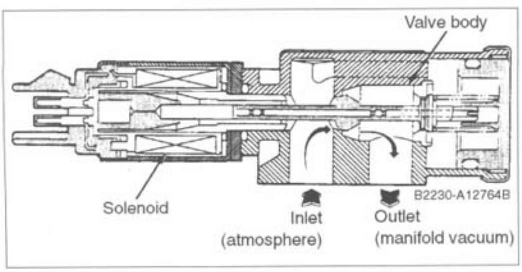


Fig. 4-3. Opening of plunger in ISC-BPA valve is controlled by solenoid, in response to signals from control module.

You may find three types of BPA valves on late model EEC systems. The first is a Hitachi model, shown in Fig. 4-1 above. When clogged with fuel sludge, the valves can be cleaned. A second Hitachi valve has a vent and filter (used to equalize pressure in the valve, not to pass air). This type cannot be cleaned. See Fig. 4-4. A third type is made by Nippondenso, and also cannot be cleaned. See Fig. 4-5.

Fig. 4-4. If you see vent filter (arrow), you know this is a different Hitachi unit that cannot be cleaned.

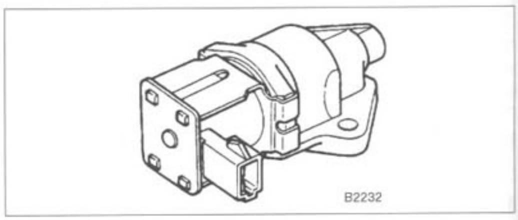


Fig. 4-5. If you see a black plastic housing, do not use cleaning solvent on this Nippondenso valve.

4.2 MECS Throttle-Bypass Air

Most Mazda Engine Control (MEC) engines control Throttle-Bypass Air in a combination of electronic Idle Speed Control (ISC) and mechanical ByPass Air (BPA). This is known as Bypass Air Control (BAC), where incoming air can bypass the closed throttle through two separate passages. Depending on the engine, there may be a single ISC-BPA valve (also known as a BAC valve) or two separate valves.

Electronic Control

The ISC valve is electronically controlled by duty-cycle signals from the control module, controlling bypass air according to engine rpm and load signals. See Fig. 4-7. The air valve is normally half open. Increased duty-cycle signals cause increased air flow to increase or maintain engine rpm, or to control air flow during deceleration. The ISC operates at all temperatures.

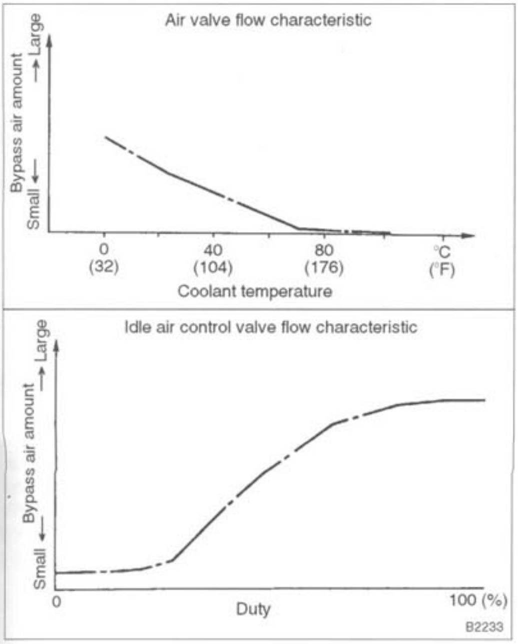


Fig. 4-6. Upper curve shows amount of bypass air controlled by coolant temperature. Lower curve shows amount of bypass air controlled by duty cycle of ISC linear solenoid valve.

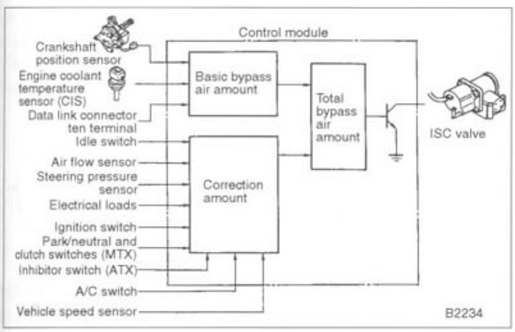


Fig. 4-7. Electronic control of ISC valve depends on sensor inputs of rpm and coolant temperature. Additional control is based on many additional sensor inputs.

Coolant Control

The BPA valve is directly controlled by coolant flow through the valve, bypassing more air when coolant temperature is lower. See Fig. 4-8. Think of it as a thermostat for intake air.

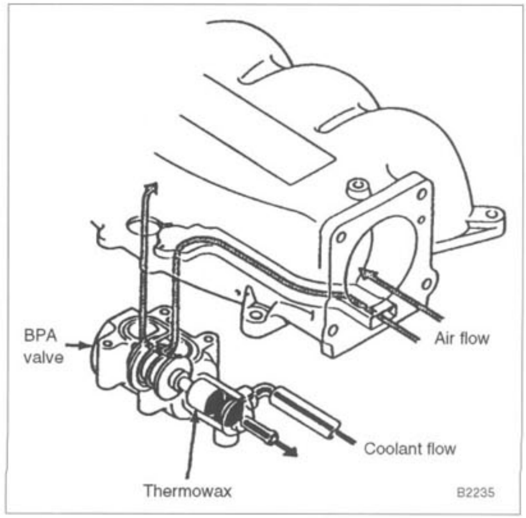


Fig. 4-8. Dark arrows indicate coolant flow through BPA, bypassing throttle plate(s). Gray arrows indicate passage of air.

The colder the coolant, the greater the bypass air through this passage. Below about 50°C (about 120°F), cold coolant flow causes the thermowax material to contract, increasing air flow. Above those coolant temperatures, the BPA is closed and has no effect on bypass air.

NOTE —
The 1.6L Capri engine needs a bit more air when cool. It bypasses intake air until coolant temperatures above 60°C (about 140°F).

The electronically-controlled ISC and the coolant-controlled BPA are usually combined in a single unit. See Fig. 4-9 and Fig. 4-10. Look for the ISC-BPA on the throttle body. Exception: ISC-BPA for early 1.3L and 1.6L mounts on the bulkhead. In later 1.3L and 1.6L engines, look for the ISC-BPA on the side of the intake manifold.

Intake air bypasses the throttle plates through the ISC valve and through the BPA valve, returning to the intake manifold. Coolant flows through the BPA valve to add air flow when the engine is cool. The same coolant flow passes through the ISC valve to cool the solenoid. The coolant has no control function in the ISC.

Look for a different ISC and BPA on the 1.8L engine in the late model Escort/Tracer. Look for the BPA valve on the intake plenum, separate from the ISC valve, mounted on the throttle body.

The coolant-controlled idle-air bypass continues in the '93 and later Probe 2.0L because the Idle Air Solenoid is more limited than the others.

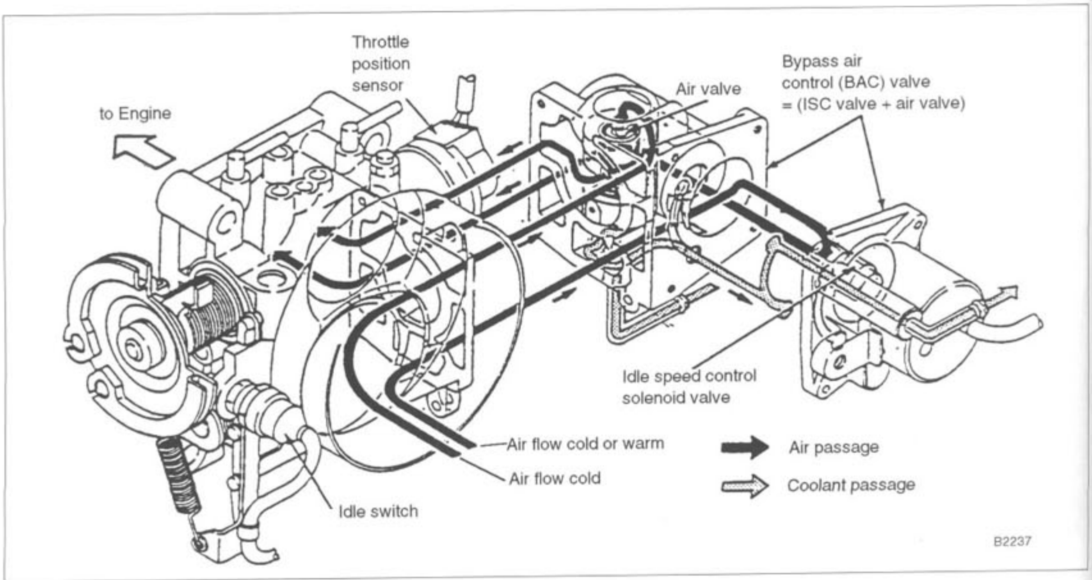


Fig. 4-9. Exploded view of combination ISC-BPA.

Fig. 4-10. Combination ISC-BPA (arrow) on 1.8L engine.

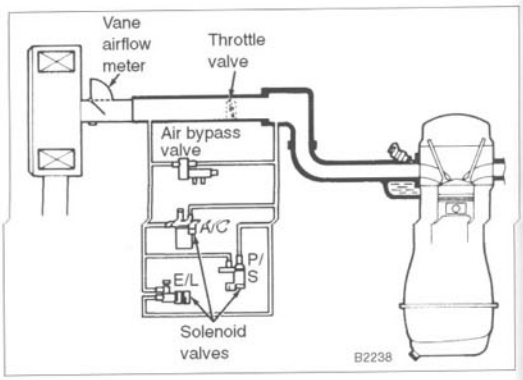


Fig. 4-11. Idle-Up system on 1.6L Tracer engine uses four throttle bypasses, generally directly controlled by electrical circuits and not by control module.

Idle-Up Solenoid Valves

Earlier MEC 1.6L engines (1988–90 Tracer) use three separate solenoid valves to operate a primitive throttle-Bypass Air known as Idle-Up, with four separate passages around the closed throttle. See Fig. 4-11.

1. The Bypass Air valve is a Bosch-type Auxiliary Air Valve, complete with both coolant flow for long-term engine temperature influence and an electric heating coil for warm-up.
2. The Air/Conditioning solenoid bypass valve is opened by power from the A/C compressor clutch circuit.
3. The Power Steering solenoid bypass valve is opened by the P/S pressure switch.

4. The Electrical Load (E/L) solenoid bypass valve is opened by a separate control module based on electrical load of headlights, blower motor, engine cooling fan, and rear-window defroster. The E/L solenoid is also energized through its control unit by the control module under two conditions:
   - During deceleration to reduce exhaust emissions on sudden throttle closing
   - At high altitudes to stabilize idle rpm

Clearly, in this Idle-Up system, idle speed is not stabilized by rpm feedback, but simply boosted as needed by feed-forward signals.

5. EMISSION CONTROL ACTUATORS

Emissions are controlled in part by engine design—by the valve design and valve timing, by the swirl of the incoming air-fuel mixture around the combustion chamber, and by many other factors. Emission control includes many systems. Some, such as PCV, are not under control by the control module so I'll deal only with those involving the EEC system:

- Exhaust Gas Recirculation (EGR)
- Secondary Air—Thermactor (TAB/TAD)
- Evaporative Emissions—Canister Purge (CANP)

5.1 Exhaust Gas Recirculation (EGR)

EGR recirculates a small amount of exhaust gas into the engine through the intake manifold. This lowers combustion chamber temperatures to minimize the emission of Nitrogen Oxides (NO_x) at part throttle. See Chapter 3 for more information on EGR.

- EGR is shut off at idle and during warm up: NO_x formation is minimal and EGR could cause rough idle
- EGR is shut off during Wide Open Throttle (WOT) operation because it causes loss of power (WOT is usually for short periods.)

Because EGR causes some loss of power, the control module changes the engine calibration (fuel injected) and the spark timing. The control module operates the EGR valve only when it receives all the following input signals:

- Warm engine signal from the ECT
- Part-throttle signal from the TPS
- Part-load signal from the MAF or MAP
- Time since start, from the timer in the control module

EGR Control

In most Ford systems, the EGR valve is vacuum operated under control of the EEC control module. Look for the EGR assembly mounted on the exhaust manifold, or near the throttle body, with the EGR sensor on top. Two Ford EGR systems control flow by monitoring pressures, or back-pressures at the EGR valve. A third, known as Electronic EGR (EEGR), controls flow by monitoring valve-position.

When the EGR system delivers exhaust gas into the intake manifold, the control module gets EGR feedback signals to reduce the fuel injection accordingly. The engine needs less fuel because there's less oxygen to burn in the recirculated exhaust gas.

Pressure Feedback EGR

Pressure-Feedback EGR systems control flow rate by monitoring pressure drop across a special metering orifice. See Fig. 5-1. These systems are known as Pressure-Feedback EGR (PFE) and Delta-Pressure Feedback (DPFE). (Delta is

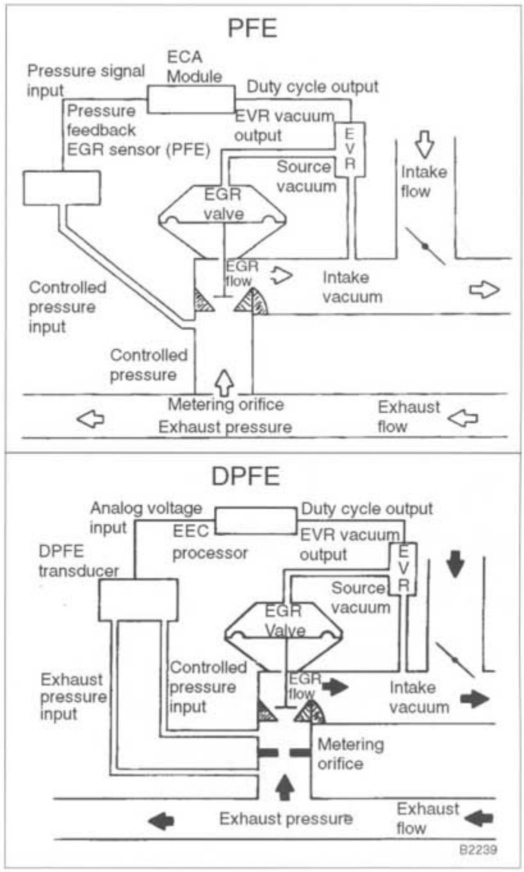


Fig. 5-1. Pressure Feedback EGR (PFE) measures exhaust pressure downstream of metering orifice. Delta PFE measures between that controlled pressure input and exhaust-pressure input. DPFE gives a more accurate measure of EGR requirements.

engineer-speak for difference.) The control module calculates the desired flow based on pressure drop beyond the metering orifice of the EGR valve. With pressure feedback from the transducer, the duty-cycle signal from the control module controls how much the EGR Vacuum Regulator (EVR) opens the EGR valve to achieve the desired pressure drop. A duty-cycle output of 50% would hold the EVR half open.

Electronic EGR (EEGR)

Electronic EGR (EEGR) monitors the position of the EGR *valve pintle. See Fig. 5-2 and Fig. 5-3.*

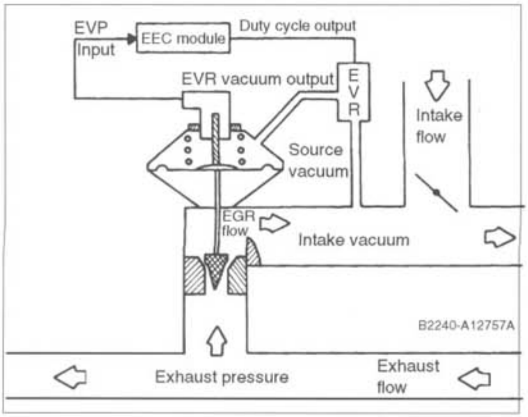


Fig. 5-2. Electronic EGR (EEGR) controls flow rate by using EGR Valve Position (EVP) sensor to monitor position of EGR valve pintle.

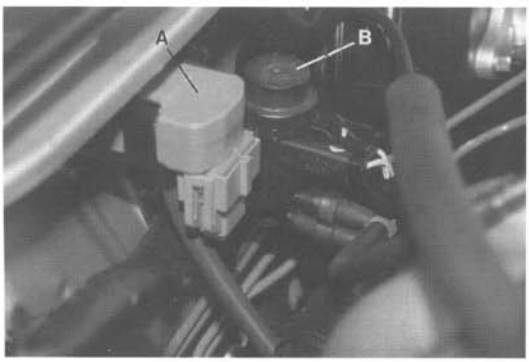


Fig. 5-3. Installed position of PFE Sensor (**A**) and EVR (**B**).

The control module calculates the desired flow and the corresponding lift of the EEGR pintle valve. The EGR Valve Position (EVP) sensor sends a feedback signal so the control module duty-cycle signal can control how much the EGR Vacuum Regulator (EVR) opens the EGR valve. A duty-cycle output of 50% would hold the EVR half open. Although PFE and EEGR are electronically-controlled, EEGR gets the name Electronic because it relies on more electronic processing in the control module.

EVP is a linear potentiometer sensor, operating on VREF of 5v. As the sensor follows the EGR valve pintle, it signals a changing voltage to the control module between:

- 0.2v., minimum EGR flow
- 4.9v., maximum EGR flow

Backpressure Variable Transducer (BVT)

The Backpressure Variable Transducer (BVT) regulates EGR on 1988 1.9L Escort engines. The EEC-controlled solenoid determines when EGR is applied. The BVT determines how much. The BVT operates on two back pressures, one from the exhaust manifold, and the other from the EGR Control Chamber. The signal from the control chamber to the BVT could be positive pressure or it could be vacuum because this chamber connects to the intake manifold when the EGR valve is open.

MECS EGR Control

EGR control in 2.2L non-turbo engines is the same as the BVT control described above. See Fig. 5-4. 2.2L turbo-engine EGR control is by twin solenoids in one unit, one to apply vacuum, the other to vent vacuum. See Fig. 5-5. This is similar to the Dual EGR solenoid valve assembly used on some 2.3L Mustang engines. No EGR is required on other MECS engines, 1.8L, 1.6L, and 1.3L.

EGR is applied and regulated by the engine control module.

- One solenoid opens the vacuum side to admit vacuum to the EGR control valve
- Other solenoid opens the vent side to vent vacuum from the valve

The two valves work together to control vacuum, operating the EGR valve. Both solenoid valves receive variable duty-cycle signals from the control module according to EGR requirements. The solenoid valves are called "dithering valves." They dither, or move back and forth to balance the vacuum control and the vacuum vent to deliver just the proper EGR flow for the engine conditions.

5.2 Secondary Air—Managed Thermactor Air (MTA)

Secondary air is delivered into the exhaust gasses to reduce emissions of HC and CO. This additional air supplies oxygen to combine with unburned fuel coming from the combustion chamber. In Managed Thermactor Air (MTA) under EEC control, sometimes identified as Conventional Ther-

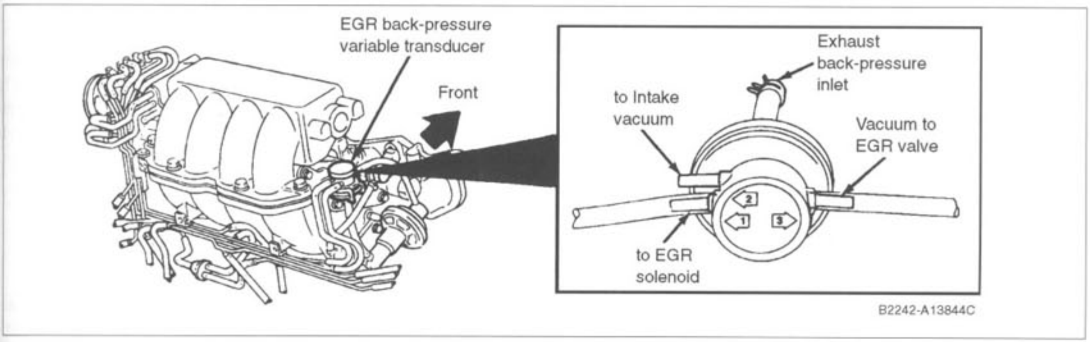


Fig. 5-4. MECS EGR Backpressure Variable Transducer (BVT) senses engine vacuum and exhaust backpressure to control vacuum to EGR valve.

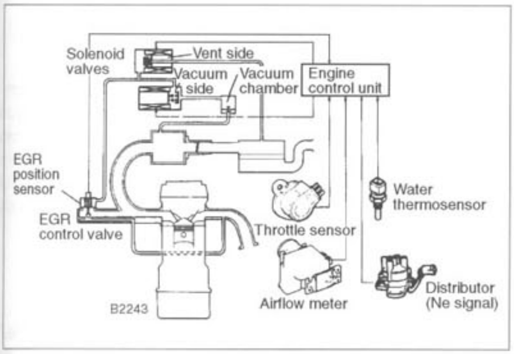


Fig. 5-5. Solenoid valves regulate MECS EGR control valve. One solenoid applies vacuum, other vents vacuum.

mactor (CT), secondary air from the engine-driven air pump is directed to one of three outlets:

- Upstream—meaning upstream of the catalytic converter. Upstream air is diverted to the exhaust manifold
- Downstream—meaning downstream of the three-way section of the catalytic converter, into the mid-bed air port
- Dumped—meaning vented or "dumped" into the atmosphere

Since 1988, most Ford engines operate without secondary air injection. You'll find it on the larger engines—1988-90 3.8L engines, and most 4.9L and above. No MECS engines require secondary air injection.

In some smaller EEC engines, secondary air is provided by a Pulse Air system. This operates on natural pressure changes in the manifolds and has no electronic controls.

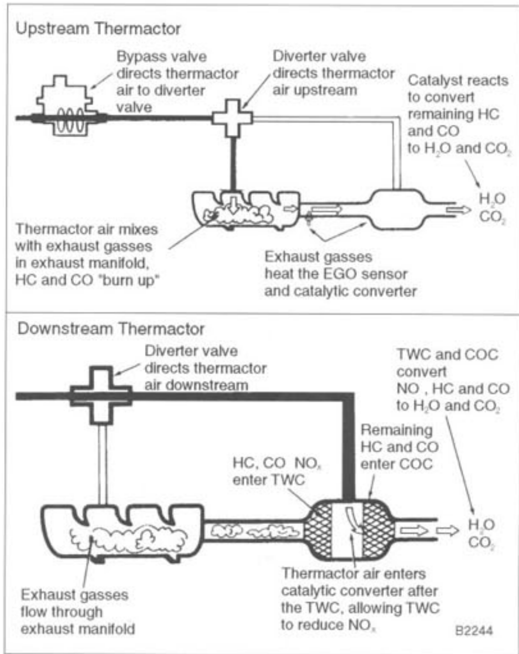


Fig. 5-6. Thermactor operation showing bypass valve (TAB) and diverter valve (TAD).

The control of secondary air by the control module depends on engine temperature and time since engine start.

The easiest way to keep Thermactor Air actuators straight is to think of two valves in series. I think the problem arises because Ford named one TAB and the other TAD. Vacuum to *each valve is controlled by a solenoid controlled by the control* module.

- Thermactor Bypass Air (TAB) controls bypass of secondary air when none is needed. When secondary air is needed, TAB sends it to TAD
- Thermactor Air Diverter (TAD) diverts the secondary air either upstream to the exhaust manifold or sends it downstream to the catalytic converter

The secondary air system is called Managed Air Thermactor. The TAB valve is called AMT-1, and the TAD valve is called AMT-2.

5.3 Canister Purge (CANP)

Canister Purge (CANP) controls the purging of the canister containing fuel vapors. The control module determines the proper engine operation for purging, usually warm-engine cruising. When the Canister Purge Regulator Valve receives a signal, the solenoid valve opens passage from the canister to the intake manifold.

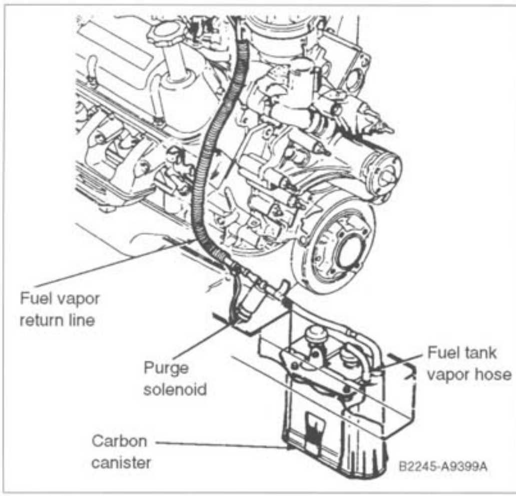


Fig. 5-7. Canister Purge Solenoid Valve opens on signal from control module, passing fuel vapors from carbon canister into intake manifold.

6. *Information Signals*

Much information, or data, flows inside the EEC system. The system also sends information out to advise the driver, to assist the technician in diagnostics, and to control other systems.

6.1 Driver Information

Shift Indicator Light (SIL)

Shift Indicator Light (SIL) signals the driver of a manual-transmission car to upshift. The SIL illuminates when the combination of higher rpm and light loads suggests the driver is racing the engine. Shifting to a higher gear will improve economy and emissions. The engine must be warm so the control module combines input from ECT, MAP, and rpm to determine when to light the SIL.

Data Output Line (DOL)

Data Output Line (DOL) supplies information for trip computers. Pulse-time signals to the injectors can be computed as gallons per hour fuel flow. Vehicle Speed Signals (VSS) can be read as miles per hour. Each can display metric for liters per 100 kilometers. Combining these two provides signals of instantaneous and trip fuel economy that can be displayed on the trip computer.

Malfunction Indicator Light (MIL)

Malfunction Indicator Light (MIL) could read "Check Engine," "Service Engine Soon," "Check DCL" (Data Communications Link). In addition to advising the driver, the system helps technician diagnostics by flashing the MIL. On some cars and trucks, the DCL sends trouble codes and operating data.

6.2 Self-Test Output (STO)

For Self-Test Output (STO), the DCL relates to the Self-Test Connector. STO was first conceived to check out engines at the end of the factory assembly line. Now, the industry recognizes the importance of output signals to service diagnosis in the field. DCL provides for:

- Self-Test Input (STI) to the control module for purposes of signalling the individual actuators, monitoring their responses, and looking for trouble codes in the memory
- Self-Test Output (STO) delivers vehicle information, operating conditions, and diagnostic information. STO trouble-code signals turn on the MIL and store the data in the KAM. More on that in Chapter 10. For accuracy, STO data is referenced to Signal Return voltage

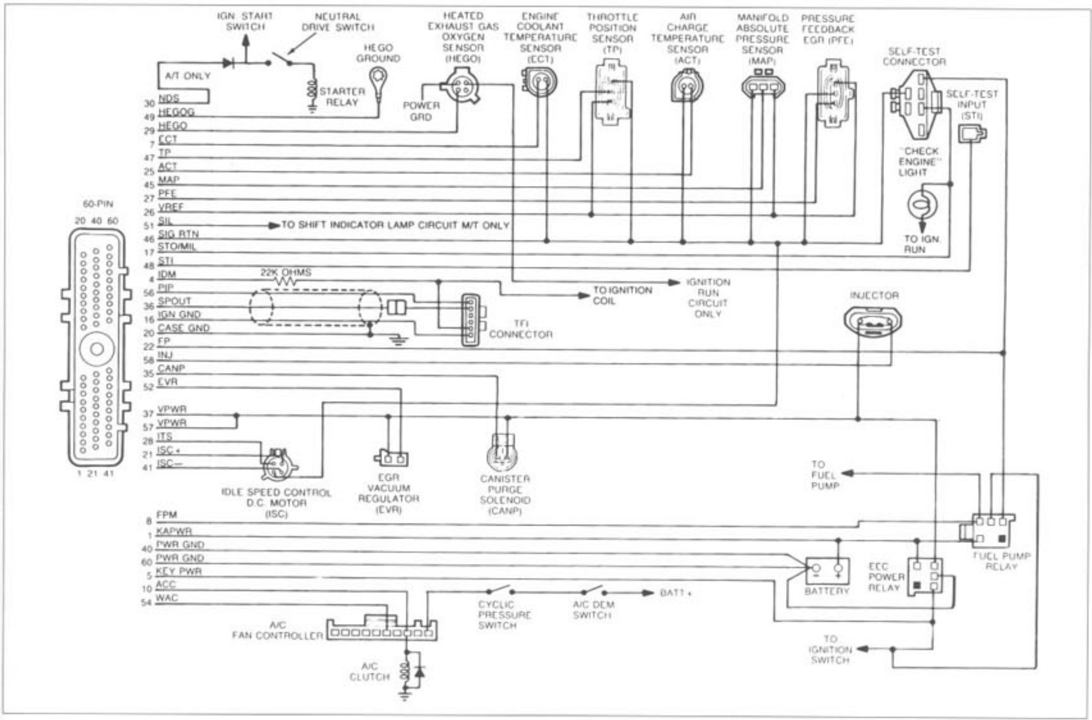


Fig. 6-1. Self-Test Connector provides Self-Test Input (STI) circuit to control module to initiate Self-Test, and Self-Test Output (STO) to read diagnostic information. STO can turn on "Check Engine" light and store trouble code in KAM.

MECS-I reads out only those diagnostic faults that are present during the test. It does not store intermittent faults. See Chapter 10. MECS-II stores and reads out codes similar to EEC.

6.3 Other Information Signals

Engine Temperature (ECT) and Vehicle Speed (VSS) information is sent to several other systems not directly related to engine control:

- Automatic Transmission/Transaxle uses data on vehicle speed, engine speed, temperature, and BOO to influence lock-up of the converter clutch, and, in some vehicles, the shift points
- Automatic Adjustable Shock Absorber Control (ACL) and other electronic ride controls use VSS data

7. Relays and Controls

Several other output signals are sent by the control module. See Fig.6-1 for a typical wiring diagram. The key energizes the EEC power relay and, in most vehicles, a separate fuel-pump relay.

7.1 Fuel-Pump Relay (FPR)

The Fuel-Pump Relay turns on the fuel pump as signalled by the control module. See Fig. 7-1. When the vehicle has 2 fuel pumps, it has also 2 relays. See Chapter 7 for more information.

7.2 Vehicle-Speed Control

The Vehicle-Speed Control (cruise control) system uses vehicle speed (VSS) to compare the actual speed with the set speed. The control module controls speed by controlling the actuator vacuum through the Speed Control Vacuum Solenoid

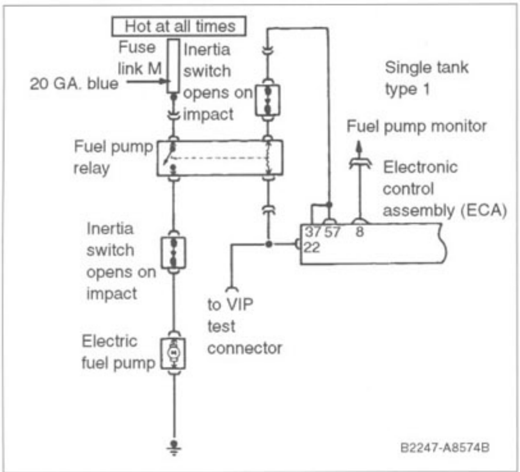


Fig. 7-1. Fuel pump relay controls power to fuel pump to insure fuel delivery during cranking and running, but to cut off if engine stops, even with key ON.

(SCVAC) and the Vent Solenoid (SCVNT). The control module controls the Speed Control Command Switch (SCCS) to cut off cruise control when the speed is below minimum control speed, or when the driver operates the Brake On/Off (BOO) switch.

7.3 Wide-Open Throttle A/C Shutoff Relay (WAC)

The Wide-Open Throttle Air Conditioner (WAC) Shutoff Relay receives EEC signals to briefly cut off the air-conditioner under full-throttle conditions, or under prolonged idle.

7.4 Electro-Drive Cooling Fan (EDF)

The Electro-Drive Cooling Fan (EDF) Relay receives EEC signals based on coolant temperature and vehicle speed to supply power to operate the fan. On vehicles with A/C, a second relay controls the second fan, High-Speed Electro-Drive FAN (HEDF).

7.5 Controller Modules

In some vehicles, the separate relays operate together in Controller Modules.

Integrated Relay Control Module (IRCM)

The Integrated Relay Control Module IRCM combines several relays into one module, replacing several separate relays found in earlier model-year cars. As shown in Fig. 7-3, the IRCM operates with Vehicle Power (VPWR) and the key switch (KPWR) under control module control to switch several circuits:

- Fuel pump(s)
- Control module power
- EDF and HEDF for engine cooling
- A/C solid-state Relay

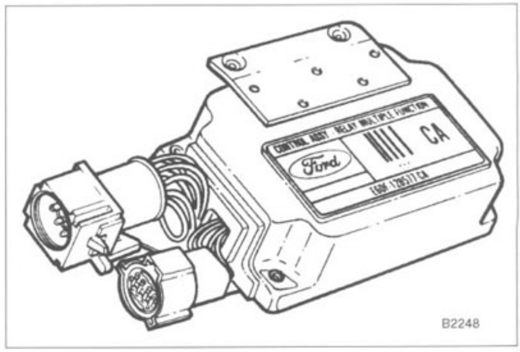


Fig. 7-2. Integrated Relay Controller Module combines several relays controlled by control module. It includes a diode to protect EEC system from reverse polarity, as in mis-connected jump-start cables.

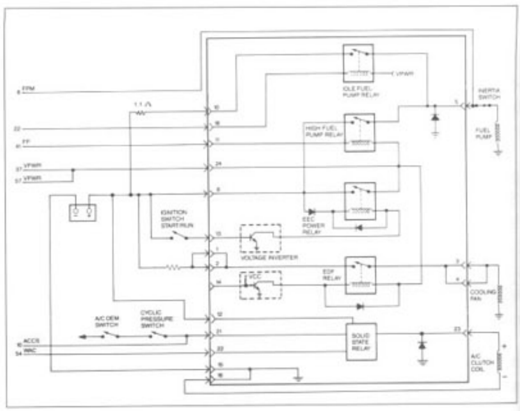


Fig. 7-3. Integrated Relay Control Module switches fuel pump(s), control module power, cooling fan(s), and Air Conditioner.

On newer models, the IRCM is called the Constant Control Relay Module (CCRM). Do not confuse IRCM with the new J1930 term for Intake Manifold Runner Control (IMRC).

Air-Conditioner and Cooling-Fan Controller Module (ACCM)

In some vehicles, you'll find the A/C relays combined in one Air-Conditioner and Cooling Fan Module. Under control of the control module, based on signals from ECT, VSS, and BOO, it provides:

- A/C cut-off briefly at Wide Open Throttle (WOT)
- EDF/HEDF cuts off briefly at WOT, provided the engine temperature is below limits
- Both A/C and EDF/HEDF cut off for a few seconds *when the BOO switch indicates Brake ON*
- EDF/HEDF cuts off when vehicle speed is above 50 mph (80 kph)

Variable Control Relay Module (VCRM)

The Variable Control Relay Module (VCRM), first used on Mark VIII 4.6L-4V, brings together several control functions and self-diagnosis. VCRM controls:

- Vehicle power to EEC and Powertrain Control Module
- Fuel pump
- Engine cooling fan
- Air-conditioner clutch

In addition, any failure detected by VCRM is sent to the Powertrain Control Module and stored as Diagnostic Trouble Codes (DTC).

Fuel Pump Control

Through VCRM, the two-speed fuel pump on the Mark VIII normally operates on less than battery voltage, reduced by a VCRM resistor. The pump is sized to deliver normal quantity fuel at low voltage, running quieter and lasting longer.

At higher loads and rpm, VCRM receives a signal from the Powertrain Control Module to bypass the resistor, sending full battery voltage to the pump. This delivers extra fuel for maximum power output.

Engine Cooling Fan Control

Through VCRM, the engine cooling fan operates at the required speed, rather than On/Off as in most fan controls. Engine cooling fan needs are determined in the Powertrain Control Module based on inputs from sensors: coolant temperature, vehicle speed, air-conditioner demand, A/C head pressure. Receiving fan-speed requirement signals from the Powertrain Control Module, the VCRM adjusts fan speed by varying battery-voltage pulses in a duty cycle.

Air-Conditioner Head Pressure Control

VCRM can turn off the Air-Conditioner pump clutch if head pressure rises near the safe limits of the system.

7.6 Other Fuel-pump Cut-off Switches

Inertia Switch (IS)

Ford is one of the few manufacturers using an inertia switch in all fuel-injected cars as a safety switch to interrupt power to the fuel-pump relay in the event of an accident. Few people think of it as a control item to be checked in a No-Start condition, when the fuel pump should run but does not. You'll find the Inertia switch located in the trunk of passenger cars. After checking to be sure that you do not smell or see gasoline, push the reset button in to restore the pump circuit.

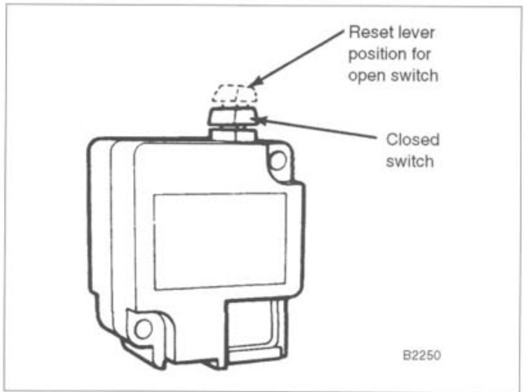


Fig. 7-4. Typical inertia switch interrupts fuel-pump control *circuit in accident.*

WARNING —
If you see or smell gasoline, do not reset inertia switch.

Anti-Theft Switch

In vehicles with an anti-theft system, a switch interrupts power to the fuel-pump relay if the system detects evidence of break-in. Troubleshooting a NO START engine may include checking the anti-theft circuit, if fitted.

7.7 Lock-Up Solenoid (LUS)

The lock-up signal from the control module to the automatic transmission torque converter requires the following:

- Warm engine
- Part-throttle
- Calibrated engine rpm

When the solenoid is energized, transmission fluid flows to the torque converter, locking the clutch. The LUS will be unlocked by stepping on the brake pedal (BOO switch), or planting your foot on the accelerator (WOT). Do not confuse LUS with LOS, "Loss of Signal."

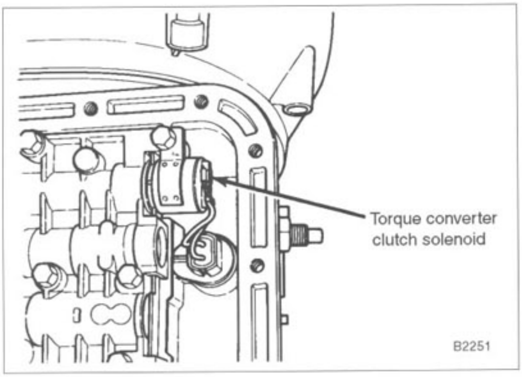


Fig. 7-5. Lock-Up Solenoid (LUS) receives output signal from control module to lock torque-converter clutch.

7.8 MECS Relays

You'll find two kinds of relays to control the fuel pump and the A/C clutch through the control module.

1. Fuel Pump Relay (FPR) (2.2L turbo). The control module grounds the FPR wire to turn on the fuel pump during start and during deceleration.
   - In 2.2L turbos, the VAF sensor cuts off the pump when closed, and this relay keeps it running during deceleration
   - Other MECS engines control the fuel pump by the VAF-closed switch
2. Wide-Open Throttle Air Conditioning (WAC). The control module opens ground to cut off the A/C clutch during start and during Wide Open Throttle (WOT)
   - Smaller engines, 1.3L, 1.6L, 1.8L—WAC Relay
   - 2.2L engines—Condenser Fan Relay (CFR)

In 1993 and later Probe engines, a relay cuts off the A/C relay under several conditions:

- WOT
- After engine start, 3–4 seconds
- Acceleration from idle, 2 sec.—2.0L
- High coolant temperature, above about 115°C (240°F)

8. Nissan Engine Control System—Mercury Villager

Bypass Air Valve (BPA)

Villager Bypass air is controlled in the old-fashioned Bosch way. A rotary valve in a bypass around the closed throttle is controlled by a bi-metal strip. When the strip is warm, it bends to close the valve. When cold, the strip opens the valve. The strip temperature depends on the engine temperature—contact with the cylinder head, and on the electric heater wound around the strip. The control module supplies electrical power at start up, but it does not modulate the bypass air. In other words, no coolant temperature input, no calculations. The only job of the control module is to feed power to the electrical heater.

Fast Idle Control (FIC)—Air Conditioner

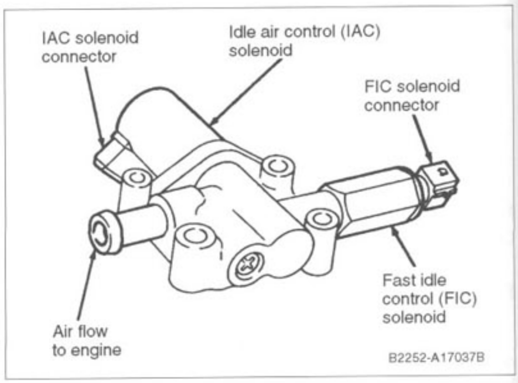


Fig. 8-1. Villager Fast Idle Control (FIC) Solenoid bypasses additional air during operation of air conditioner compressor to handle additional load during idle.

Villager Fast Idle Control (FIC) provides additional bypass air to prevent idle stall during air-conditioner operation. The FIC solenoid operates on signal from the control module, opening when the engine control module signals operation of the A/C. Although FIC and BPA are both mounted in the throttle bypass, they are separate—FIC compensates for air-conditioner load; BPA compensates for cold engine.