Air Fuel Control

The Stoichiometric mixture of 14.7:1 is critical to emission control.

14.7 grams of Air mixed with 1 gram of Gasoline creates the most efficient air/fuel ratio (for the catalyst)

The Stoichiometric mixture is critical for the catalytic converter to operate efficiently to reduce Hydrocarbons (HC) and Carbon Monoxide (CO)

Air Fuel Control

The PCM will sense how much air enters the engine and match it with the proper amount of fuel.

The oxygen sensor will report to the computer if the air/fuel mixture is too Rich or too Lean.

The PCM will “Trim” how much fuel is added by turning on the fuel injectors for a longer or shorter amount of time.

Air Fuel Control

Using a scan tool you can monitor “Fuel Trim” .

Fuel trim is displayed in % (percentage)

Numbers close to 0% mean the computer is sensing the proper amount of air entering the engine and adding the proper amount of fuel.

Air Fuel Control

Positive fuel trim means the oxygen sensor is reporting too much oxygen in the exhaust.

To correct this the PCM will add extra fuel.

A fuel trim of 10% means the PCM has to add 10% MORE fuel to keep the stoichiometric mixture of 14.7 grams of air to 1 gram of fuel.

Air Fuel Control

A fuel trim of -10% means the PCM has to add 10% LESS fuel to keep the stoichiometric mixture of 14.7 grams of air to 1 gram of fuel.

Fuel trim numbers over 10% or under -10% should be investigated to ensure all sensors are accurate, fuel pressure is correct, and injectors are not leaking or plugged.

Base Fuel Control

The PCM calculates all fuel quantities based on a specific fuel pressure

The Fuel pressure regulator must be accurate to ensure proper fuel trim and fuel control.

The PCM will only monitor fuel pressure on the newest fuel injection systems.

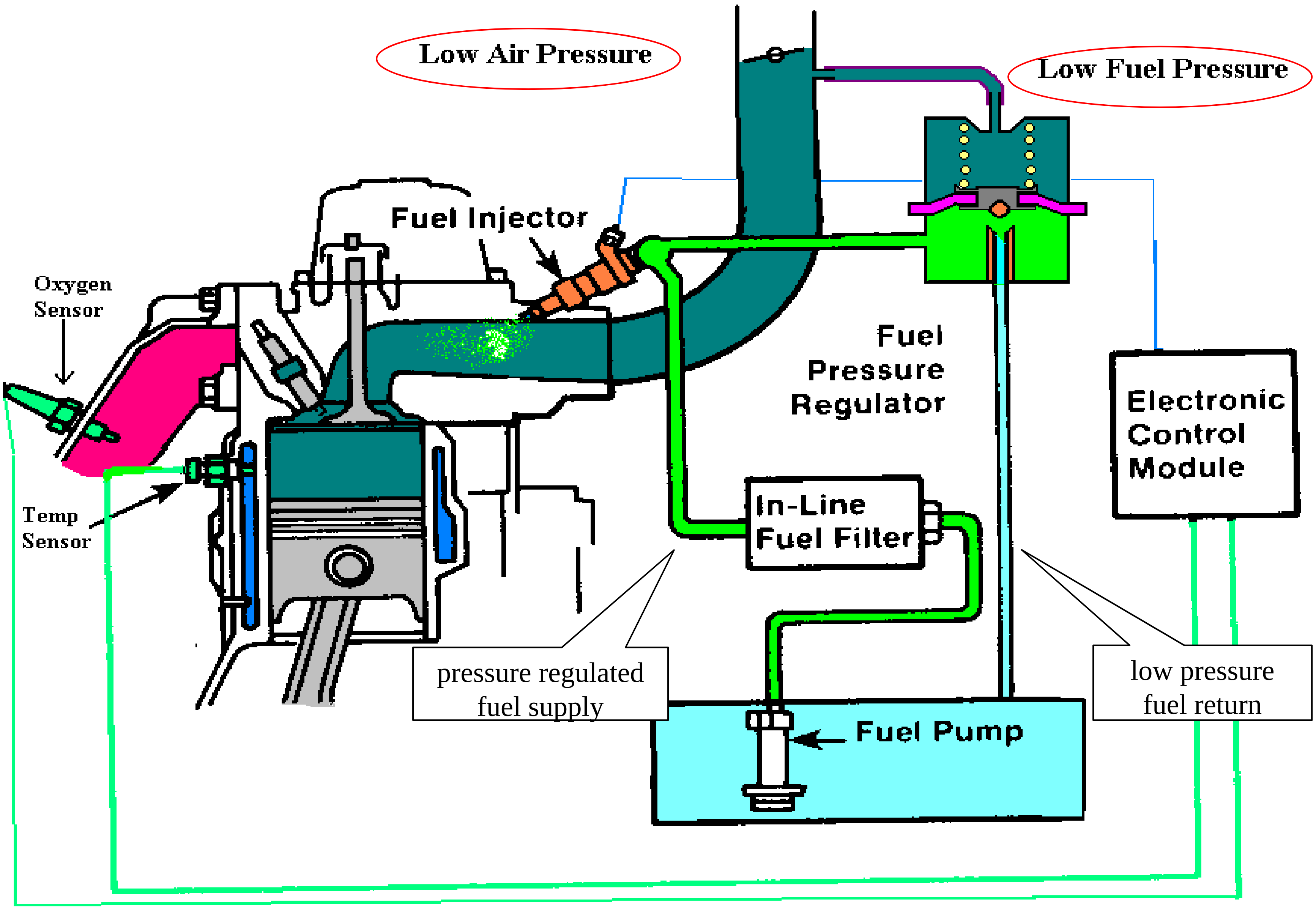
Base Fuel Control

Fuel pressure that is too high = too rich
(fuel trim under -10%)

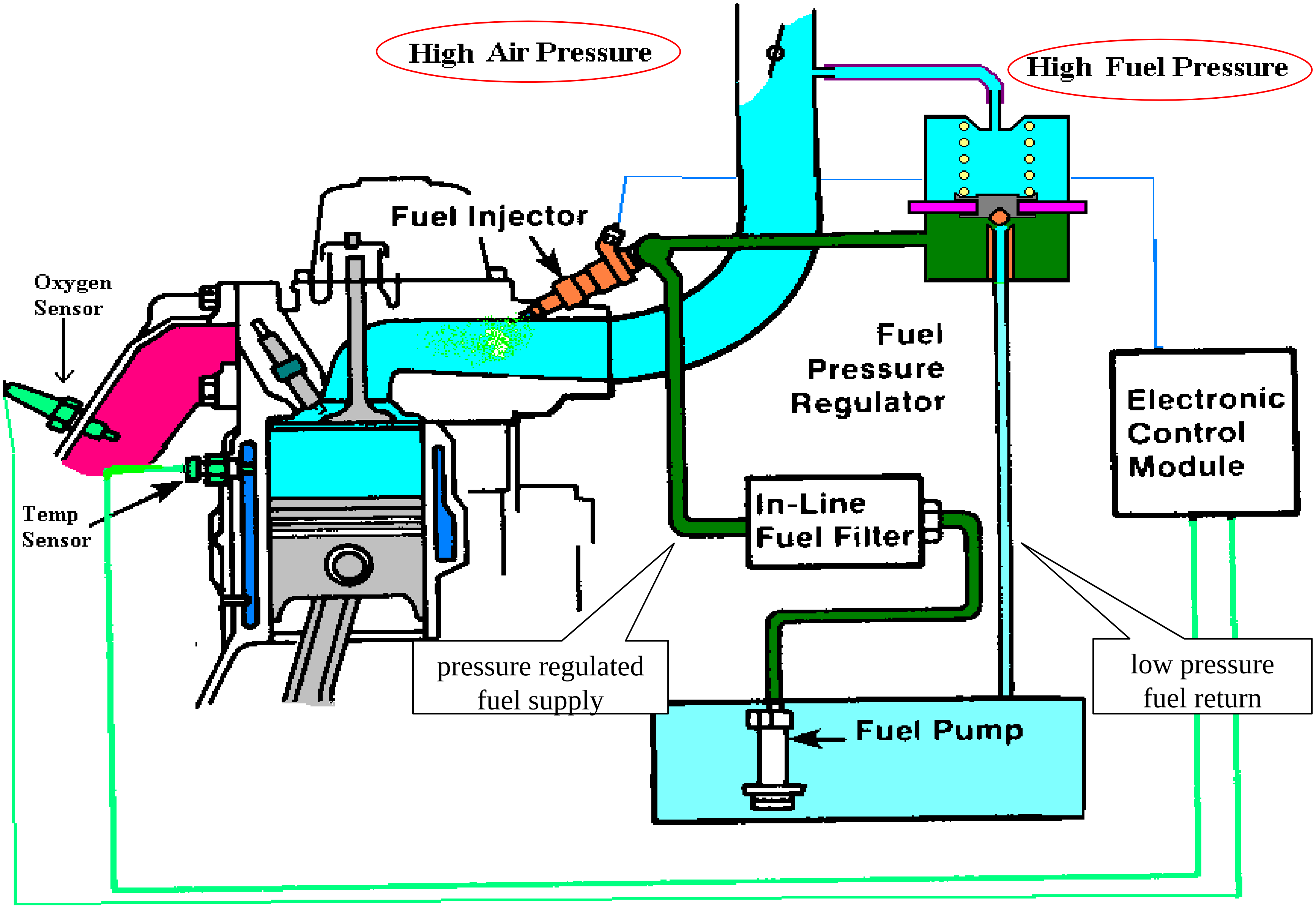
Fuel pressure that is too low = too lean
(fuel trim over 10%)

Correct fuel pressure is required for fuel trim to maintain the Stoichiometric air/fuel ratio

Vacuum controlled Fuel Pressure Regulator



Vacuum controlled Fuel Pressure Regulator



Check Fuel Pressure

Test fuel pressure with No Vacuum to the fuel pressure regulator

AND

Test Fuel Pressure with 20” vacuum applied to the fuel pressure regulator

There should be 10 PSI difference

Fuel Filters

Restricted fuel filters may allow proper fuel pressure

With LOW fuel volume.

This will cause engine to run lean

Especially under load

Replacing Fuel Filters

Fuel filters are often under about 60 psi even when the engine is OFF!

Be sure to relieve all fuel pressure before replacing fuel filters

Be sure to pressurize and carefully check for leaks at filter any time you have removed or replaced it.

Types of Fuel Injection

CIS

Continuous Fuel Injection

(very old German cars)

TBI

Throttle Body Injection

(early style of Electronic Fuel Injection)

PFI

Port Fuel Injection

(Can be Group Fired or Sequential)

CIS
Continuous Injection System

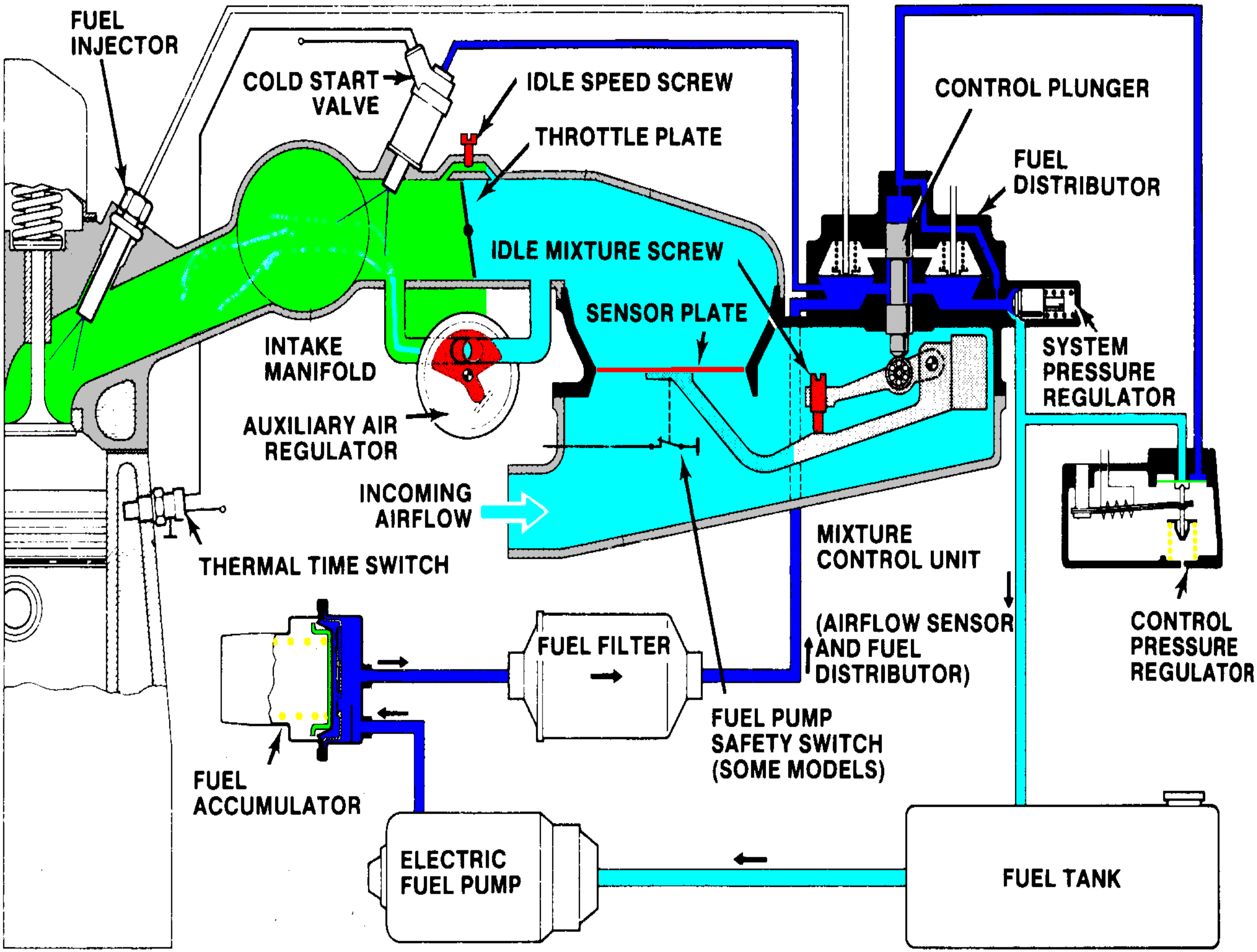
Used by European (Robert Bosh) vehicles

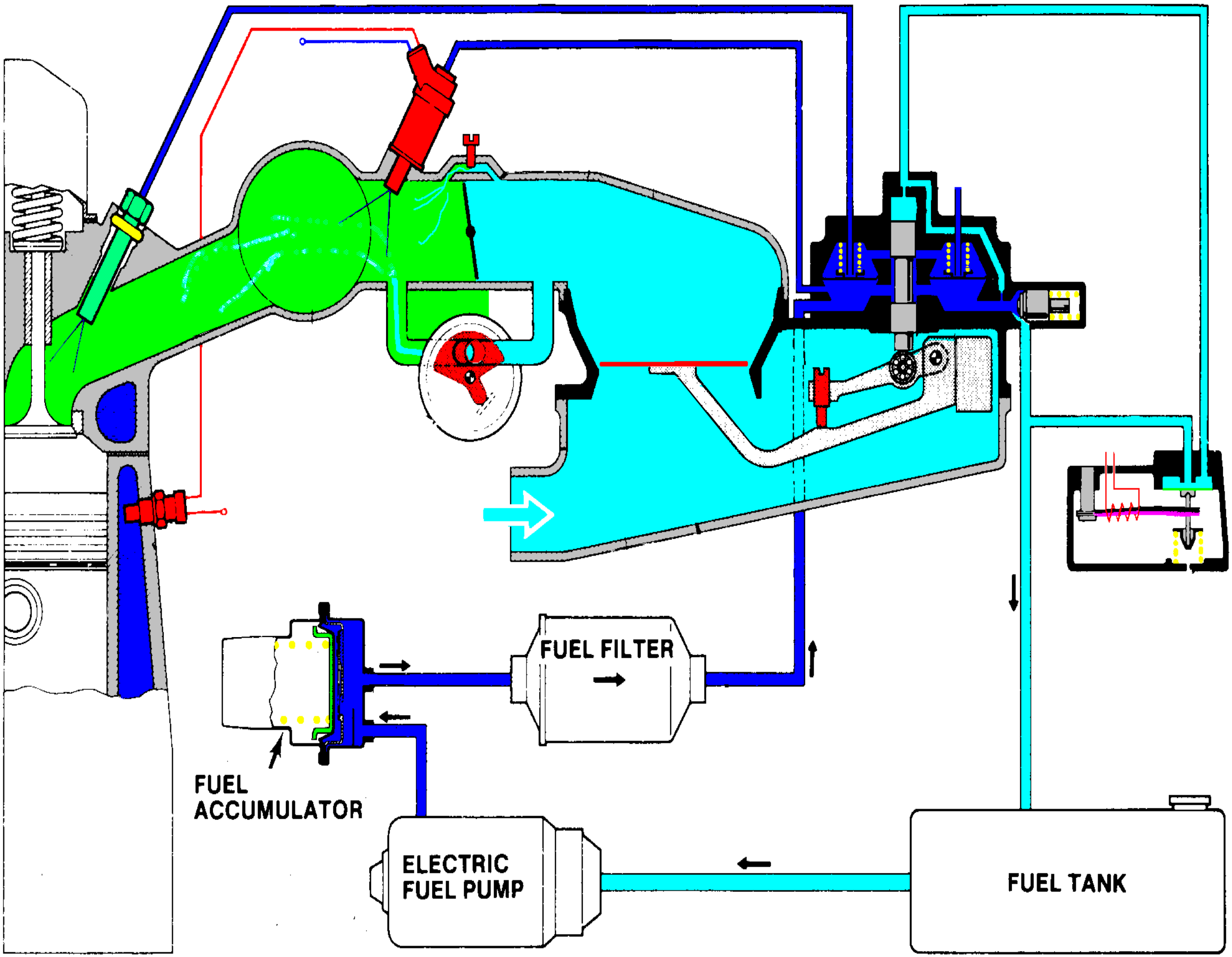
May be mechanical or computer controlled

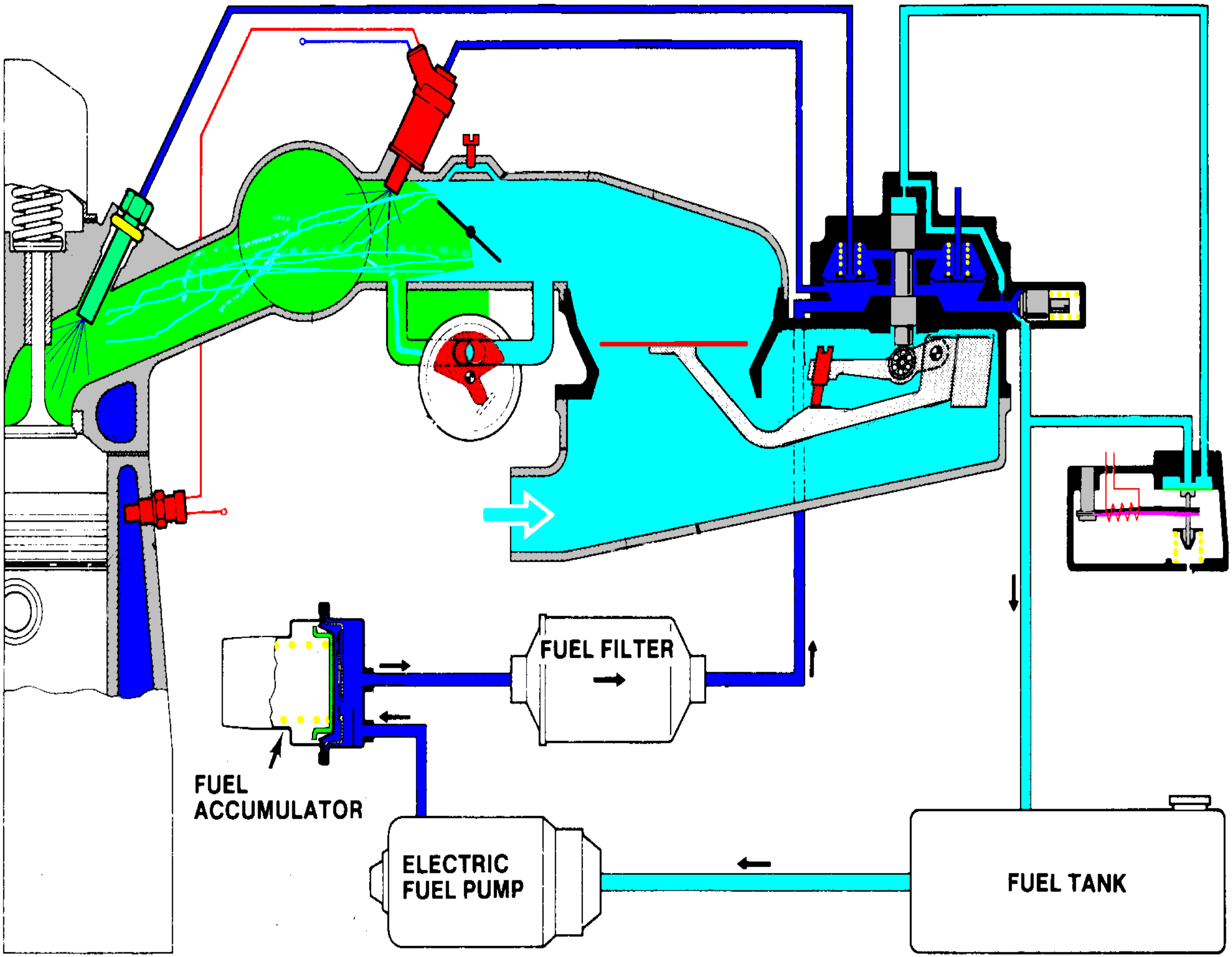
Constantly injects fuel at each intake port.

Fuel pressure regulated by mechanical intake air sensing plate.

More air = More Fuel Pressure


FUEL INJECTOR
COLD START VALVE
IDLE SPEED SCREW
THROTTLE PLATE
CONTROL PLUNGER
FUEL DISTRIBUTOR
IDLE MIXTURE SCREW
SENSOR PLATE
INTAKE MANIFOLD
SYSTEM PRESSURE REGULATOR
AUXILIARY AIR REGULATOR
INCOMING AIRFLOW
THERMAL TIME SWITCH
MIXTURE CONTROL UNIT
(AIRFLOW SENSOR AND FUEL DISTRIBUTOR)
CONTROL PRESSURE REGULATOR
FUEL FILTER
FUEL PUMP SAFETY SWITCH (SOME MODELS)
FUEL ACCUMULATOR
ELECTRIC FUEL PUMP
FUEL TANK


FUEL FILTER
FUEL ACCUMULATOR
ELECTRIC FUEL PUMP
FUEL TANK


FUEL FILTER
FUEL ACCUMULATOR
ELECTRIC FUEL PUMP
FUEL TANK

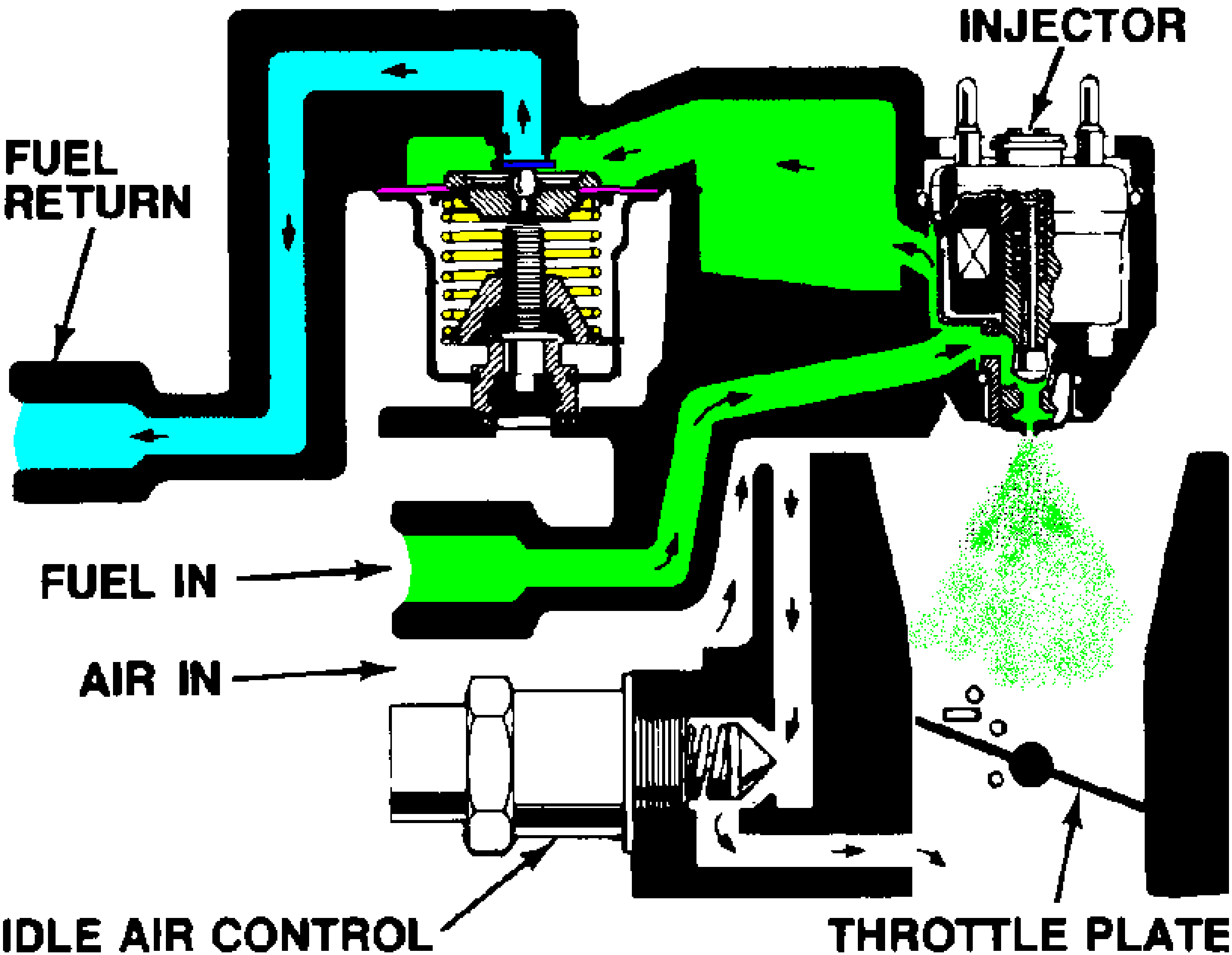
TBI
Throttle Body Injection

Fuel is injected above the throttle plate

PCM turns injectors on and off

More fuel is added by leaving injector on longer

All PCM calculations <u>assume</u> correct fuel pressure

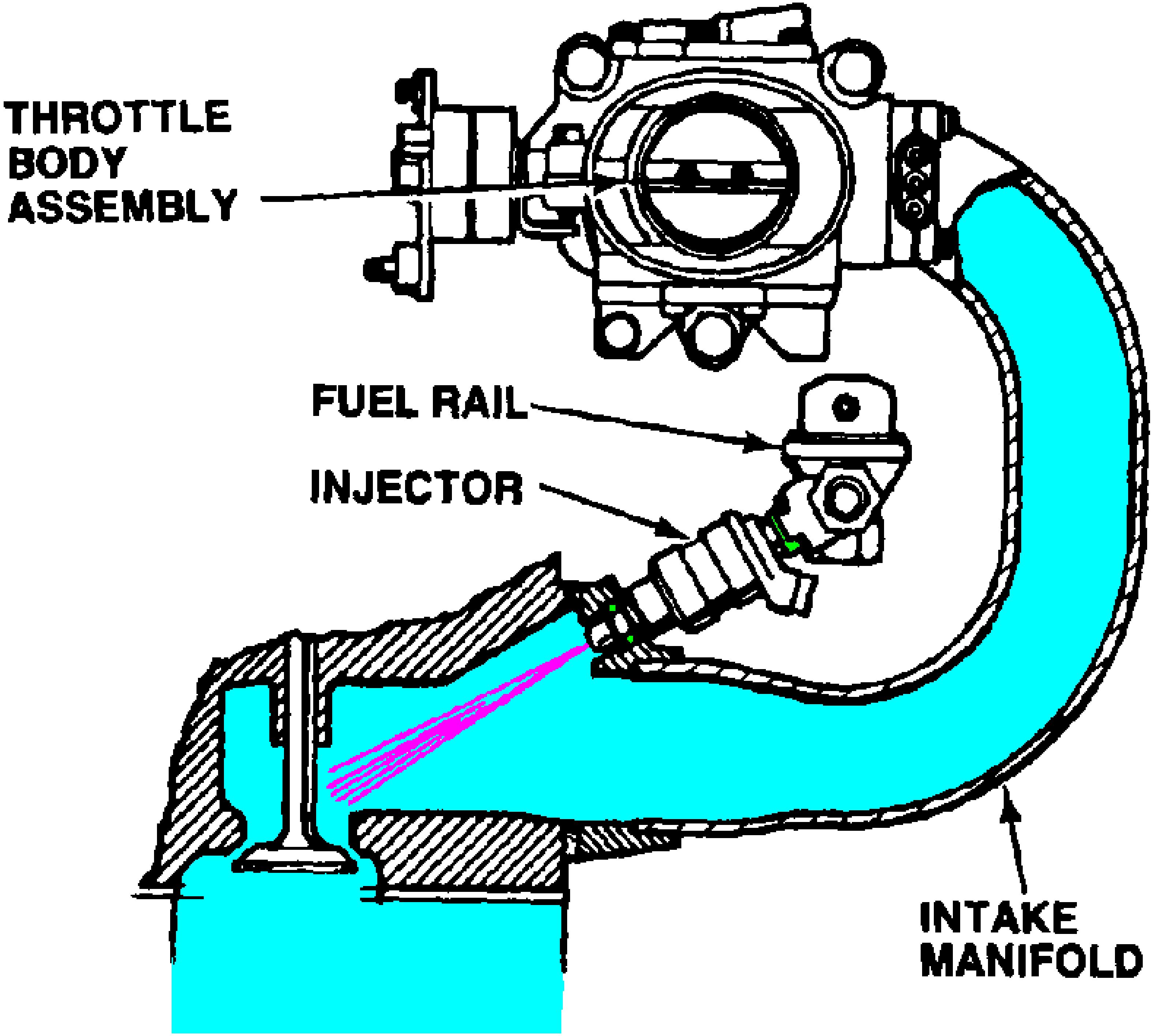

INJECTOR
FUEL RETURN
FUEL IN
AIR IN
IDLE AIR CONTROL
THROTTLE PLATE

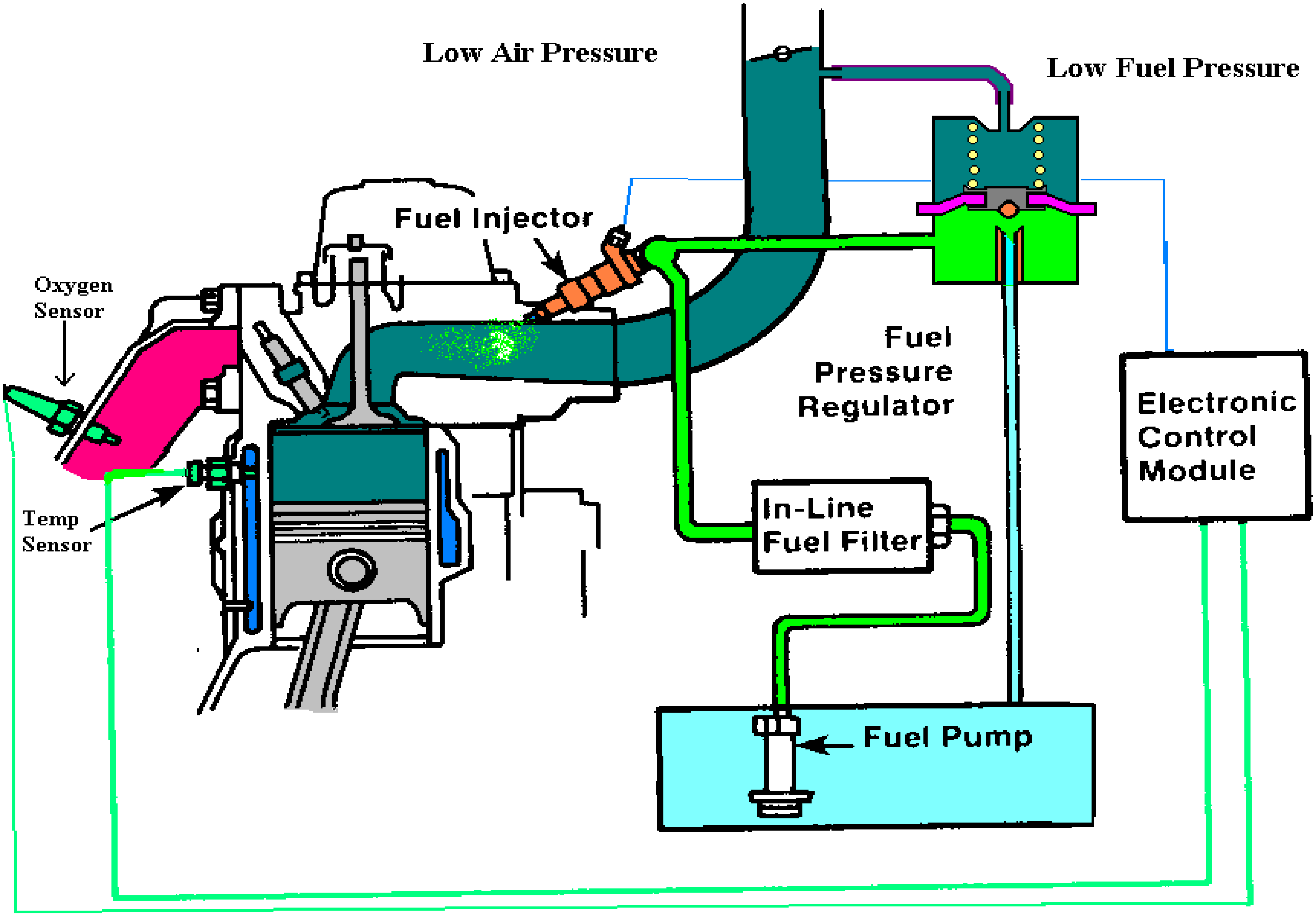
PFI
Port Fuel Injection

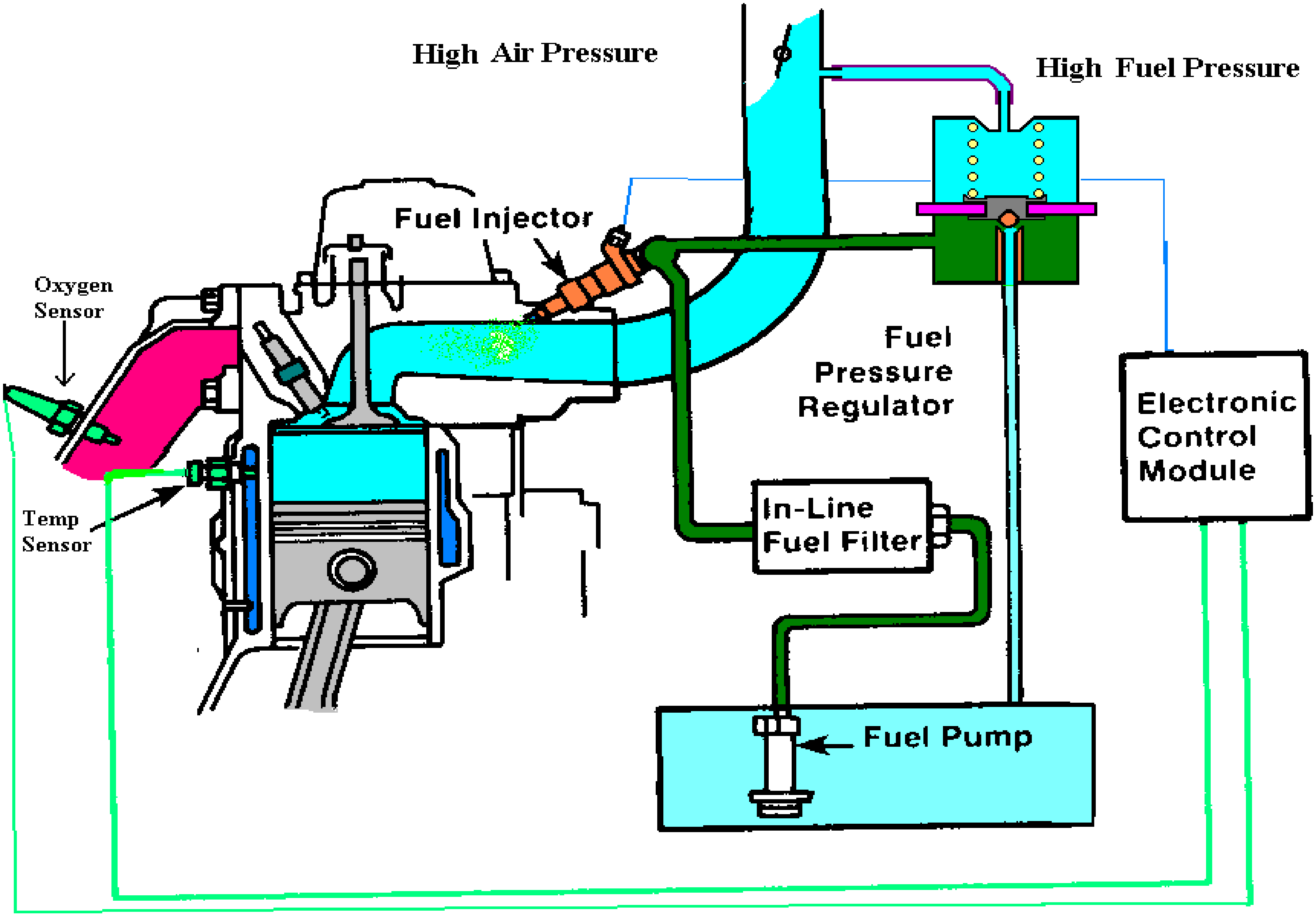
One fuel injector for each cylinder

Fuel pressure regulator keeps the quantity of injected fuel constant

All PCM calculations <u>assume</u> correct fuel pressure


THROTTLE
BODY
ASSEMBLY
FUEL RAIL
INJECTOR
INTAKE
MANIFOLD


Low Air Pressure
Low Fuel Pressure
Fuel Injector
Oxygen Sensor
Temp Sensor
Fuel Pressure Regulator
Electronic Control Module
In-Line Fuel Filter
Fuel Pump



High Air Pressure
High Fuel Pressure
Fuel Injector
Oxygen Sensor
Temp Sensor
Fuel Pressure Regulator
Electronic Control Module
In-Line Fuel Filter
Fuel Pump

Port Fuel Injection

Injectors can be fired once per engine cycle

Single Fire

Injectors may be fired twice per engine cycle

Double Fire

Injectors are fired simultaneous or in groups

Sequential fuel injection fires individual injectors just before each intake stroke

Basic Maintenance

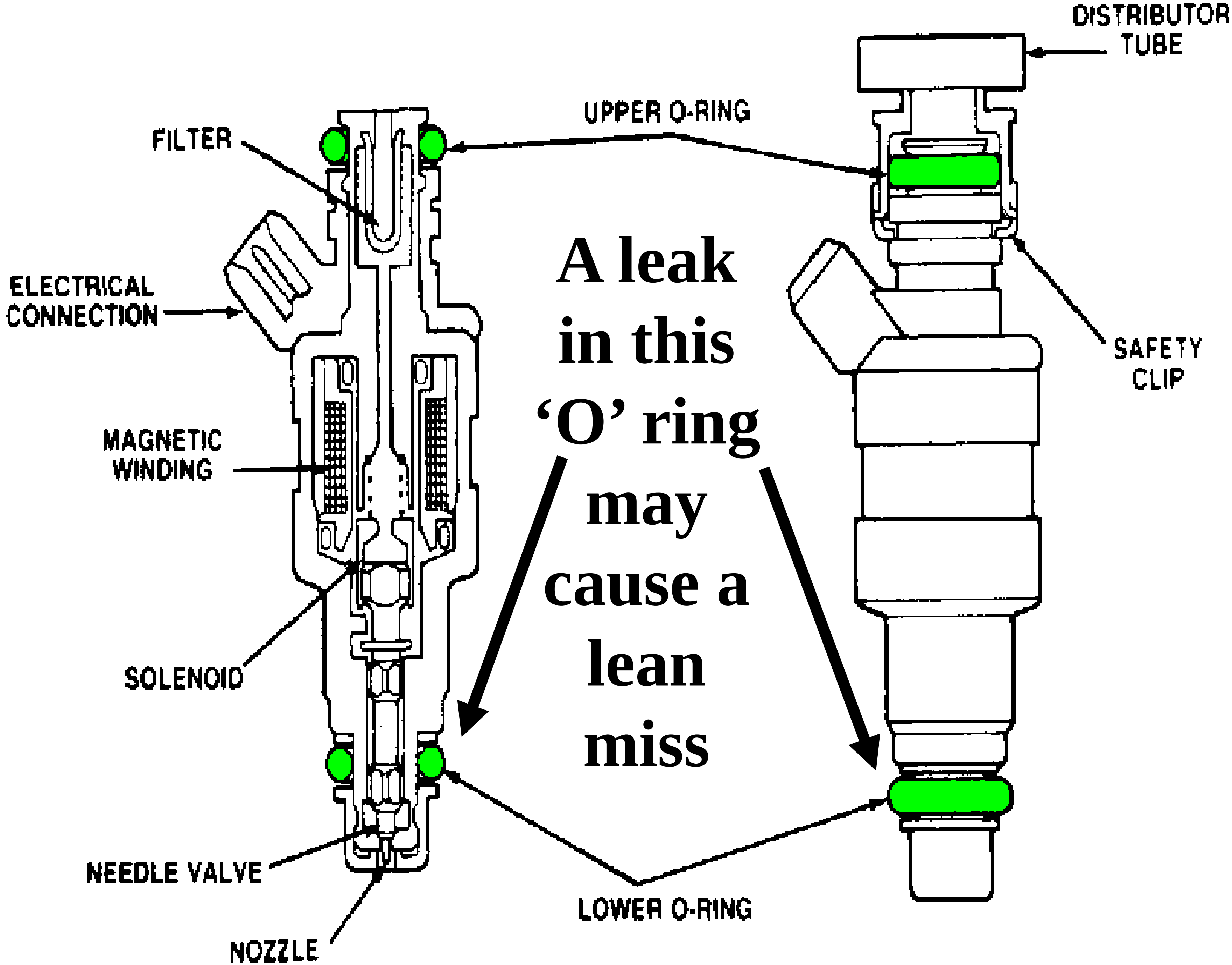
Injectors must be kept clean

Leaking ‘O’ rings can cause a lean misfire

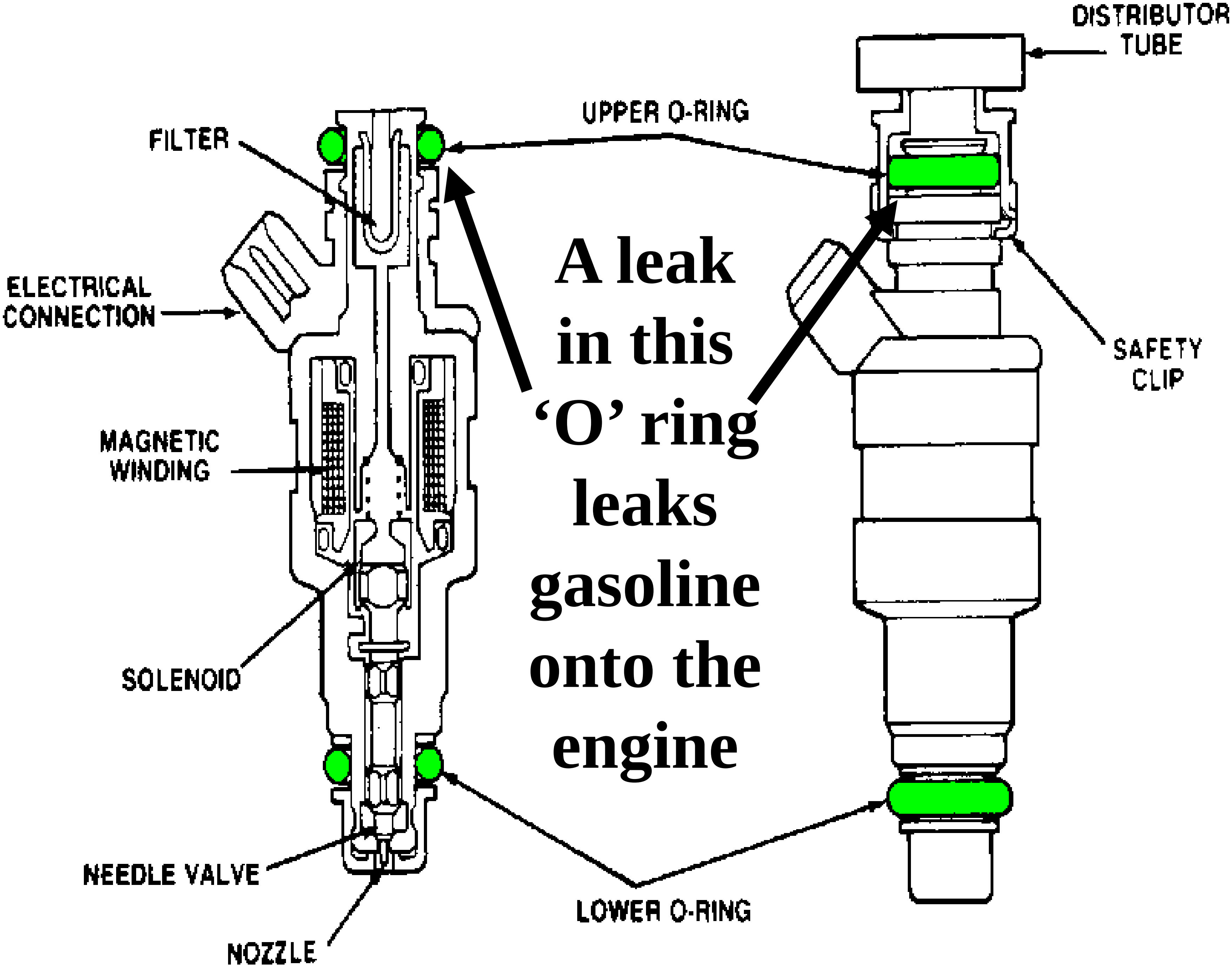
Or

Leaking ‘O’ rings can cause an external fuel leak

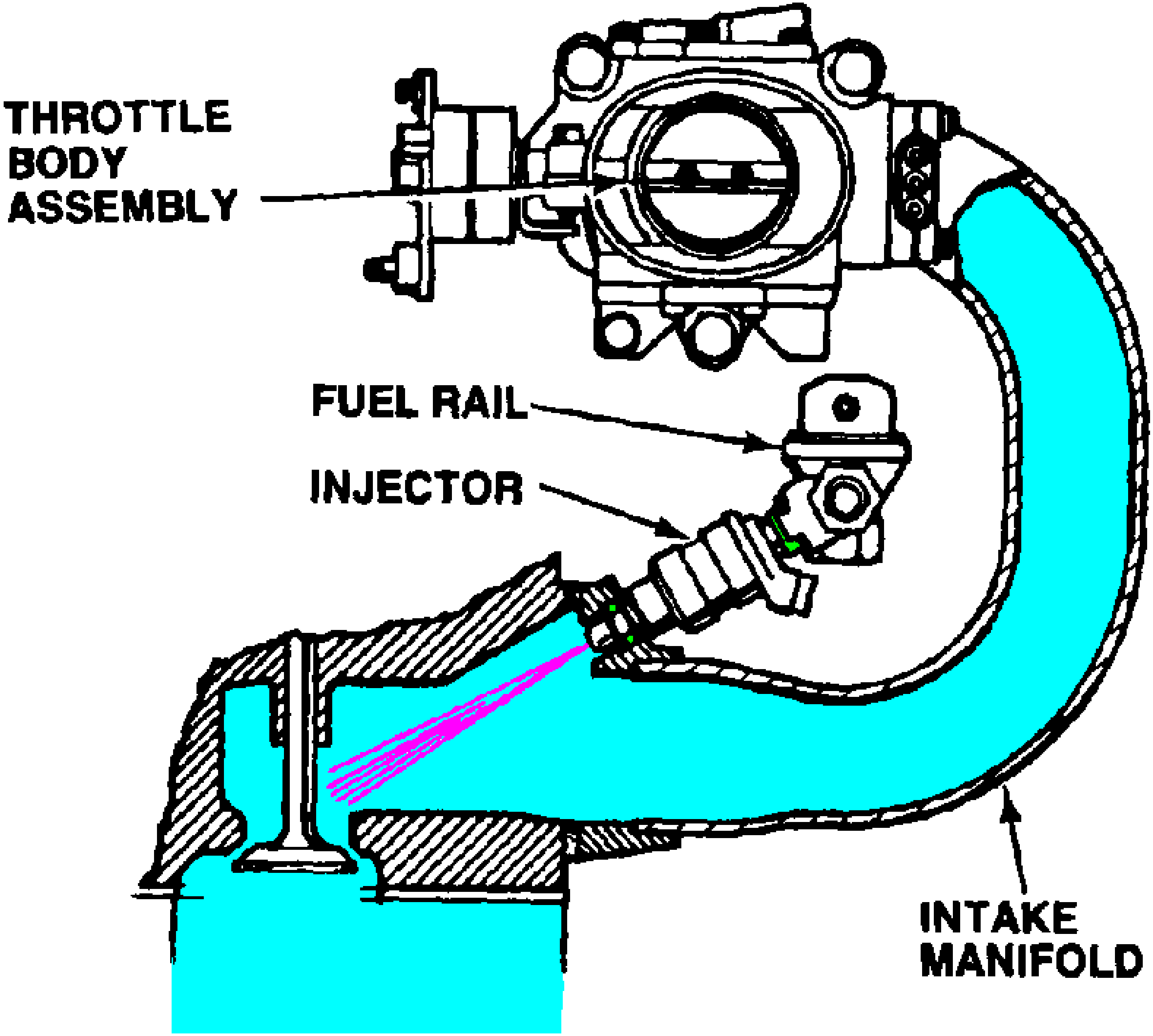
Shorted injector windings can burn out the PCM

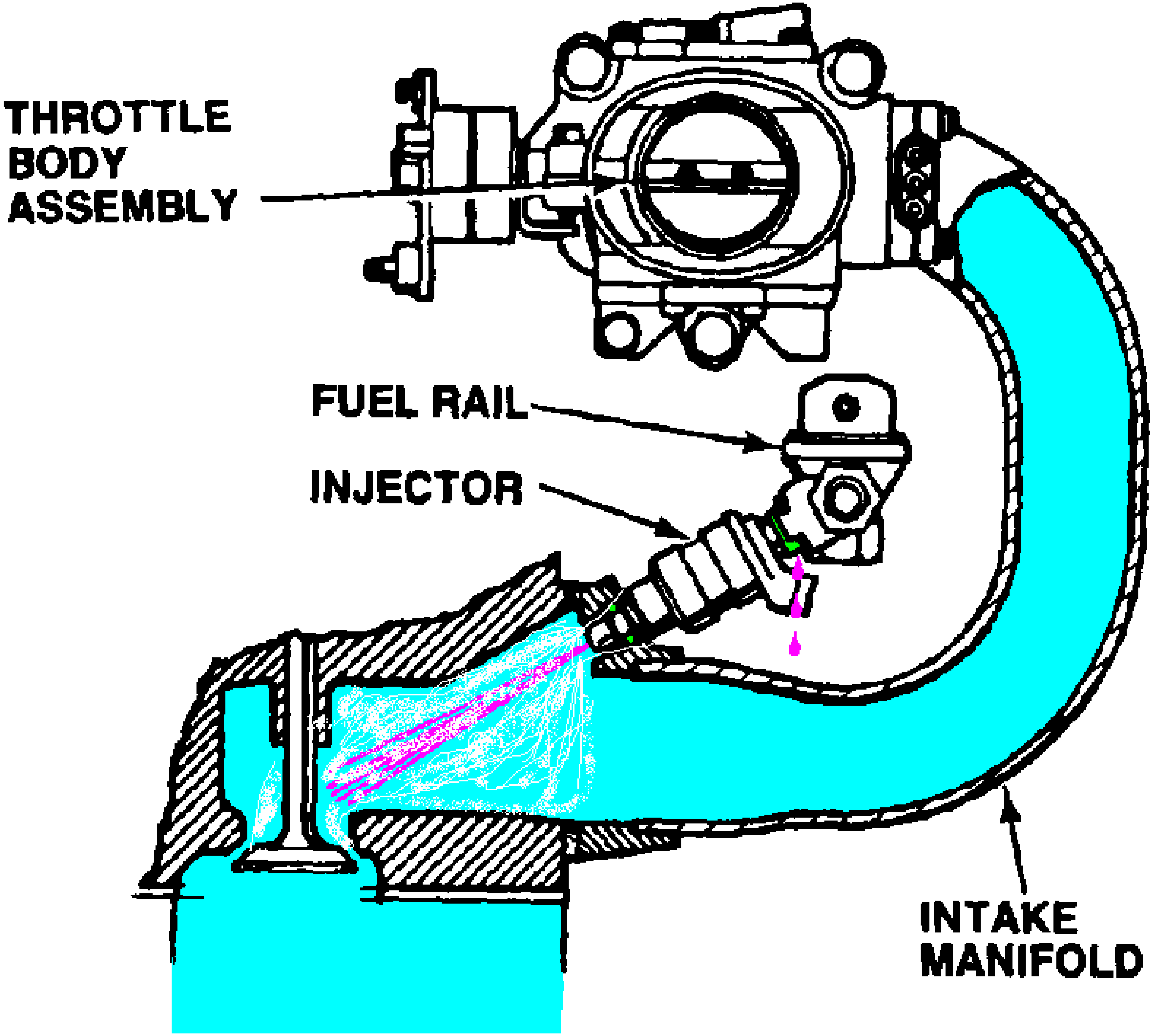


A leak
in this
‘O’ ring
may
cause a
lean
miss
DISTRIBUTOR
TUBE
UPPER O-RING
FILTER
ELECTRICAL
CONNECTION
MAGNETIC
WINDING
SOLENOID
NEEDLE VALVE
NOZZLE
LOWER O-RING
SAFETY
CLIP



DISTRIBUTOR TUBE
UPPER O-RING
FILTER
ELECTRICAL CONNECTION
SAFETY CLIP
MAGNETIC WINDING
SOLENOID
NEEDLE VALVE
NOZZLE
LOWER O-RING
A leak in this 'O' ring leaks gasoline onto the engine


THROTTLE
BODY
ASSEMBLY
FUEL RAIL
INJECTOR
INTAKE
MANIFOLD



THROTTLE BODY ASSEMBLY
FUEL RAIL
INJECTOR
INTAKE MANIFOLD

Cold Enrichment

Why do cold engines need riches mixture?

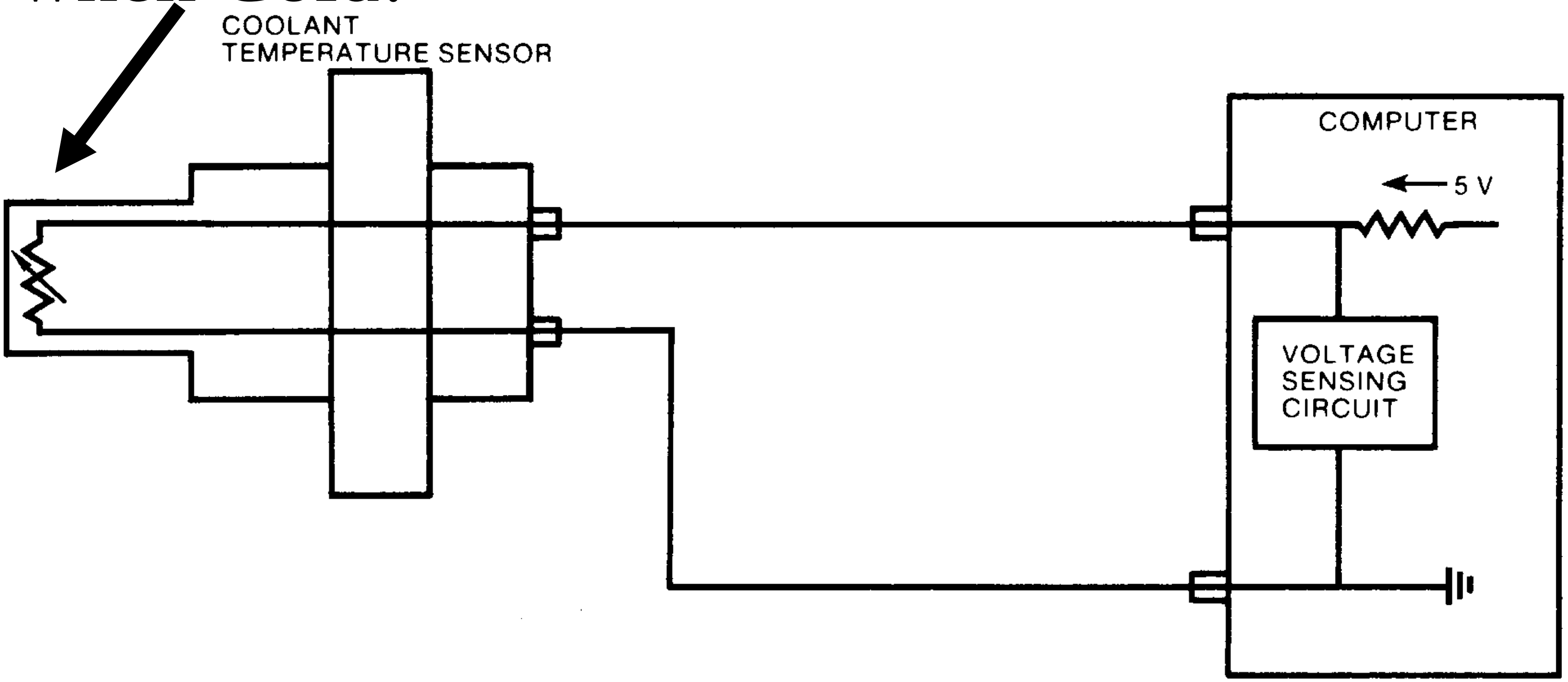
Less fuel will vaporize

What sensor is used to enrich cold engines?

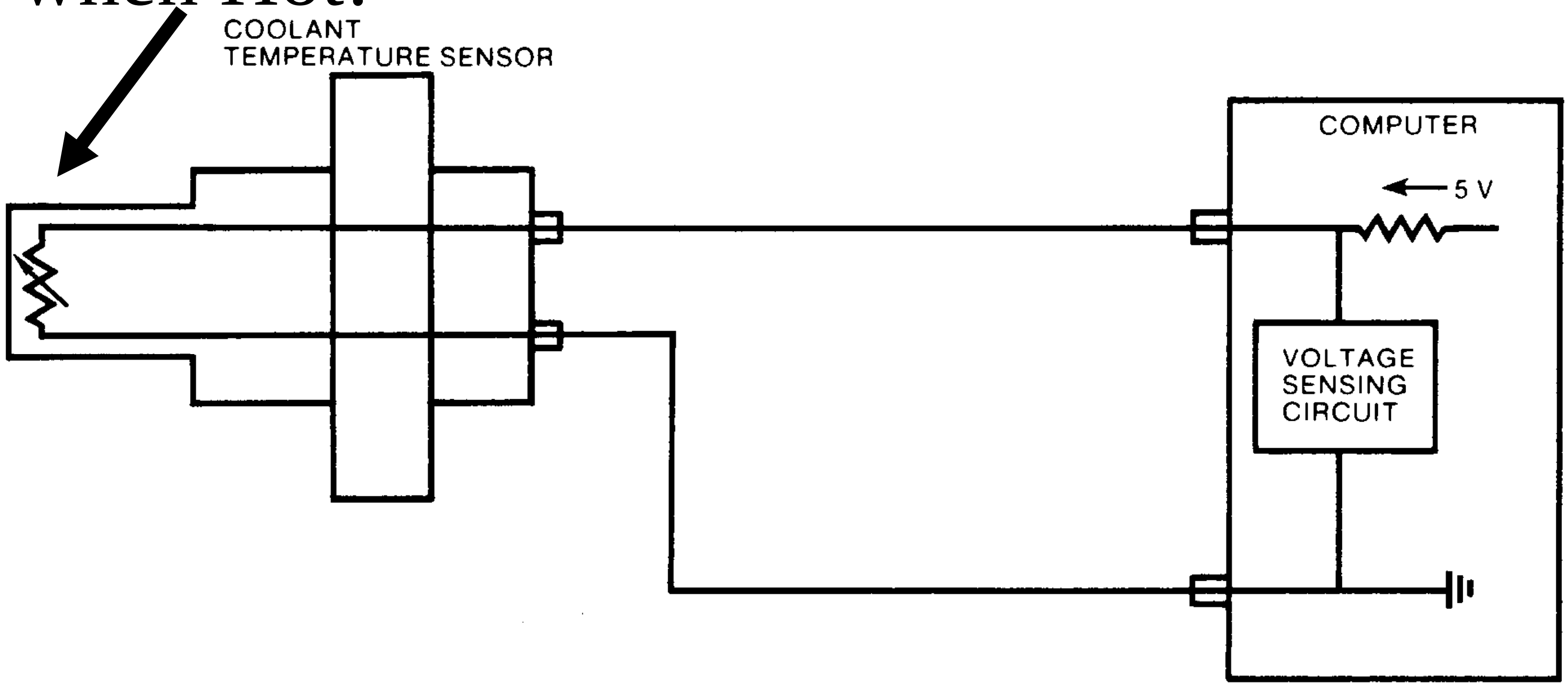
ECT

Engine Coolant Temperature sensor

High Resistance when Cold!



Low Resistance when Hot!



ECT

Most defects in the Engine Coolant Temperature sensing circuit make PCM think the engine is colder

This will cause a rich mixture

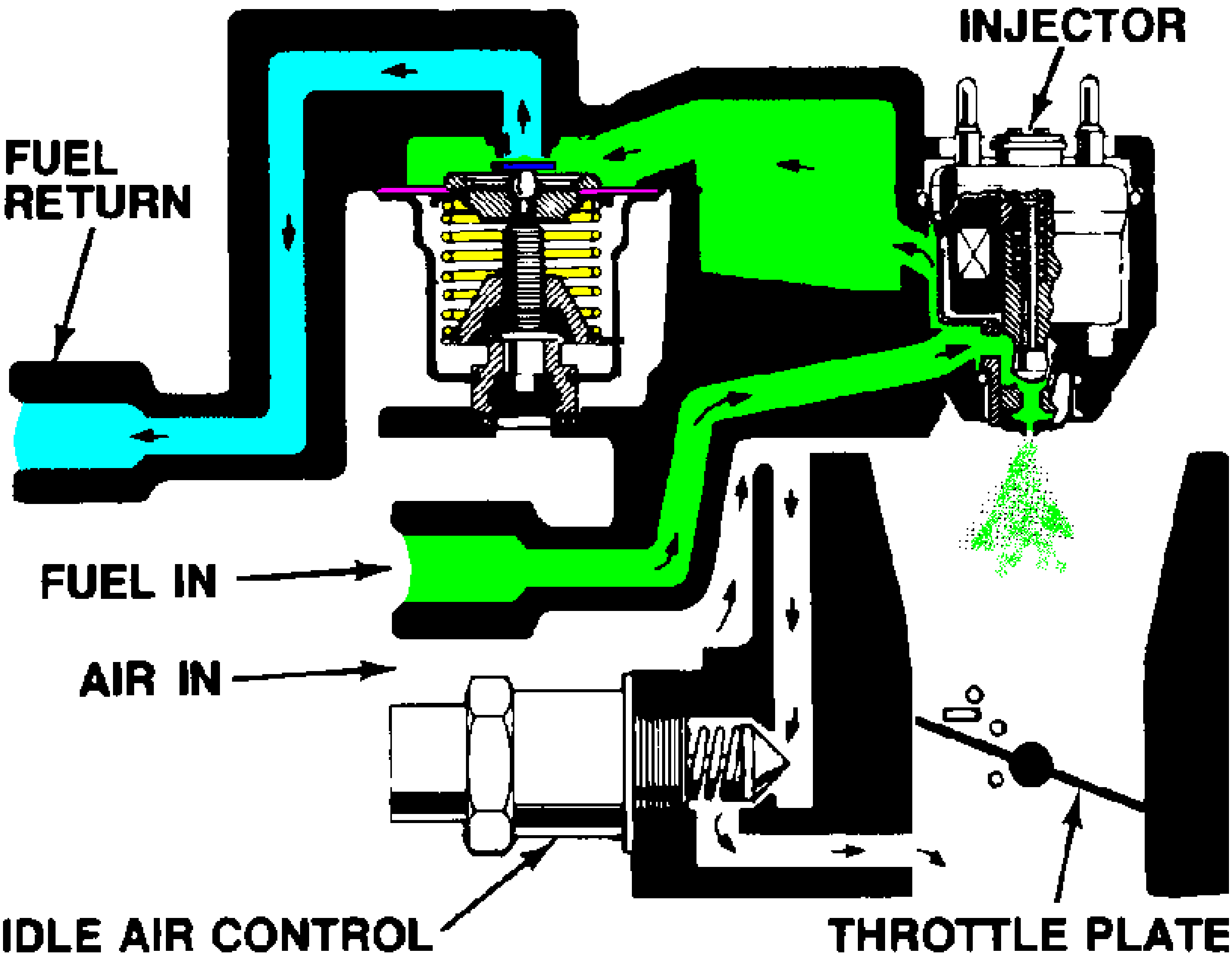
Compare actual temperature to scan tool data Using the ODB-II room!

Cold Idle

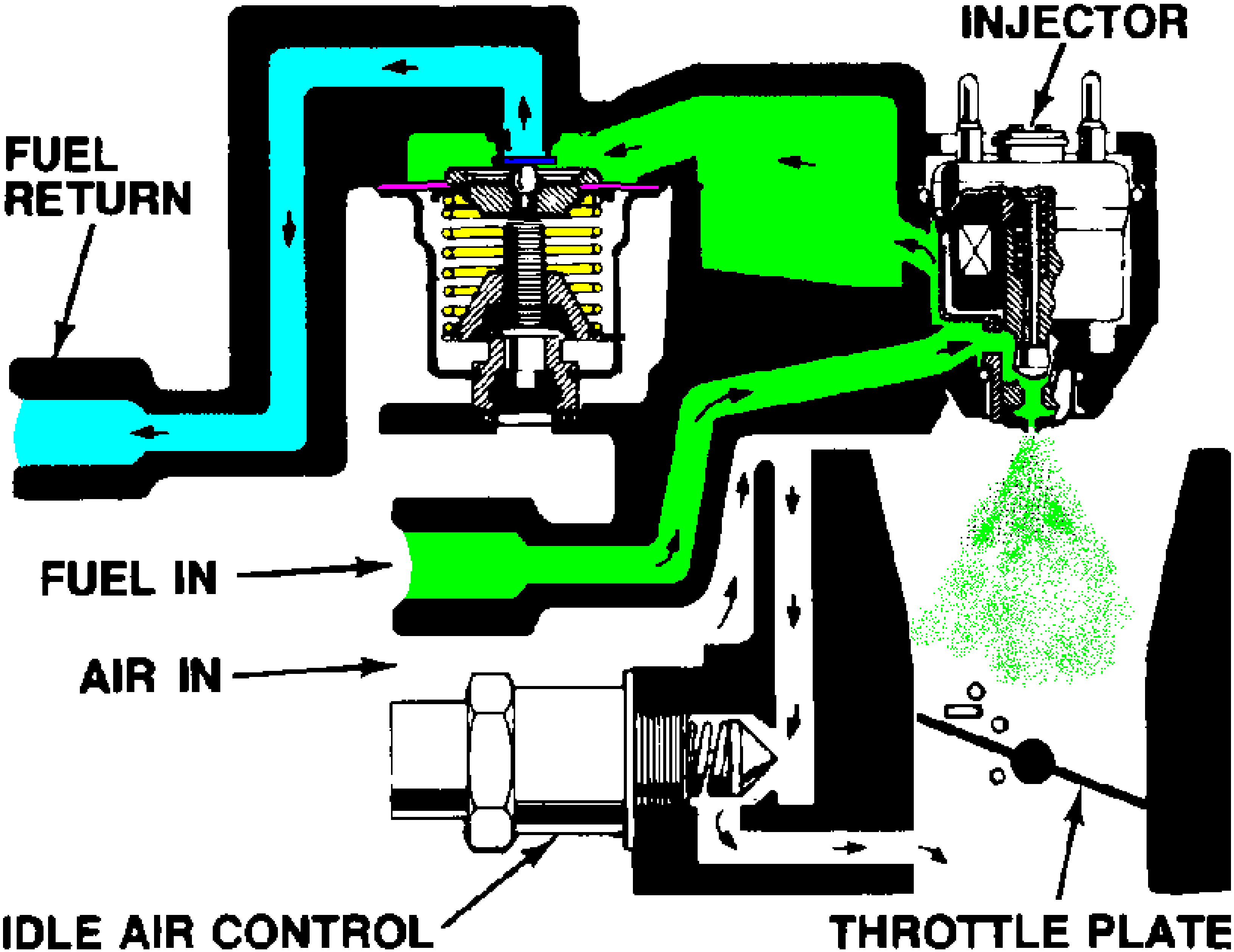
Cold engines idle at a higher RPM

This is achieved by an IAC

Idle Air Control



INJECTOR
FUEL RETURN
FUEL IN
AIR IN
IDLE AIR CONTROL
THROTTLE PLATE


INJECTOR
FUEL RETURN
FUEL IN
AIR IN
IDLE AIR CONTROL
THROTTLE PLATE

Idle Air Control

Many systems will open the IAC while the engine is cranking or starting.

This is why many engines have no measureable cranking vacuum

Main Fuel Metering

The Stoichiometric mixture of 14.7:1 is critical to emission control

PCM uses sensors measure the engine “load” to determine how much fuel to add

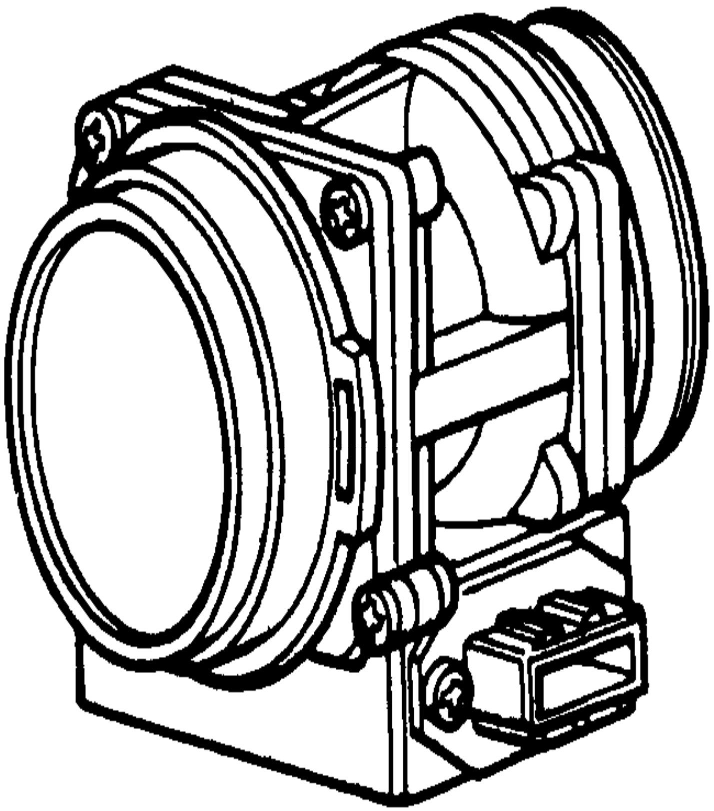
Load sensors are the MAF, the VAF, and the MAP sensors

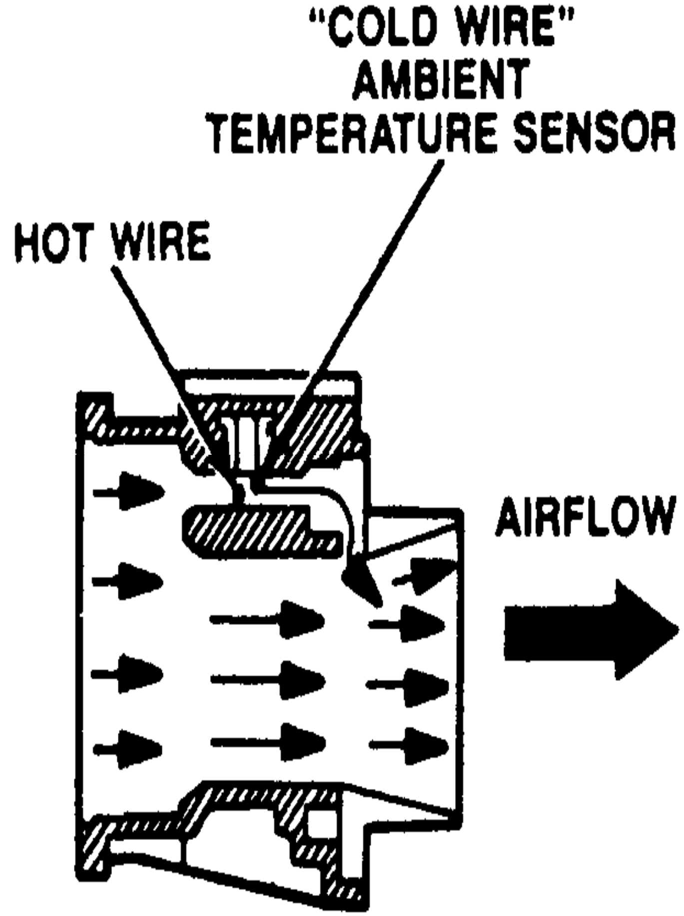
MAF
Mass Air Flow Sensor

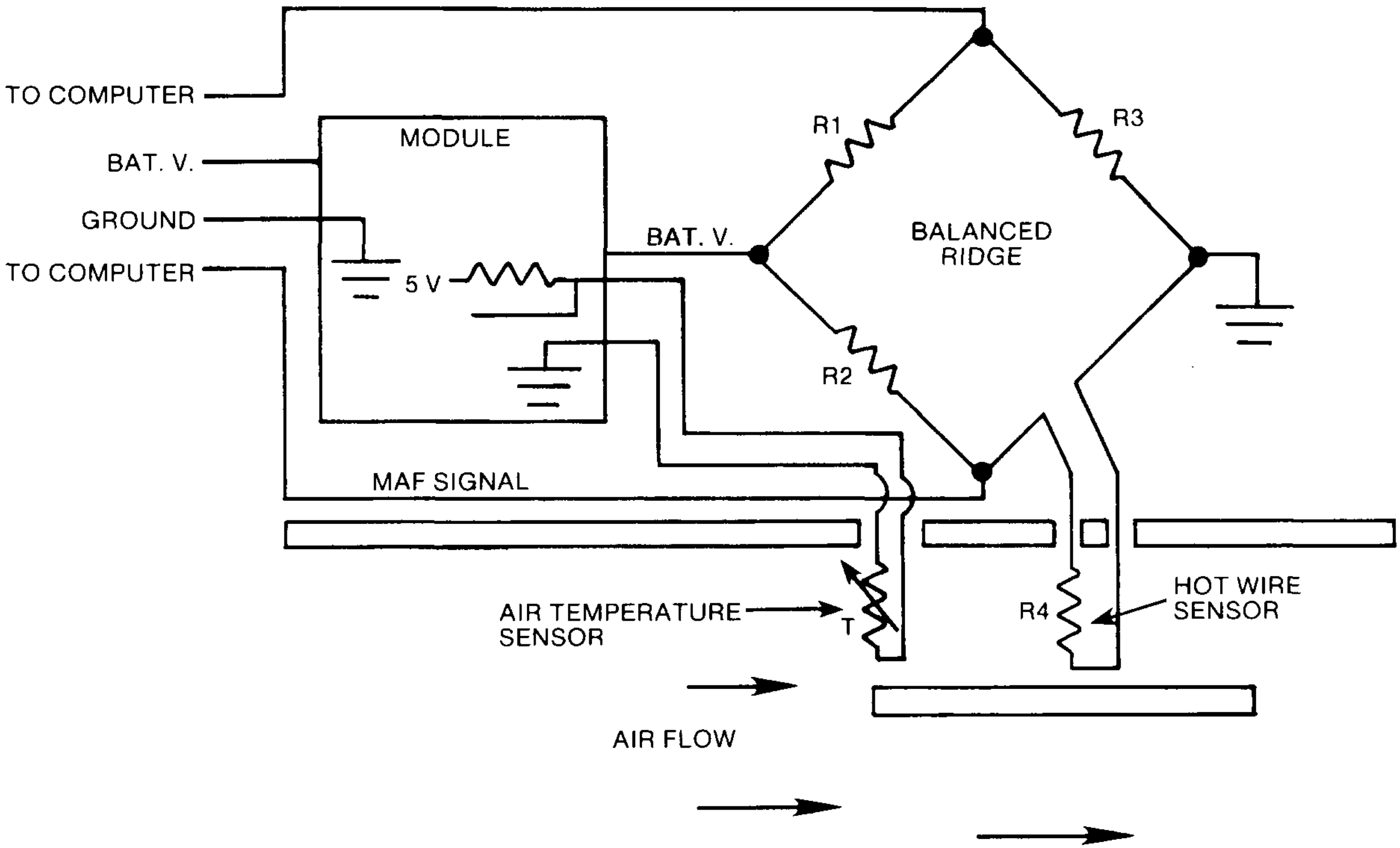
Measures volume, temperature and humidity of incoming air

Will be inaccurate if “hot wire” is dirty or contaminated

Will be inaccurate if there are any air leaks between the sensor and the intake valve.




"COLD WIRE"
AMBIENT
TEMPERATURE SENSOR
HOT WIRE
AIRFLOW

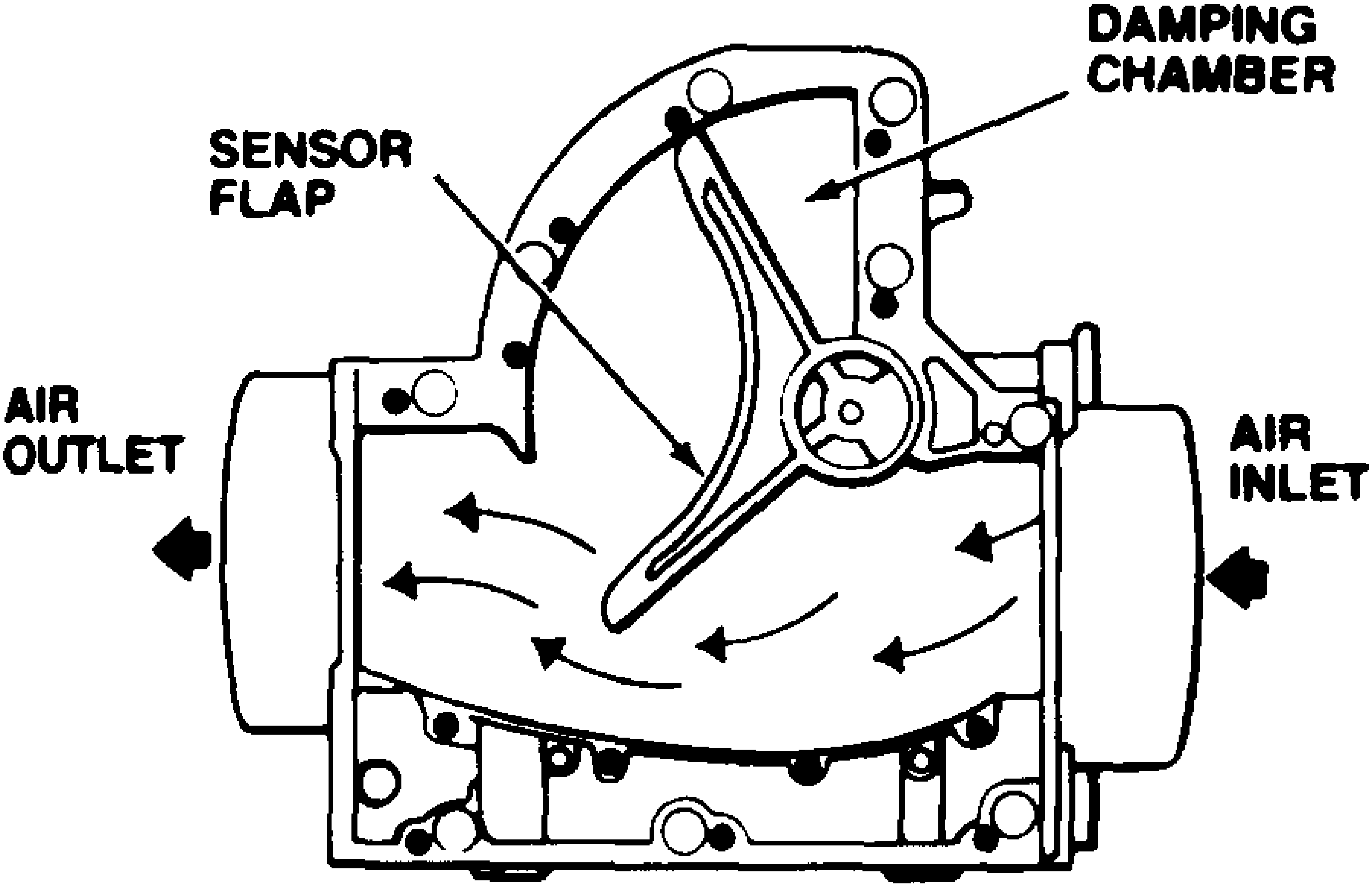

TO COMPUTER
BAT. V.
GROUND
TO COMPUTER
MODULE
5 V
BAT. V.
R1
R3
BALANCED
RIDGE
R2
MAF SIGNAL
AIR TEMPERATURE
SENSOR
T
R4
HOT WIRE
SENSOR
AIR FLOW

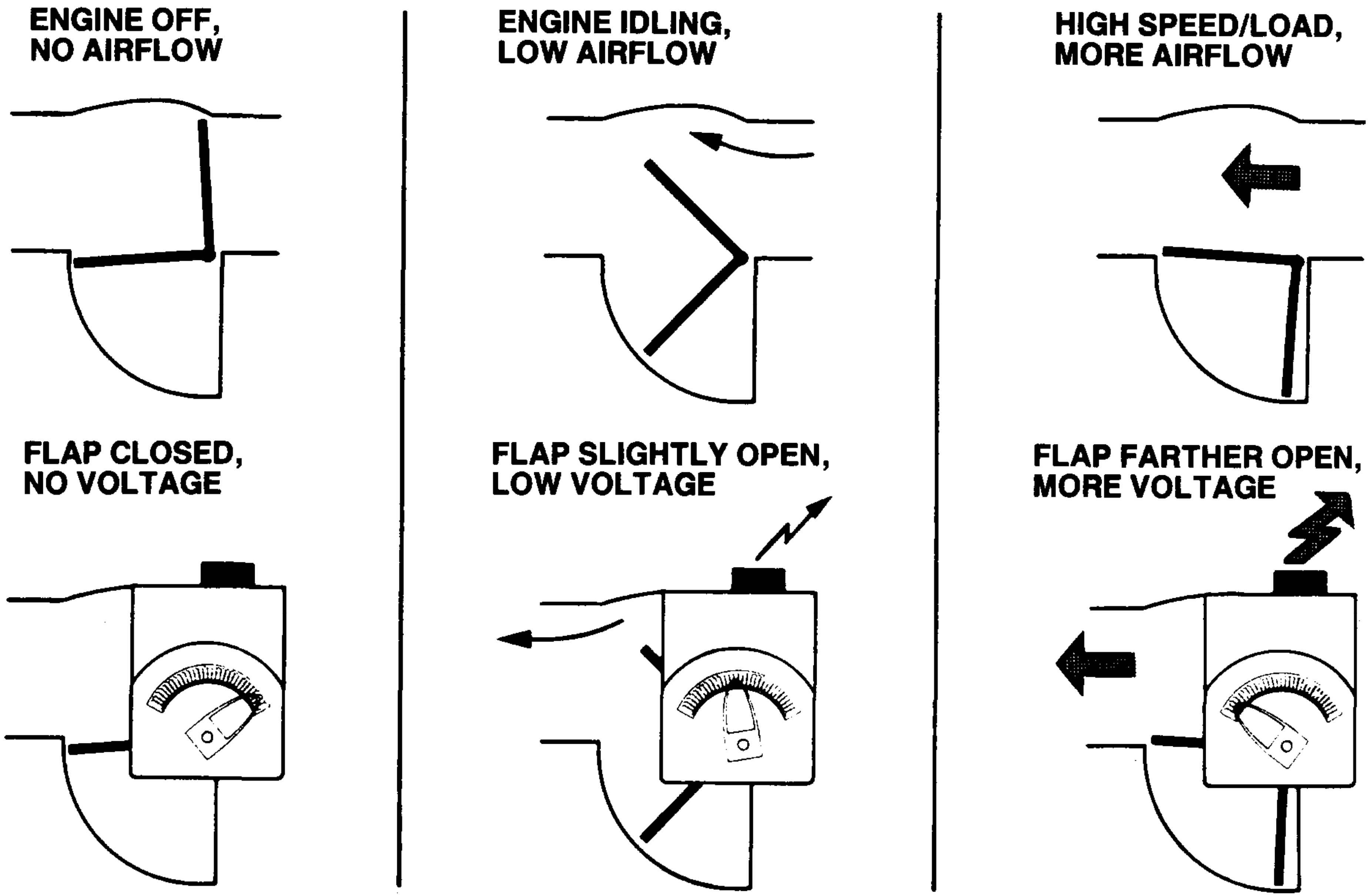
VAF
Vane Air Flow sensor

Some systems measure the volume of incoming air.

This is less accurate as temperature and humidity also affect the oxygen content of a given volume of air

Any air or vacuum leaks will fool the engine into running lean


DAMPING CHAMBER
SENSOR FLAP
AIR OUTLET
AIR INLET


ENGINE OFF,
NO AIRFLOW
ENGINE IDLING,
LOW AIRFLOW
HIGH SPEED/LOAD,
MORE AIRFLOW
FLAP CLOSED,
NO VOLTAGE
FLAP SLIGHTLY OPEN,
LOW VOLTAGE
FLAP FARTHER OPEN,
MORE VOLTAGE

Speed Density

Does not directly measure incoming air

Uses a MAP sensor...

… Temperature sensor

…Throttle Position sensor

… and RPM sensor

Indirectly calculates engine load

MAP
Manifold Absolute Pressure Sensor

Measures manifold pressure (vacuum)

Any vacuum leak will be measured and more fuel will be added

Idle speed will increase

May send a varying voltage, or frequency

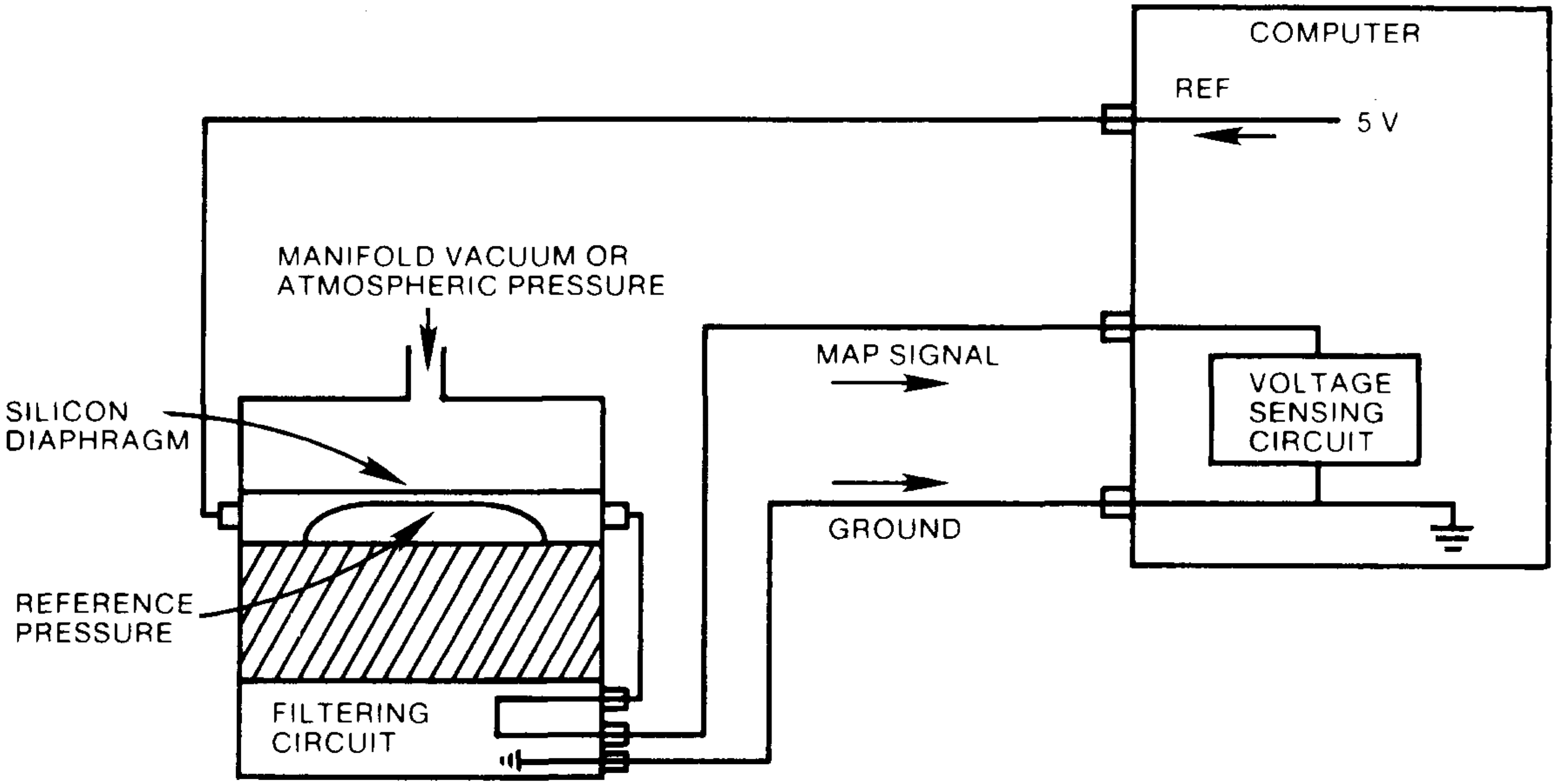


Figure 2–10 Silicon diaphragm pressure sensor

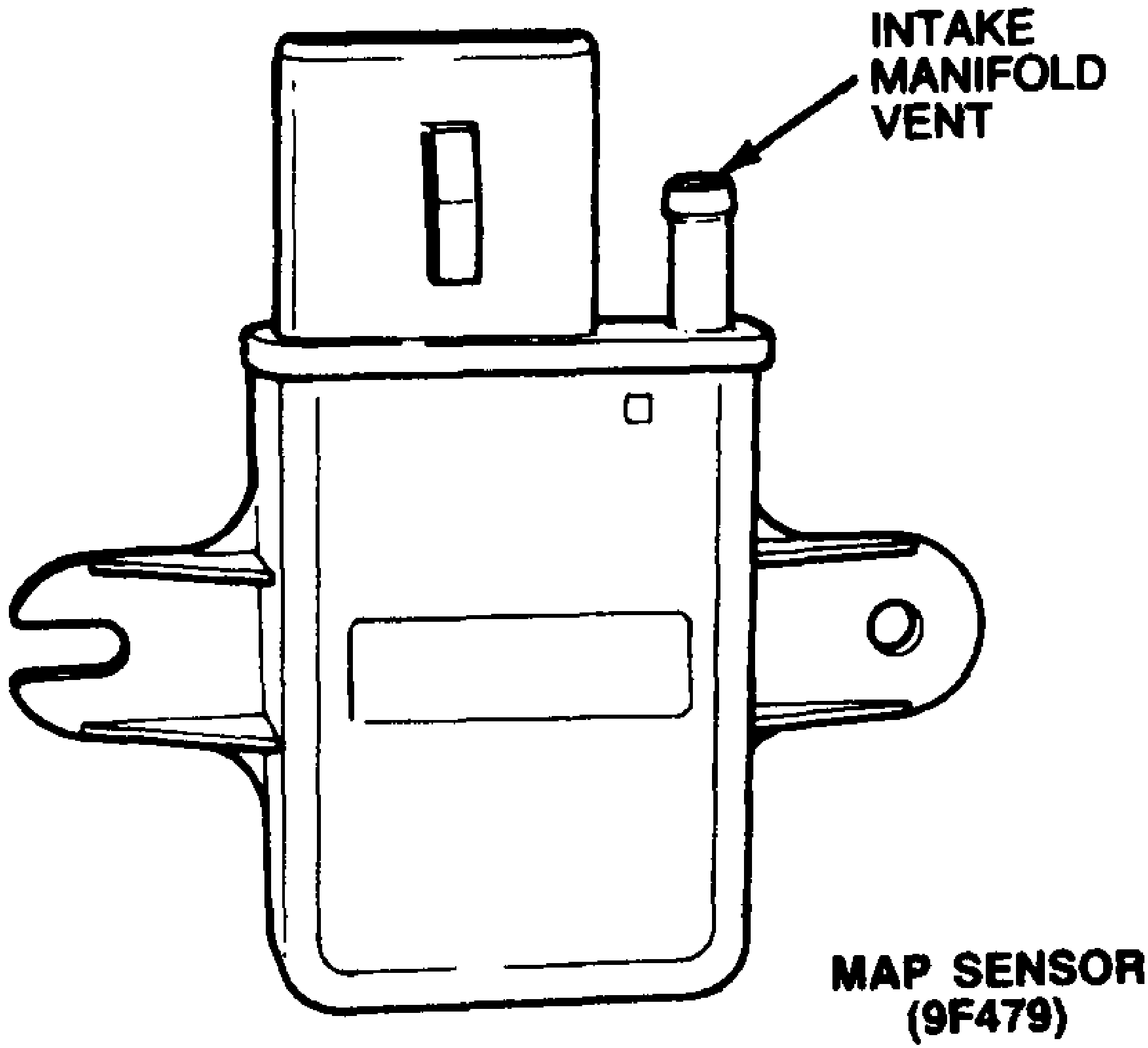


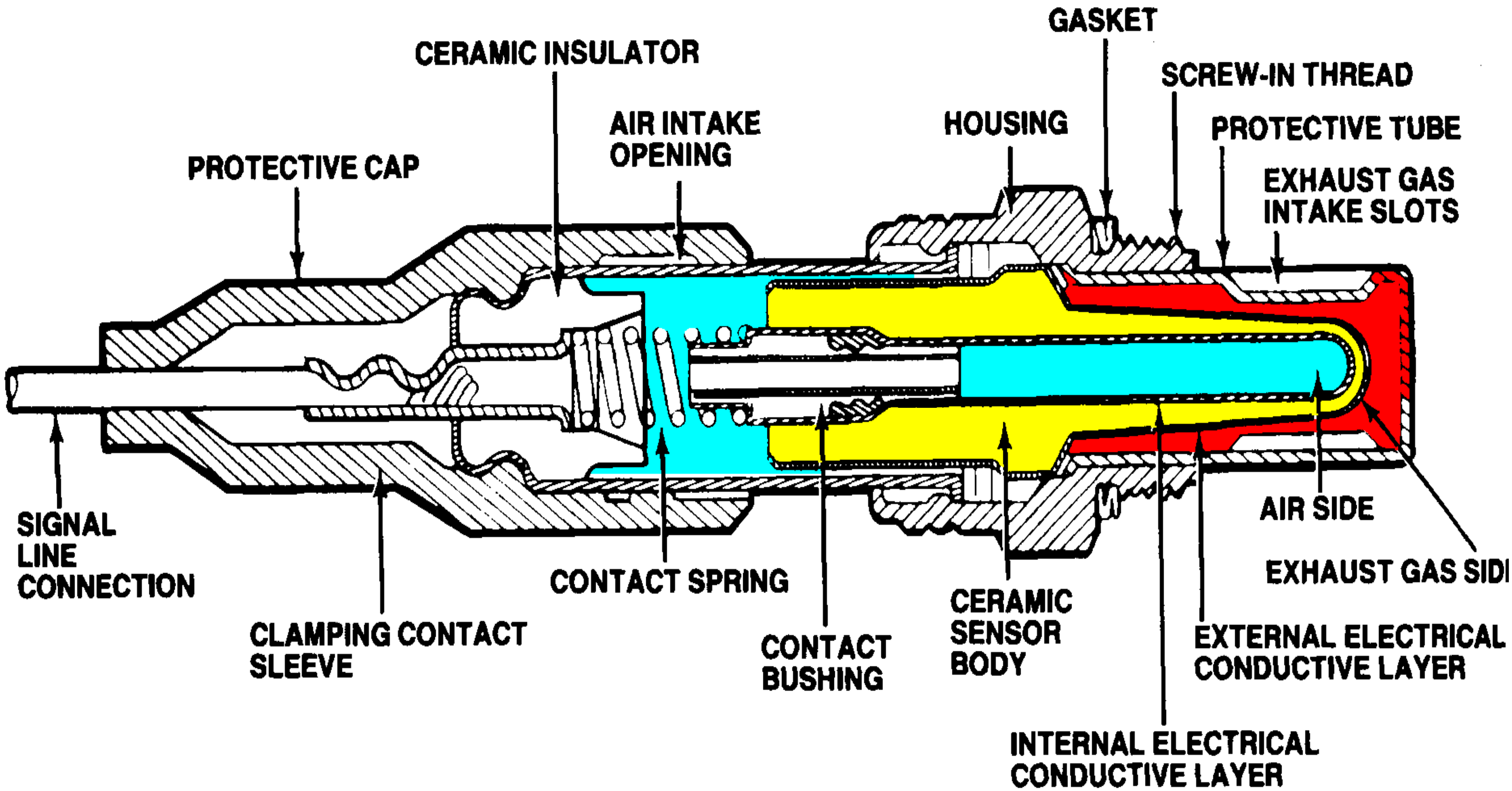
FIGURE 7-12 Manifold absolute pressure sensor. *Courtesy of Ford Motor Company.*

Closed Loop Feedback

Sensors are monitored and the correct fuel quantity is calculated

Oxygen sensor is monitored to adjust "fuel trim"

O_2 (Oxygen) sensor provides the feedback



CERAMIC INSULATOR
AIR INTAKE OPENING
PROTECTIVE CAP
HOUSING
GASKET
SCREW-IN THREAD
PROTECTIVE TUBE
EXHAUST GAS INTAKE SLOTS
SIGNAL LINE CONNECTION
CLAMPING CONTACT SLEEVE
CONTACT SPRING
CONTACT BUSHING
CERAMIC SENSOR BODY
AIR SIDE
EXHAUST GAS SIDI
EXTERNAL ELECTRICAL CONDUCTIVE LAYER
INTERNAL ELECTRICAL CONDUCTIVE LAYER

O2S & HO2S

Oxygen sensor must be hot to operate

Modern Oxygen sensors have a heating element to keep them at operating temperature

Signal of 0.2V (200mV) to 1.1V (1100 mV)

Any signal below 450mV is considered “lean”

O2S & HO2S

Any air leak in the exhaust will send a “false” lean signal

Any cylinder misfire will send unburned oxygen into the exhaust and cause a lean signal

A worn out O2S will send a lean signal

O2S & HO2S

Any lean signal will have the PCM add fuel
(positive fuel trim numbers)

“False” lean signals will cause the vehicle to run rich

Closed Loop Feedback

When in closed loop the fuel control attempts to maintain a stoichiometric mixture

The Load sensor, ECT (Engine Coolant Temperature) sensor and O_2 sensors are critical

Open Loop

At times the stoichiometric mixture is not wanted

Idle, cold operation, high load (power) and accelleration all call for extra fuel and are considered “open loop”

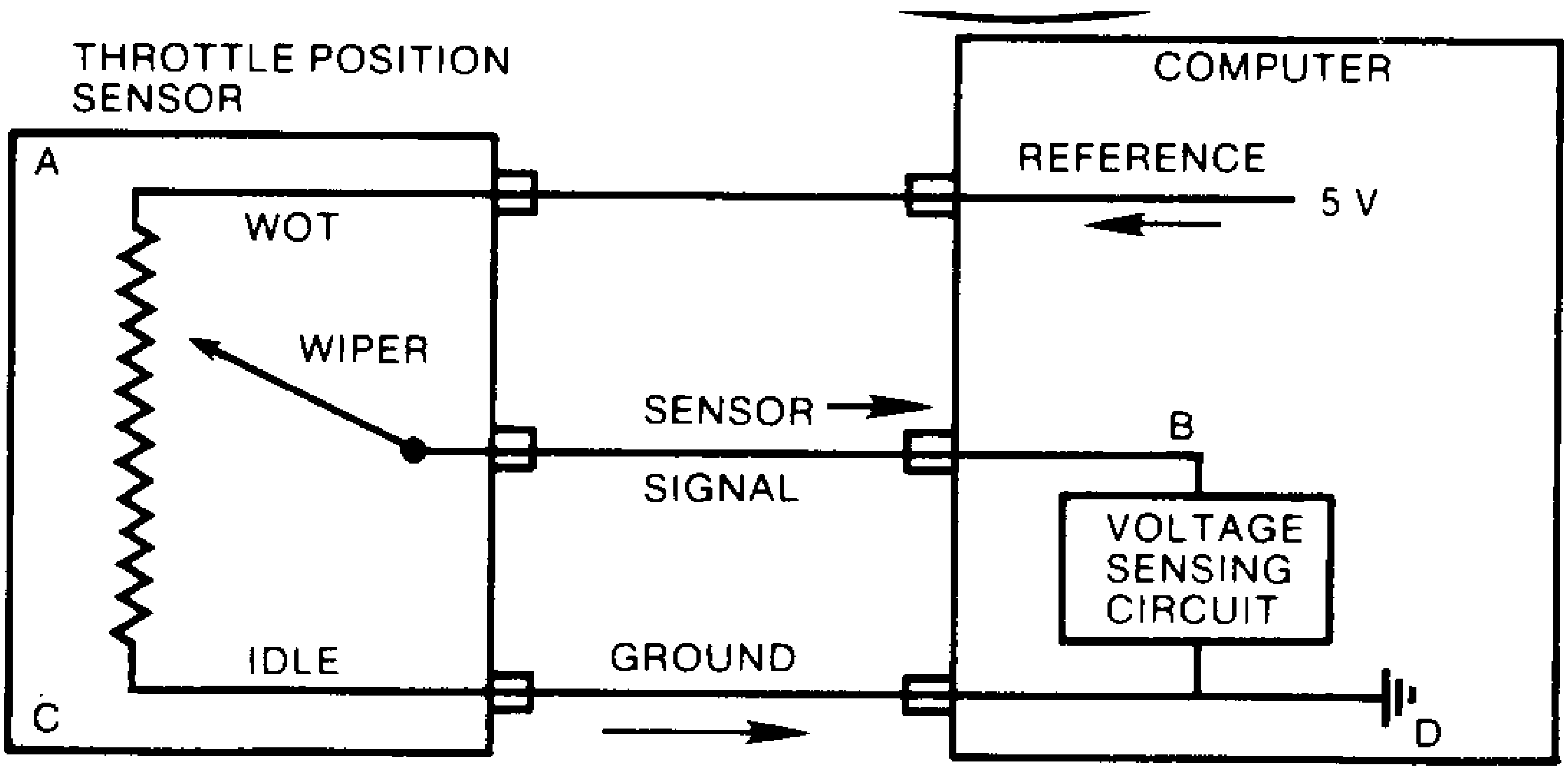
When in open loop the feedback from the oxygen sensor is ignored by the PCM

TPS
Throttle Position Sensor

The TPS asks for extra fuel when it is quickly opened

The TPS asks for extra fuel when the throttle is held wide open

The TPS asks for extra fuel when the engine is at idle (older systems)



THROTTLE POSITION SENSOR
A
WOT
WIPER
IDLE
C
SENSOR
SIGNAL
GROUND
COMPUTER
REFERENCE
5 V
B
VOLTAGE SENSING CIRCUIT
D

TPS
Throttle Position Sensor

Many Acceleration, Power and Idle problems can be traced to a defective TPS

Check voltage signal with an oscilloscope to catch small voltage dropouts