Chapter 1

Ford Electronic Engine Control—An Overview

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Contents

1. INTRODUCTION

Ford Motor Company was not the first U.S. company to offer fuel injection, but Ford is the first to go all the way, with virtually 100% fuel injection in passenger cars and trucks since 1987.

Did I say virtually 100%? Ford police cruisers with big 5.7 liter engines are the only carburetor cars in the recent Ford lineup. Ford Taurus police cruisers with 3.8L engines use electronically-controlled fuel injection.

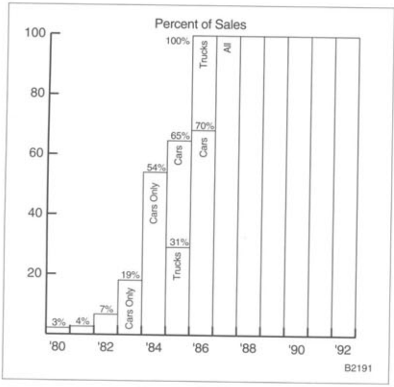

Fig. 1-1. Ford Motor Company is the first U.S. manufacturer to apply fuel injection to all cars and trucks, virtually 100% since 1987.

By 1988, most Ford engines inject the fuel to each individual cylinder intake-port, known as Multiport Fuel Injection (MFI). In this book, I'll concentrate on MFI. You'll find Ford references to this as EFI (Electronic Fuel Injection). I'll use "port injection" to refer to systems that inject at the intake port. Both Mazda Engine Control Systems (MECS), and Nissan Electronic Concentrated engine Control Systems (NECCS—used on the Villager) employ port injection. As late as 1989, a few small Ford engines were still using Central Fuel Injection (CFI), but these are not covered by this book.

1.1 What's in this book

Preview of Chapter 1—Overview

Chapter 1 introduces the idea of fuel injection and engine control, and tells you why Ford cars and trucks use fuel injection. I'll give you the broad picture of Ford fuel-injection systems, and the two main control systems, determined by where the powerplant is engineered:

Fig. 1-2. MFI (Multiport Fuel Injection) is often hidden by manifold runners (arrow).

Ford Electronic Engine Control	**Mazda Engine Control System**
EEC (say "eek")	MECS (say "mex")
NAAO—North American Auto Operations	Non-NAAO—Non-North American Auto Operations

A third system, Nissan Electronic Concentrated engine Control System (NECCS) operates beginning in the 1993 Mercury Villager. It has a relatively small population, but I'll mention the most significant differences.

All Ford systems include more than fuel metering. They control:

- Fuel injection
- Ignition timing (spark control)
- Some emission systems
- Idle rpm
- Intake air control
- Boost control

You'll also see the different types of fuel injection applied to Ford vehicles:

- MFI (Multiport Fuel Injection), also known as Electronic Fuel Injection (EFI)
- SFI (Sequential Multiport Fuel Injection), also known as Sequential Electronic Fuel Injection (SEFI)

- Mazda Engine Control Systems (MECS) applied to engines imported from Mazda. MECS-I used on 2.2L Probes, some Escorts and Tracers, Capris, and Festivas. "MECS-II" is my term for those 1993 and later engines with an advanced engine control system, closer to EEC

Preview of Chapter 2—Fundamentals

Chapter 2 will help you understand the fundamentals—the principles behind fuel injection and engine control. Some people regard fundamentals as dry theory, but I think you'll find this valuable if you are going to do even simple diagnostics and troubleshooting. Engine control systems are necessarily complex, and you cannot hope to perform successful troubleshooting if you only go by the numbers without understanding what they mean.

I'll discuss different engine needs to satisfy the driver for each driving condition—a broad picture of engine control. I'll discuss each operating mode and the different strategies of engine control. You'll see the intricate relationships among fuel metering, ignition timing, throttle-air bypass (idle-speed control), and emission controls. Different conditions are sensed as input to the computer, and output to the injectors and other actuators of the powertrain system.

Pressure is one of the most important factors in understanding fuel injection. I'll spend some time on the many different air pressures and fuel pressures in fuel injection, and the different units of measure that you will deal with and compare.

Preview of Chapter 3—Emissions and Alternate Fuels

Government standards for emissions and fuel economy are becoming increasingly important to save fuel and clean air, and to preserve the global environment. As you read this, Ford and other car makers are working to meet mandated fuel-economy standards and tighter emission limits for the 1990's. You'll see how computerized engine control is the only way to meet those needs while still providing good power and driveability. Alternate fuels may affect current engines, or Ford Flexible Fuel vehicles, or dedicated Alternate Fuel vehicles.

Preview of Chapters 4–7—The Different Parts Of The Systems

In Chapters 4, 5, 6, and 7 I'll show you how each part operates in the system. Many parts function similarly in EEC and MEC systems:

Sensors (Chapter 4) is the term generally applied to those parts that send signals to the computer, advising it of engine conditions, such as engine-coolant temperature.

Control Module (Chapter 5). Electronic Control Assembly (ECA) is the Ford term for the computer that receives and analyzes the input signals from the sensors, calculates the necessary commands to the engine, and sends control signals to the actuators.

Actuators (Chapter 6) is the term generally applied to those parts, such as fuel injectors, that are controlled by signals from the computer.

Fuel Delivery systems (Chapter 7) describes the different electric fuel pumps, filters, regulators and controls to get the pressurized fuel to the injectors.

If you don't really need to know the details of such things as a coolant-temperature sensor, use Chapters 3–7 for reference and move on.

Preview of Chapter 8—Strategies

In Chapter 8, I'll show how the complete engine control systems combine the components to satisfy the needs described in each mode of Chapter 2.

Specifically, I'll describe how each different engine condition—cruising, cranking, wide-open throttle—is monitored by the sensors, computed by the control module and is satisfied by the control signals to the injectors and other actuators.

Preview of Chapter 9—Tuning For Performance and Economy

In Chapter 9, for those who want more power from their engine-control system, I'll show you many different modifications for street-legal use or for off-road use. I'll discuss which ones are likely to work—and those probably not worth your time and dollars. I'll show you the excellent support available from Ford Special Vehicle Operations (SVO) for street-legal or for off-road racing. Most engine-control systems as installed Original Equipment (OE) by Ford are capable (without modification) of delivering extra fuel for engine modifications that increase performance, but I'll look at what you can do to modify the system delivered by the dealer.

For you owners who can tweak a Mustang carburetor by ear with a screwdriver on Saturday afternoon, this book will help you accept the performance of fuel injection as it takes away the need for your carburetor skills. Even so, you can do a lot more to your fuel-injected car than most people realize. When you understand fuel injection/engine control, you will have a better chance to remain street-legal while you stretch system performance.

Preview of Chapter 10—Diagnosis and Troubleshooting

In Chapter 10, I'll discuss Diagnosis and Troubleshooting of control system problems. I'll cover the simple diagnostic routines and testing for the average owner. Many tests can be done by counting blinks of the Check Engine light, or by swings of an analog voltmeter. I'll include some troubleshooting for technicians, such as with a scan tool.

Scan tool is a generic term for a hand-held unit that connects to the engine control system to read trouble codes. In later model cars, the tool can read signals to and from the computer. Ford calls its early scan tools Self-Test Automatic Readout (STAR) and its later tool, SuperSTAR, which has more capabilities. More on that in Chapter 10.

Fig. 1-3. Scan tool is plugged into diagnostic connector to read trouble codes. Analog voltmeter can also be used. Reading trouble codes is essential to troubleshooting electronic engine control.

In many cases, you can do simple diagnosis and testing using only simple tools, a volt-ohmmeter (VOM) and a fuel-pressure gauge. Some have complained that these modern engines mean the end of the shade-tree mechanic. "Hoo boy, I'll never touch that baby," I've heard owners say as they peer underhood. After you've read this book, you won't be saying that.

Preview of Chapter 11—Servicing

In Chapter 11, I'll show some of the specific procedures, still without specialized tools. Owners can improve your dialog with service technicians. Even if you don't want to do much of the work yourself, you'll still know enough about troubleshooting and repairs to communicate with the technician who may use special tools to service your car. Whether you're DIY (Do It Yourself), or PIY (Pay It Yourself), you'll find value in these pages.

Preview of Chapter 12—Service Data

In Chapter 12, you'll find the technical data you need to aid you in your diagnosis and service: trouble code definitions, electrical tests of major components, and wiring diagrams.

1.2 Terminology

Before I begin the first chapter, a word about terminology. Car makers and the Society of Automotive Engineers (SAE) have heard the complaints from service technicians: the use of different names for the same part in different cars is a servicing headache.

The push for common terminology came for emission control reasons, both from the Environmental Protection Agency (EPA), and from the California Air Resources Board (CARB). One reason for excessive in-use emissions is the inability of many technicians to properly service modern electronic-controlled engines. Technicians have a hard time applying the training we are developing to diagnose emission-control problems because the same part could be called by different names and acronyms (initials). And the same acronym could mean two different parts!

Beginning in 1991, Ford and most car companies cooperated with the SAE in developing a set of part names and acronyms that can become common to all cars. Beginning with 1991 cars, you'll find these SAE terms on the underhood decals, known as VECI (Vehicle Emission Control Information), and in 1993 and later manufacturers' service literature.

Examples of Acronyms, Names and Definitions from SAE Recommended Practice J1930:

- Multiport Fuel Injection:
  Ford term, EFI; J1930 term MFI
- Sequential Fuel Injection:
  Ford term, SEFI; J1930 term SFI
- EEC module:
  Ford term, Electronic Control Assembly (ECA); J1930 term, Powertrain Control Module (PCM)

NOTE —
Beginning about 1990, Ford refers to the module as PCM only when it controls both engine and transaxle. Beginning in 1993, PCM means all engine control modules.

To reduce confusion, I will use the SAE terms MFI for EFI and SFI for SEFI, but retain the Ford term for CFI. Other makers may call the engine-control module ECM (Electronic Control Module), or ECU (Electronic Control Unit). I'll usually call it the control module.

Before SAE and the manufacturers began to bring these terms together, I discussed the nomenclature problem with the head of service training at GM. He explained that parts get named in the Engineering Department at the time the part is originated. By the time they get to Training, perhaps two years later, he said, it's a done deal, a real mess to change them.

Beginning with 1993 models, manufacturers have responded, changing their terms and acronyms according to the SAE Recommended Practice, J1930. To help you refer to other

Consider some terms in current service literature and the opportunities for confusion:

For the air temperature sensor in the intake manifold:

- GM: MAT (Manifold Air Temperature)
- Ford: ACT (Air Charge Temperature)
- Chrysler: CTS (Charge Temperature Sensor); and to complicate the problem, at Chrysler, CTS also stands for Coolant Temperature Sensor!

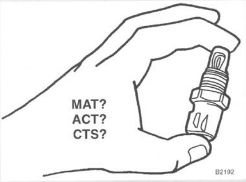

Fig. 1-4. Nomenclature can be a problem. Even within one company, Ford has different names for the same part. The name can change depending on where the engine-control system is engineered, Ford or Mazda, and even on the model year for the same engine.

Ford materials, I'll use Ford terms or generic terms, with occasional reference to SAE terms, but at the start of chapters where you might get confused I'll give you a brief list of terms and equivalents. Be sure to look in the glossaries for the terms that will be common to all cars.

Metrics

Did you know that virtually all modern cars are manufactured in the Metric system? Car components flow around the world in the global economy, in and out of the U.S., the only major country that still deals in pounds and ounces, feet and inches. Naturally, our cars must be made metric. For communicating with the service industry, only in the U.S., the metric dimensions must be converted into English units. (Canadians are already making the switch to metrics.)

Generally, I'll list both English and metric units. But I advise you, in the car business, the sooner you start thinking metric, the easier it will be for all of us.

I make it easier by making my conversions in "sensible metrics", so my values may not always match the Ford values. I avoid ridiculous conversions that make the metric system seem even more difficult.

Examples from a Ford Service Manual:

1. "Coolant level is specified as 0–2 inches (0–51 mm)." First, could the coolant level be read to an accuracy of 1 mm? Second, if it could, does 1 mm make any difference to the cooling system? Sensible metrics says, 0–2 in. (0–50 mm).
2. Pinion-bearing preload is specified as "the number of threads protruding from the front of the nut, 2.29–2.54 mm (0.90–1.00 inch)." Can you measure thread protrusion to 0.01 mm? Neither measurement makes sense. Try this: Threads should protrude about 1/10 of an inch (about 3 mm).

Any technician knows the difference between metric hand tools and English-unit tools. When a 10 mm wrench doesn't fit, it's easy to reach for an 11 mm. But if a 5/8 in. doesn't fit, you have to think to reach for an 11/16 in. wrench. Most gauges read both Metric and English units, so try the metric measurements; you'll find they're really easier.

2. BASICS OF FUEL INJECTION

Fig. 2-1. Electronic control of fuel injection and ignition helps clean up the tangle of underhood hoses that are necessary when vacuum circuits are used.

Today's cars are changing under the hood. The tangles of vacuum hoses—as well as emission-control miseries—are being replaced by the orderly installation of fuel-injection systems. But before we talk about specific Ford systems, you'll need to understand some basics about fuel injection.

Air-Fuel Mixtures

Internal-combustion engines create power by burning fuel mixed with air. In gasoline-fueled engines, the proportions of air and fuel—the air-fuel ratios or "mixtures"—are of critical importance to the quality of combustion and, therefore, to engine power output and running characteristics. Since the amount of air required by the engine varies with rpm and load, the required amount of fuel varies too.

The overall purpose of the engine-control systems covered by this book is to burn the fuel in the most efficient manner for the constantly changing engine-operating conditions.

What is Fuel Injection?

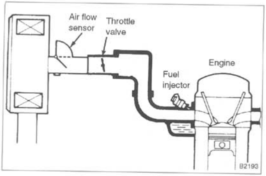

Fig. 2-2. Throttle controls the amount of air entering engine. Air flow sensor measures amount of air entering engine.

The throttle of an engine regulates air flow into the engine. The proportions of air and fuel are critical, but the throttle cannot meter the correct amount of fuel into the moving air. The fuel metering system responds to throttle changes and adjusts to continuously supply the engine with a combustible mixture of air and fuel. Fuel injection is an accurate and sophisticated type of fuel metering system.

Until the 1990s, there were two basic types of fuel metering systems in use, carburetors and fuel injection. These systems mix fuel and air, but in very different ways. To help you understand the differences in fuel injection, I'll review carburetors.

Contrast with Carburetors

Carburetors take advantage of the venturi principle: The Italian physicist, G. B. Venturi, discovered that the more air flows through an opening, the less pressure (I know, it would seem like more pressure, but in a venturi, it's less). Air flow through the carburetor throat, as determined by the throttle opening, creates a low pressure condition at the venturi, or throat. This reduced pressure pulls fuel into the intake air stream where it is vaporized to form a combustible air-fuel mixture. A wider throttle opening causes more air flow which results in more fuel flow. Fuel is "metered" more or less in proportion to air flow.

For many decades, a carburetor was a relatively simple way of metering fuel into the airstream entering the engine. But, beginning in the 1980s, drivers demanded more performance and more driveability; they would not accept the "stumbles" of the 70's. About the same time, the government demanded *tighter control of emissions and better fuel economy. These* demands require more precise control of fuel metering. Carburetors cannot provide the required precise fuel metering, especially under extreme operating conditions, even with their complex set of fuel circuits, jets, air bleeds, chokes and valves.

In 1980, a carburetor engineer, previously from Ford, worked with me to write the carburetor chapters of the MOTOR's 8th Edition of Auto Engines and Electrical Systems. He told me "The Ford 7200-VV variable-venturi feedback carburetor is a dream until it goes wrong; then it's a nightmare." About that time, my wife was ordering a Ford LTD. We specified the 5.7 engine with that electronically-controlled carburetor. The LTD was a dream. For years, starting and driveability were close to fuel-injection standards, but the 7200-VV became a nightmare, requiring three costly overhauls!

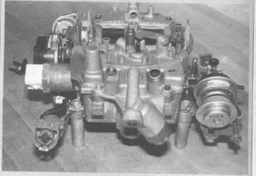

Fig. 2-3. The last major Ford carburetor, the 7200VV is in many ways more complex than most fuel-injection systems.

Fuel Injection

Fuel injection systems deliver fuel by forcing it under pressure into the incoming airstream. Fuel-injection systems directly or indirectly measure the amount of incoming air and deliver the fuel in precise amounts based on the amount of air. Because fuel is delivered to the airstream under pressure, the quantity of fuel delivered can be positively controlled. With this positive control, fuel metering can be more precisely managed to meet the special demands of many different operating conditions. This results in greater efficiency over a wider range of operation.

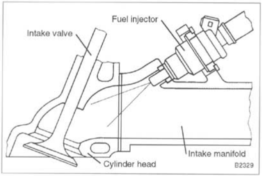

Fig. 2-4. Most Ford fuel injection systems inject fuel into incoming airstream near intake valve but outside the cylinder.

Benefits

Owners of fuel-injected cars experience better starting and driveability, especially when the engine is cold. In the 1990s, drivers demand an engine that starts on the turn of the key, handles cold acceleration without stumble, does not stall at the stoplight, and stops without run-on (dieseling).

For the manufacturer, fuel injection means better emission control and better fuel economy, both important in meeting increasingly-stringent government regulations. In an early paper to the SAE, Ford engineers listed the following advantages of fuel injection:

- Reduces air-fuel ratio variability
- Matches fuel delivery to specific operating requirements
- Prevents stalling caused by fuel-bowl wash during cornering
- Eliminates engine run-on (dieseling) when key is turned off

Until the 1980s, with looser emission limits in Europe, many European cars were built with fuel injection for delivery in the U.S., but with carburetors for delivery in Europe. In 1981 in Paris, I spoke with a chief engineer of one of the largest European manufacturers. He was reluctant to change his engines for export to the U.S. from carburetors to the more expensive fuel injection. He suggested that we in the U.S. were a little paranoid about clean air. Now, Europeans recognize the importance of clean air. "Green" is the term used to describe emission-controlled cars in Europe, derived from the Green Party in Germany, the initial force behind European Clean-Air legislation. In the 1990s, European manufacturers are rushing to replace carburetors with computer-controlled fuel-injection systems for cars sold in Europe. Now, many late-model European cars are sold in both the U.S. and Europe with the same fuel-injected engines using the same lead-free-fuel catalyst emission controls.

Cold-driveability of fuel injected engines is so good that you do not warm the idling engine in the driveway before drive-off ("for more than a few seconds", according to Ford owner's manuals). Those who care for their engine will drive off with moderate power for a few minutes, until the engine warms up and the oil flows freely. But if you live next to a freeway ramp, you can push your engine before it is ready—that's how good fuel-injection control is.

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Background

Fuel injection is not new, particularly to racing. In 1965, Ford's 4-cam V-8s built for Indy racing used a simple Hilborn mechanical system injecting fuel continuously into each intake port. This was the basis for the Rochester mechanical system adapted for a few 1957 production Corvettes and Pontiacs. On the street, it was totally unsuccessful. Ford did not produce any fuel-injected cars for the market.

At Indianapolis, fuel-injection was the winner. By 1970, the Bendix RS-11 system took over at Indy in the Offenhausers and in the Ford engines. The fuel-injected Ford-powered car took first place in the 1970 Indy. It used a mass-airflow sensor, a way of measuring the mass, or weight of the air flowing into the engine. Based on the airflow, the system mechanically controlled fuel delivery to the intake ports. While well suited to near-constant high-speed operations of racing, it could not satisfy the changing needs of a street engine, which must start and run well from cold.

Electrojector—the Original EFI

Flashback to the mid 1950s, when a complete electronic fuel injection system was being developed in another Bendix Division in upstate New York. As defined, the electronic system used electronics to:

- Measure engine conditions
- Compute the amount of fuel needed
- Control fuel flow in proportion to air intake to satisfy engine conditions

The Electrojector system, as it was called, turned out to be ahead of its time—the first units used vacuum tubes for the electronics and took 30 seconds to warm up before the engine could be started! As transistors became available, the electronic warm-up problem disappeared, but the electronic system cost 20 times as much as a carburetor, and was less reliable. Manufacturers learned that using several carburetors was cheaper than one fuel-injection system. Bendix shelved the electronic system in 1961. In the U.S., it was to stay on the shelf for 12 years.

Bosch Influence

Beginning in 1937, in Germany, Robert Bosch GmbH had been adapting mechanical diesel-injection pumps to gasoline injection, in aircraft, in racing, and in the famous 1955 Mercedes 300SL. But, if the Bendix electronic system was expensive, the Bosch mechanical system was even more so, while lacking in metering accuracy, driveability, and, by the mid-1960s, new worry for the engineers, emission control.

It was emission-control concerns that drove Volkswagen to ask Bosch for an electronic system for the VW Type 3 air-cooled engine. In 1966, a cross-licensing agreement between Bosch and Bendix enabled Bosch to quickly adapt the Bendix system. In 1967, VW brought out the world's first production electronic fuel-injection system. It came to be known as Bosch D-Jetronic.

Bosch/Bendix/Cadillac

In a strange case of hands across the sea, some 1976–80 Cadillacs were built with an electronic fuel-injection system sharing features of the U.S. Bendix Electrojector and the German Bosch D-Jetronic. It was called EFI. Like the Bosch D-Jetronic, the analog computer controlled only fuel injection. It was an MFI system, like the D-Jetronic. One of the Cadillac engineers told me they had no technician training. They tested the system with an infamous "Blue Box." When the box failed, they started over, sometimes replacing the whole system.

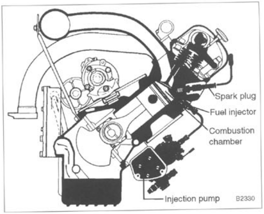

Fig. 2-5. Early Bosch mechanical fuel injection system used on Mercedes Benz 300 SL was adapted from Diesel injection system. Injection was directly into cylinder.

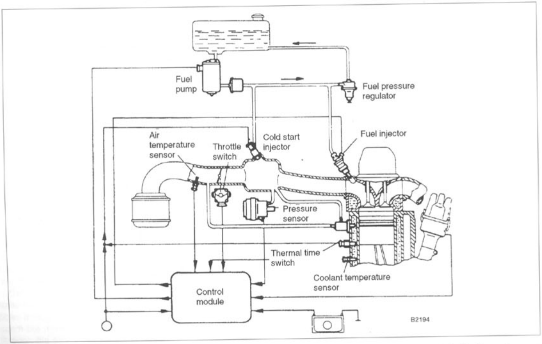

Fig. 2-6. First production electronic injection system was Bosch D-Jetronic, adapted from Bendix Electrojector for the 1967 Volkswagen Beetle to meet U.S. emission-control limits.

> Some people say the engines that took the Wright brothers into the air in 1903 were fuel injected. I examined one of the first Wright engines on display at the Engineer's Club in their home town, Dayton, Ohio. True, it had no carburetor, also no fuel pump. Fuel fed by gravity from a small tank, 1 quart (1L), through a hand-set metering valve to a shallow chamber next to the cylinders. As warm air flowed over the surface, it vaporized some gasoline and carried it into the cylinders. A flywheel magneto supplied ignition current. Cold start delivered 16 horsepower, but after warm-up, the warmer air cut power back to 12. Crude, yes. Did it work? Yes. Fuel injection? No.

3. FORD FUEL INJECTION TYPES

3.1 Control Systems

Electronic Engine Control (EEC)

Ford-developed EEC systems are controlling most Ford engines around the world. They are generally based on Bosch principles, patent licenses, and in some cases, Bosch parts, but controlled by Ford EEC computers. Ford EEC-IV controls even racing engines such as the Ford Cosworth Indy Car.

Mazda Engine Control System (MECS)

Ford's partnership with Mazda in the late 1980s resulted in increased use of Mazda engines—with Mazda Engine Control (MEC) systems. MECS-I can be described as a Bosch-licensed "L-Motronic" system, made by NipponDenso. "L-Motronic" is my term for a traditional Bosch vane-type air-flow sensor fuel-injection system (Bosch-speak is "L-Jetronic"), combined with control of spark timing from the same computer (Bosch-speak is "Motronic").

MEC-I systems applications include:

- 1.3L engines in Festiva, manufactured by Mazda-owned Kia in Korea for Ford
- 1.6L engines with turbocharger and without, in 1991 and later Capri manufactured by Ford of Australia from Mazda 323 design
- 1.8L performance engines of some '91 and later Escorts and Mercury Tracers. This is the same engine Mazda builds for its own 323 and Protege
- 2.2L engines, with turbocharger and without, in 1988–92 Ford Probe cars built by Mazda in Michigan

NOTE —
Beginning in 1994, all 2.0L engine control is by Ford EEC instead of Mazda MECS, both MTX and C4DE.

MEC-II systems include:

- 2.5L V-6 engines in 1993 and later Probe cars
- 2.0L 4-cylinder 4EAT (Automatic Transaxle) 1993 only

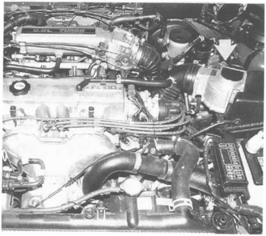

Fig. 3-1. MEC system in 1991 Ford Probe 2.2L Turbo engine. Look for the Vane Air Flow sensor (arrow), used in all MEC systems. Also used on EEC systems in earlier Ford 1.6 and 2.3L engines.

Ford sells Escort/Tracers made in Mexico and in Michigan. MECS controls 1.8L DOHC engine. EEC controls 1.9L SOHC Ford engine.

Ford sells Probe cars manufactured by Auto Alliance, a joint Ford/Mazda plant in Michigan. Four-cylinder Ford (Mazda) engines though 1992 are controlled by MEC systems. In the 1990–92 Probes, six-cylinder 3.0L Ford engines are fitted with Ford EEC. V-6 2.5L engines are fitted with MECS-II. The systems differ enough that I will describe them as: "MECS-I", 1988–92, and "MECS-II", 1993 and later. Look for EEC in 2.0L Probes, except 1993 with 4EAT that use Mecs-II

Fig. 3-2. MECS-II controls 2.5L V-6 in 1993 Probes. Also 2.0L 4-cylinder with automatic transmission (4EAT).

3.2 Injection Systems

All fuel-injection systems in U.S. Ford cars are electronic. All meter fuel in short pulses, delivered intermittently. Between 1980 and 1989, Ford systems are divided according to where the fuel is injected into the intake manifold.

Central Fuel Injection (CFI)

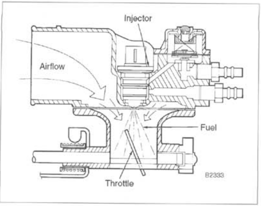

Fig. 3-3. CFI delivers fuel directly above throttle plate, similar to carburetor location. (Low-pressure shown.)

Central Fuel Injection (CFI) delivers fuel above the throttle plate, about where carburetor fuel is drawn into the airstream. As in carbureted engines, the manifold carries air-fuel mixture. Most CFI systems deliver with one injector, but some use two.

While CFI represents a few million of Ford fuel-injection car and truck production through 1987, CFI has been supplanted with the second type, Multiport Fuel Injection.

Multiport Fuel Injection (MFI)

Multiport Fuel Injection (MFI) systems look different from carburetor or CFI systems, with prominent intake manifolds leading to the cylinders. Usually you can see the injectors at each cylinder. Port systems deliver fuel at each intake port opposite the intake valve. That means the intake manifold delivers air instead of the air-fuel mixture, as in CFI or carburetors.

Ford MFI systems deliver fuel to multiple injectors, ganged in two banks of cylinders, 2 x 2 in four cylinders, left-bank/right bank in V-6 and V-8s.

Multiport systems usually deliver more power and better driveability than CFI systems for a number of reasons:

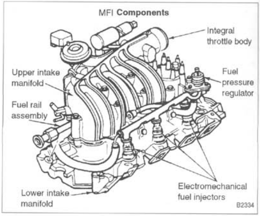

Fig. 3-4. Multiport Fuel Injection is used in all Ford systems in the 1990's; Ford CFI began in 1980.

- Greater power by avoiding venturi losses as in a carburetor. In addition, most Ford engines use tuned intake runners that help to ram in more air per stroke to improve torque characteristics
- Improved driveability by reducing the throttle-change lag which occurs while the fuel travels from the throttle body to the intake ports
- Increased fuel economy by avoiding condensation of fuel on interior walls of the intake manifold (manifold wetting)
- Simplified turbocharger and supercharger applications. The compressor need only handle air
- Improved power by operating with cooler, denser intake air

Sequential (Multiport) Fuel Injection (SFI)

Sequential Multiport Fuel Injection (SFI) systems deliver fuel to one injector at a time—each cylinder in firing order sequence. Hence the name "Sequential". Ford calls this SEFI. SFI systems look no different from MFI; the difference is in the computer.

Sequential systems provide less variation between cylinders for smoother idle and reduced emissions; SFI provides smoother acceleration and rpm limitation because fuel control is by individual cylinder rather than by banks as MFI.

Beginning in 1988, the advantages of multiport injection won out over CFI. SFI, first installed in 1986, is winning out over ganged MFI.

Fig. 3-5. Long intake runners, called ram manifolds, are widely used in Ford fuel injection.

4. Total Engine Control

Most people think of Fuel Injection as a replacement for a carburetor—a computer system controlling only the fuel delivered, as in the early Bosch systems. In contrast, Ford determined almost from the start that total engine control by computer had many advantages. Where other books treat fuel injection as a subject separate from engine control, I will stress that today, fuel injection is part of engine control.

Using many of the same signals needed for computer control of fuel delivery, Ford computers also control:

- Ignition, or spark-timing and dwell, eliminating most vacuum hoses and their servicing headaches
- Idle-air bypass to control idle rpm, and to manage air flow during deceleration
- Emission systems, improving driveability and again reducing the number of vacuum hoses
- Boost control in some engines

Ignition timing has always been important to power and economy, even when Henry Ford's Model A provided the driver with hand controls for timing and fuel. Later, a form of automatic control was provided by flyweights in the distributor that mechanically advanced timing for increasing rpm, and by vacuum diaphragms that retarded timing for increasing engine load.

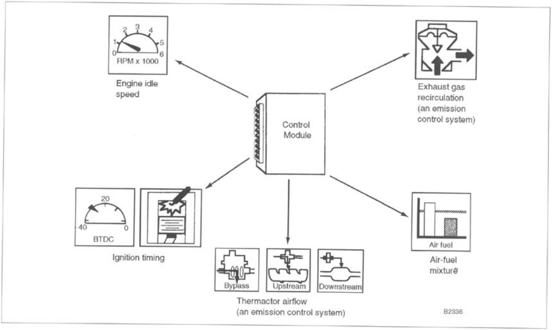

Fig. 4-1. Control module of EEC system controls more than fuel injection. It controls engine conditions in several ways.

From the 1931 Model A Book, paraphrased: "Before starting the engine, place the spark lever (left hand) at the top of the quadrant. This is the retard position. Always retard the spark lever when starting your engine. Starting the engine with the spark advanced may cause the engine to kick back and damage the starter parts. After the engine is started, advance the spark lever about half way down the quadrant. Only for high speeds should the spark lever be advanced all the way down the quadrant. When the engine is under heavy load as when climbing steep hills or driving through heavy sand, the spark lever should be retarded sufficiently to prevent a spark knock." Now do you wish to return to the "good ole days"?

Fig. 4-2. Ford Model A driver controlled spark timing and fuel directly. EEC systems control timing and fuel to satisfy many requirements, many times per second.

Spark Timing

The correct timing of spark-plug firing depends on many of the same variables that control fuel metering, including engine speed, engine temperature, altitude and, in some cases, whether the engine is knocking. Electronic ignition control uses these variables to compute the spark timing point. The control module refers to a timing map, a set of data points in the Control module memory that give the best timing point for all conditions.

In addition to controlling timing, in Ford supercharged engines, electronic systems control the boost.

Idle-Air Bypass—Closed Throttle

Control of idle-air for controlling idle speed contributes to fuel economy and reduced emissions. Using many of the same variables already input, the control module adjusts idle rpm by varying the amount of air that enters the engine when the driver's foot is off the accelerator.

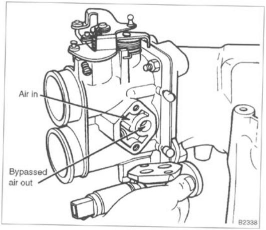

Fig. 4-3. Idle-air bypass controls air flow around throttle plate. It includes Idle Speed Control (ISC), but also functions during more engine operating conditions than just idle.

Control of air passing the throttle-body is also important to operations during deceleration from cruise or Wide Open Throttle (WOT). When you take your foot off the accelerator, the control unit allows extra air intake. This reduces emissions during deceleration, and prevents engine stalling.

NOTE —
I don't like the traditional nomenclature of Idle Speed Control (ISC). Because of its importance to deceleration control (indeed the engine may be slowing from 7500 rpm!), I will use the term Idle-Air Bypass (ISC). This is close enough to the Ford term Idle Speed Control-ByPass Air (ISC-BPA) while describing accurately the purpose of this important system: more than just idle-speed control.

Emission Control

Emission-control functions are usually included in the engine control unit functions. For example, I'll describe those Ford electronic systems that control:

- Secondary air (air injected into the exhaust stream)
- Opening and closing of the fuel-vapor charcoal canister purge valve
- Flow of EGR (Exhaust Gas Recirculation). More on Emission Control in Chapter 3

5. Applications

In this brief run-through of Ford's fuel-injection/engine control systems, you may follow the patterns of application and see where your car fits in.

5.1 Systems

NOTE —
In this book, I do not cover the early fuel-injection systems, used 1980–87. I list them only to show the background of Ford Electronic Engine Control.

1978: EEC-I is Ford's first application of Electronic Engine Control. Beginning in a small way, Ford introduces EEC-I in 5.0L V-8 engines in Lincoln Versailles for the purpose of reducing emissions. EEC-I controls spark timing and emissions, EGR flow, and secondary air—Thermactor as Ford calls it. No fuel injection, in fact, no control of fuel, even in carburetors.

1979: EEC-II is Ford's first electronic control of fuel—in carburetors, adding to control of ignition timing, idle rpm, and emissions. It starts first in California with its stricter limits. First use: Full-size cars with 5.8L engines, Ford, California only, and Mercury, 50 states.

1980: MCU—Microprocessor Control Unit is a simplified system of fuel control in carburetors. It begins in California 2.3L engines and continues through 1985 in several cars and the 4.9L light truck. MCU controls carburetor air-fuel ratio and the Thermactor, but does not control ignition timing.

Mid-year 1980: EEC-III signals an industry-milestone year of tighter emission-control limits in all cars. Ford began fitting EEC-III CFI fuel injection to Lincoln 5.0L V-8's.

1981–83: EEC-III CFI expands to 5.0L engines in Lincoln/-Mark VI, Continental, full-size Ford/Mercury, and T'Bird/Cougar. Idle Speed Control (ISC) is added in 1981, knock control in '82.

1983: EEC-IV begins with the 1.6L MFI engines in Escort and Lynx and EXP/LN7. Also in 2.3L MFI turbocharged engines in T'Bird/Cougar. From 1985 through 1988, MFI spreads to 5.0L, 3.8L, 3.0L, and 1.9L, and to 2.3L in trucks. Ford's first MFI engines include expanded diagnostics. Turbo engines include individual-cylinder knock control, and turbo-boost control.

1985–87: EEC-IV controls CFI in 3.8L, 2.5L, 2.3L, and 1.9L engines; and MFI, as carburetors are gradually eliminated. The first Sequential (SFI) systems appear on T'Bird/Cougar 3.8L. Truck engines get MFI beginning in 1986.

1988: MEC systems begin with the 1.6L Mazda engine in the Mercury Tracer, followed by the 1989 2.2L Probe engine, and continue on 1.3L engines in Festiva. All car and truck engines are port-injected with minor exceptions.

1993: Second-generation MECS (I call it "MECS-II") in Probe 6-cylinder 2.5L, and 4-cylinder 2.0L 4EAT(automatic transaxle) only. Watch for 2.0L MTX (manual transaxle). It uses EEC-IV. In the shop, this could catch you by surprise.

1994: First EEC-***V*** cars with the Thunderbird/Cougar and Mustang. EEC-V is faster, with more memory and with Flash EEPROM (computer chip reprogrammable in the shop) and advanced systems, known as On-Board Diagnostics II (OBD-II). Thunderbird/Cougar: 4.6L engine from the Lincoln/Crown Victoria/Grand Marquis. Mustang: 240-horsepower engine from the Cobra, and 3.8L V-6 standard engine to replace 2.3L. Aspire: new name for slightly lager Festiva.

1995: (Mid 1994) Ford Contour and Mercury Mystique CDW-27 world car (Mondeo in Europe) replace Tempo/Topaz. Four-cylinder 2.0L Zeta engine, 16-valve DOHC, SFI/DIS. V-6 2.5L 24-valve DOHC SFI/DIS. Dual-stage Intake Manifold Runner Control (IMRC) similar to Mark VIII.

5.2 Vehicles

In this book, I'll cover production Ford and Mazda fuel injection/engine control installed since 1988.

Table a. Ford Platforms and Families

Platform	Ford	Mercury	Lincoln
BT17	Festiva		
CT20	Escort '92+	Tracer	
Erika	Escort to '91	Lynx	
DN5	Taurus	Sable	
FN9			Continental
Fox	Mustang		
LS			Mark VII & VIII
Panther	Crown Victoria	Grand Marquis	Town Car
MN12	T'Bird	Cougar	
Topaz	Tempo	Topaz	
ST16	Probe		
SA30		Capri	

Some engines are optional in some lines.

Abbreviations

Table b on the following pages uses these abbreviations:

AXODE: Automatic Transaxle, OverDrive (4-speed), Electronic
DIS: Distributorless Ignition Systems (J1930:Electronic Ignition, Low Data Rate)
EDIS: Electronic Distributorless Ignition Systems (J1930: Electronic Ignition, High Data Rate)
EEC: Ford Electronic Engine Control
MAF: Mass Airflow sensor
MECS: Mazda Electronic Control System
MFI: Multiport Fuel Injection (Ford: EFI)
NECCS: Nissan Electronic Concentrated engine Control System
SFI: Sequential (Multiport) Fuel Injection (Ford: SEFI)

NOTE —
Unless otherwise noted, all engines listed use EEC engine control, distributor ignition, and MAP (speed-density) airflow measurement

Table b. Applications

Engine family	Model	Engine control system and fuel injection type
1993 Passenger Cars		
1.3L	Festiva (Mazda)	MECS-MFI
1.6L	Capri (Mazda)	MECS-MFI
1.6L Turbo	Capri (Mazda)	MECS-MFI
1.8L	Escort / Tracer	MECS-MFI
1.9L	Escort / Tracer	SFI-MAF-DIS
2.0L	Probe–MTX	EEC-SFI-MAF
2.0L	Probe–4EAT (Mazda)	MECS-SFI-MAF
2.3L OHC	Mustang	MFI-MAF/DIS
2.3L HSC	Tempo/Topaz	SFI-MAF
2.5L	Probe (Mazda)	MECS-SFI-VAF-SC
3.0L	Tempo / Topaz	SFI-MAF
3.0L	Taurus/Sable	SFI-MAF
3.0L	Taurus FFV	SFI-MAF/DIS
3.0L	Taurus SHO M/T	SFI-MAF/DIS
3.2L	Taurus SHO A/T	SFI-MAF/DIS
3.8L	Taurus / Sable /Police	SFI-MAF
3.8L	Continental	SFI-MAF
3.8L	T'Bird/Cougar	SFI-MAF
3.8L SC	T'Bird	SFI-MAF/DIS
4.6L	Town Car, Crown Vic. / Grand Marquis	SFI-MAF/EDIS
4.6L -4V	Mark VIII	SFI-MAF/EDIS
5.0L HO	T'Bird / Cougar, Mustang	SFI-MAF
1993 Light Trucks		
2.3L OHC	Ranger	MFI-MAF/DIS
3.0L V-6	Ranger	SFI-MAF
3.0L	Aerostar	SFI-MAF
3.0L	Mercury Villager	NECCS-SFI-MAF
4.0L	Aerostar / Explorer / Ranger—49 state	MFI-MAF/EDIS
4.0L	Aerostar / Explorer / Ranger—CA	SFI-MAF/EDIS
4.9L	E/F-Series, Bronco	MFI
5.0L	E/F-Series, Bronco	MFI
5.0L	E-series—CA	SFI
5.8L	E/F-Series, Bronco	MFI

Table b. Applications (continued)

Engine family	Model	Engine control system and fuel injection type
1992 Passenger Cars		
1.3L	Festiva (Mazda)	MECS-MFI
1.6L	Capri (Mazda)	MECS-MFI
1.6L Turbo	Capri (Mazda)	MECS-MFI
1.8L	Escort / Tracer (Mazda)	MECS-MFI
1.9L	Escort / Tracer Integrated 4EAT	EEC- SFI-MAF
2.2L	Probe (Mazda)	MECS-MFI
2.2L Turbo	Probe GT (Mazda)	MECS-MFI
2.3L OHC	Mustang	MFI-MAF/DIS
2.3L HSC	Tempo / Topaz	SFI-MAF
3.0L	Tempo / Topaz	SFI-MAF+AXODE
3.0L	Taurus SHO	SFI-MAF/DIS
3.0L	Taurus / Sable	SFI-MAF
3.0L	Probe	EEC-MFI
3.8L	Taurus / Sable /Police	SFI-MAF
3.8L	Continental	SFI-MAF
3.8L	T'Bird/Cougar	SFI-MAF
3.8L SC	T'Bird	SFI-MAF/DIS
4.6L	Town Car, Crown Vic. / Grand Marquis	SFI-MAF/EDIS
5.0L HO	T'Bird / Cougar, Mustang	SFI-MAF
5.0L HO	Mark VII	SFI
1992 Light Trucks		
2.3L OHC	Ranger	MFI-MAF/DIS
2.9L	Ranger	MFI
3.0L	Aerostar	SFI-MAF
4.0L	Aerostar /Explorer / Ranger	MFI-MAF/EDIS
4.9L	E/F-Series, Bronco	MFI
5.0L	E/F-Series, Bronco	MFI
5.8L	E/F-Series, Bronco	MFI

continued on next page

Table b. Applications (continued)

Engine family	Model	Engine control system and fuel injection type
1991 Passenger Cars		
1.3L	Festiva (Mazda)	MECS-MFI
1.6L	Capri (Mazda)	MECS-MFI
1.6L Turbo	Capri (Mazda)	MECS-MFI
1.8L	Escort / Tracer (Mazda)	MECS-MFI
1.9L	Escort / Tracer	EEC-SFI-MAF/EDIS
2.2L	Probe (Mazda)	MECS-MFI
2.2L Turbo	Probe GT (Mazda)	MECS-MFI
2.3L OHC	Mustang	EEC-MFI-MAF/DPDIS
2.3L HSC	Tempo / Topaz	MFI
2.5L HSC	Taurus	SFI-MAF+AXODE
3.0L	Probe	MFI
3.0L	Taurus / Sable	SFI-MAF+AXODE
3.0L SHO	Taurus	SFI-MAF/DIS
3.8L SC	T'Bird	SFI-MAF/DIS
3.8L	T'Bird / Cougar	SFI-MAF
3.8L	Continental, Taurus / Sable	SFI-MAF+AXODE
4.6L	Lincoln Town Car	SFI-MAF/EDIS
5.0L	Crown Victoria / Grand Marquis	SFI
5.0L HO	T'Bird / Cougar, Mustang	SFI-MAF
5.0L	Mark VII	SFI
1991 Light Trucks		
2.3L OHC	Ranger	SFI-MAF/DIS-DP
2.9L	Ranger	MFI
3.0L	Aerostar	MFI-MAF
4.0L	Aerostar / Explorer / Ranger	MFI-MAF/EDIS
4.9L	E/F-Series, Bronco	MFI
5.0L	E/F-Series, Bronco	MFI
5.8L	E/F-Series, Bronco	MFI

Table b. Applications (continued)

Engine family	Model	Engine control system and fuel injection type
1990 Passenger Cars		
1.3L	Festiva A/T (Mazda)	MECS-MFI
1.9L	Escort	MFI-MAF
1.9L HO	Escort	MFI
2.2L	Probe (Mazda)	MECS-MFI
2.2L Turbo	Probe GT (Mazda)	MECS-MFI
2.3L OHC	Mustang	MFI (MAF in CA)
2.3L HSC	Tempo / Topaz	MFI
2.5L HSC	Taurus	CFI
3.0L	Probe	MFI
3.0L	Taurus / Sable	MFI
3.0L SHO	Taurus	SFI-MAF/DIS
3.8L	T'Bird / Cougar	SFI
3.8L	Continental, Taurus / Sable	SFI
5.0L	Lincoln Town Car	SFI
5.0L	Crown Victoria / Grand Marquis	SFI (MAF in CA sedans)
5.0L HO	Mustang	SFI-MAF
5.0L	Mark VII	SFI
1990 Light Trucks		
2.3LOHC	Ranger	MFI/DIS
2.9L	Ranger / Bronco II	MFI-MAF/EDIS
3.0L	Aerostar	MFI
4.0L	Aerostar / Explorer / Ranger	MFI-MAF/EDIS
4.9L	E/F-Series, Bronco	MFI
5.0L	E/F-Series, Bronco	MFI
5.8L	E/F-Series, Bronco	MFI

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Table b. Applications (continued)

Engine family	Model	Engine control system and fuel injection type
1989 Passenger Cars		
1.6L	Tracer (Mazda)	MECS-MFI
1.9L HO	Escort	MFI
2.2L	Probe (Mazda)	MECS-MFI
2.2L Turbo	Probe GT (Mazda)	MECS-MFI
2.3L OHC	Mustang	MFI
2.3L OHC Turbo	Merkur	MFI
2.3L HSC	Tempo / Topaz	MFI
2.3L HSO+	Tempo / Topaz 4wd	MFI
2.5L HSC	Taurus	CFI
3.0L	Taurus	MFI
3.0L SHO	Taurus	SFI-MAF/DIS
3.8L SC	T'Bird / Cougar	SFI-MAF/DIS
3.8L	T'Bird / Cougar; Cont; Taurus / Sable	SFI
5.0L	Crown Victoria / Grand Marquis, Town Car	SFI
5.0L HO	Mustang	SFI-MAF
5.0L HO	Mark VII	SFI
1989 Light Trucks		
2.3L OHC	Ranger	MFI-DIS
2.9L	Ranger / Bronco II	MFI
3.0L	Aerostar	MFI
4.9L	E/F-Series, Bronco	MFI
5.0L	E/F-Series, Bronco	MFI
5.8L	E/F-Series Bronco	MFI

Table b. Applications (continued)

Engine family	Model	Engine control system and fuel injection type
1988 Passenger Cars		
1.6L	Tracer (Mazda)	MECS-MFI
1.9L	Escort	CFI
1.9L HO	Escort	MFI
2.2L	Probe (Mazda)	MECS-MFI
2.2L GT	Probe (Mazda)	MECS-MFI
2.3LOHC	Mustang	MFI
2.3L Turbo	Mustang, Merkur	MFI
2.3L HSC	Tempo / Topaz	CFI
2.3L HSO+	Tempo / Topaz	CFI
2.5L HSC	Taurus	CFI
3.0L	Taurus	MFI
3.8L	T'Bird / Cougar	MFI
3.8L	Continental, Taurus / Sable	MFI
5.0L	Cr own Vic / Grand Marquis, Town Car	SFI
5.0L HO	Mustang	SFI-MAF
5.0L	Mark VII	SFI
1988 Light Trucks		
2.3LOHC	Ranger	MFI
2.9L	Ranger / Bronco II	MFI
3.0L	Aerostar	MFI
4.9L	E/F-Series, Bronco	MFI
5.0L	E/F-Series, Bronco	MFI
5.8L	E/F-Series, Bronco	MFI