Chapter 41

Gasoline Injection Fundamentals
Objectives

After studying this chapter, you will be able to:

• List some of the advantages of direct fuel injection systems.

• Describe the major assemblies of a modern gasoline injection system.

• Compare the operation of indirect gasoline injection to direct electronic gasoline injection.
Objectives

• Summarize the operating voltages, current levels, and other values of sensors and injectors that are important to technicians.
• Summarize the operation of oxygen sensors to control an engine air-fuel ratio.
• Correctly answer ASE certification test questions on gasoline injection systems.
Gasoline Injection Fundamentals

• Gasoline injection system
  – Uses pressure from electric or mechanical fuel pump to spray fuel into engine’s intake manifold
    • Multiport or manifold injection
  – Combustion chambers
    • Direct injection
Electronic fuel injection systems have five subsystems

- Fuel delivery system
- Air induction system
- Sensor system
- Computer control system
- Fuel metering system
Gasoline Injection Fundamentals (Cont.)

• Fuel delivery system
  – Feeds clean, liquid gas from storage tank to engine

• Air induction system
  – Filters, routes, and controls outside air flowing into cylinders
Gasoline Injection Fundamentals (Cont.)

• Sensor system
  – Measures pressure, temperature, engine speed, and exhaust cleanliness for engine control module (ECM)

• Computer control system
  – ECM responds to sensor signals to control fuel injector and meter precise amount of fuel
Gasoline Injection Fundamentals (Cont.)

• Fuel metering system
  – Controls amount of fuel injected into engine
Gasoline Injection Fundamentals (Cont.)

• Fuel delivery system of modern direct electronic fuel injection (DEFI) system
  – Electric fuel pump
  – Mechanical fuel pump
  – Fuel filter
  – Pressure regulator solenoid
  – Electronic fuel injectors
  – Fuel flow control valves
  – Connecting fuel lines
Atmospheric Pressure

- Pressure formed by air surrounding earth
- At sea level, atmosphere exerts 14.7 psi
- At higher altitudes, air pressure and air density drop
  - Lowers amount of fuel injected into engine

Atmospheric pressure decreases with altitude

- No air pressure high above earth
- 14.7 pounds per square inch at sea level
- Weight of air
Vacuum

• Vacuum
  – Pressure lower than atmospheric pressure formed in enclosed area

• Many sealed parts in and on engine contain vacuum pressure

• Vacuum measured in units of negative psi, inches of mercury, Pascals, or bars compared to outside atmospheric pressure
Differences in Pressure Cause Flow

- Difference in pressure between two areas used to cause flow
- Engine acts as vacuum pump, producing low-pressure area in intake manifold and cylinders
  - This pulls air into engine to support combustion
Engine Throttle Valve

- Engine throttle valve
  - “Butterfly” or flap-type valve in throttle body assembly that controls airflow and engine power output
- When closed, throttle valve restricts flow of air and fuel
  - Keeps engine speed and power low for idling at low rpms
Engine Throttle Valve (Cont.)

• Engine sensors
  – Detect changes and adjust fuel flow through injectors

• Engine idle speed
  – Operating speed of engine when vehicle is in Park or Neutral
**Engine Throttle Valve (Cont.)**

- When driver presses accelerator
  - Throttle cable slides inside its housing and swings throttle valve open
  - Atmospheric pressure pushes more air into engine intake manifold
Throttle-by-Wire Systems

- Throttle-by-wire or drive-by-wire systems
  - Moves throttle valves electronically instead of using mechanical linkage from accelerator pedal

- Accelerator pedal sensor
  - Feeds electric signal to ECM corresponding to pedal position
  - ECM sends control current to servo motor actuator that opens and closes throttle valve
Throttle-by-Wire Systems (Cont.)

• Engine throttle actuator
  – Small, reversible servo motor with emergency release

• Throttle safety release
  – Used to return engine to idle even if engine throttle actuator fails
Gasoline Injection Timing

• Older fuel injection systems
  – Continuous fuel injection
    • Injectors spray fuel whenever engine is running
  – Intermittent fuel injection
    • Injectors open and close regardless of intake valve positions

• Timed injection system
  – Sprays fuel during intake or compression strokes, in relation to piston and valve action
Injector Pulse Width

- Injector pulse width
  - Indicates amount of time each injector is energized and kept open
- ECM controls injector pulse width and amount of fuel sprayed into engine
  - Using all power train sensors
Direct and Indirect Injection

• Fuel injection systems
  – Gasoline injection system often classified by where it injects fuel into engine

• Indirect injection system
  – Sprays fuel into engine intake manifold

• Direct injection system
  – Sprays high-pressure fuel into engine’s combustion chambers
Indirect Injection Systems

- Throttle body injection system (TBI), or single point injection
  - Injector nozzles mounted in throttle body assembly located on top of engine
- Multiport injection system
  - Has fuel injectors in intake ports
- Cold-start fuel injector
  - Used in early designs to richen fuel mixture for cold engine startup
Indirect Injection Systems (Cont.)
**Direct Fuel Injection**

- Direct fuel injection (DFI) systems
  - Inject fuel directly into engine combustion chambers
- Direct electronic fuel injection (DEFI)
  - Uses electric fuel pump, mechanical fuel pump, and high-pressure injectors to spray fuel straight into combustion chambers
Direct Fuel Injection (Cont.)

• Stratified charge mode
  – Ultra-lean burn mode where small charge of fuel injects into combustion chambers during end of compression stroke

• Stoichiometric mode
  – Produces theoretically homogenous mixture of fuel and air
    • Equally mixed and dispersed
Direct Fuel Injection (Cont.)

- Full power charge mode
  - Produces homogeneous, rich mixture that generates more combustion pressure and power
  - Needed when engine accelerates quickly
Electronic Fuel Injector Types

- Two common types of electronic fuel injectors
  - Solenoid fuel injectors
    - Electric current energized electromagnet pulls fuel valve open
  - Piezo fuel injectors
    - Electric current energized crystal expands to push fuel valve open
Solenoid Fuel Injectors

• Used in multiport system
• Typically consists of
  – Electric terminals
  – Injector solenoid
  – Inlet screen
  – Needle valve
  – Needle seat
  – Return spring
  – O-ring seal
  – Injector nozzle
Solenoid Fuel Injectors (Cont.)

- Control module energizes injector
- Control module disconnects power from injector coil
- Magnetic field attracts armature
- No coil magnetic field
- Spring pushes armature down
- Injector valve opens and fuel sprays into engine
- Injector valve closes and blocks fuel flow from pump

Power source
Piezo Fuel Injectors

- Uses crystalline ceramic material instead of electromagnet to open injector valve
- Converts electrical energy directly into motion
- More precise
Fuel Pressure Regulator

• Fuel pressure regulator
  – Controls amount of fuel pressure in fuel rail
• DEFI fuel pressure regulator
  – Uses electric solenoid to bypass excess fuel pressure back to low pressure side of system
Fuel Pressure Regulator (Cont.)

- EFI fuel pressure regulator
- Engine vacuum, not ECM, controls fuel pressure in multiport fuel injection systems
Fuel Rail

• Fuel rail or fuel log
  – Large diameter steel tube feeds gasoline to inlet fittings of fuel injectors

• Fuel system service fitting
  – Often provided on low-pressure EFI systems for releasing and measuring fuel pressure
DEFI Amplifier Module

- DEFII amplifier
  - Increases voltage and current signal sent from ECM to operate high-pressure direct injectors
- DEFII systems often require up to 100 volts dc for proper solenoid operation
Fuel Control Sensors

- Oxygen
- Manifold absolute pressure (MAP)
- Throttle position
- Accelerator pedal
- Engine coolant temperature
- Airflow
- Intake air temperature
- Crankshaft position
- Camshaft position
- High fuel-pressure
Fuel Control Sensors (Cont.)

- Low fuel-pressure
- Fuel tank temperature
- Fuel temperature
- Vehicle speed
- Brake pedal switch
- Hybrid control module
- Traction control module
Fuel Control Sensors (Cont.)

- Oxygen \((O_2)\) sensor on exhaust manifold
- Mass airflow and intake air temperature sensor
- A/C compressor clutch signal
- Knock sensor
- Barometric pressure sensor
- Ignition pick-up in distributor
- Engine coolant temperature sensor
- EGR shutoff solenoid
- Throttle air bypass valve solenoid (idle speed control)
- Ignition module or amplifier circuit
- Diagnostic connector output
- Fuel injectors (4)
- Fuel pump relay

(Ford)
Oxygen Sensor

• Oxygen sensor, exhaust gas, or O₂ sensor
  – Measures oxygen content in exhaust gases to check combustion efficiency

• Primary oxygen sensor or front O₂ sensor
  – Monitors oxygen in exhaust gases as it leaves engine
Oxygen Sensor (Cont.)

• Secondary oxygen sensor or rear $O_2$ sensor
  – Mounted downstream in exhaust system
  – Primarily monitors catalytic converter

• Catalyst monitor
  – Any $O_2$ sensor mounted after catalytic converter
Oxygen Sensor (Cont.)

- To injectors
- MIL in dash
- Engine ECM
- Front (primary) \(O_2\) sensor
- Rear \(O_2\) sensor
- Catalyst
- Exhaust gas

Air-fuel ratio
- Rich
- Stoich
- Lean

Front \(O_2\) sensor signal
- Rich
- Stoich
- Lean

Rear \(O_2\) sensor signal
- Rich
- Stoich
- Lean

Rear \(O_2\) sensor signal (High catalyst efficiency)
- Rich
- Stoich
- Lean

Rear \(O_2\) sensor signal (Low catalyst efficiency)
- Rich
- Stoich
- Lean

Time
Oxygen Sensor Positions

• Oxygen sensor position
  – Assigned number by its location and order in relation to engine’s banks
  – Sensor closest to number one cylinder denoted as Oxygen Sensor, Bank 1, Sensor 1
Open Loop and Closed Loop

• Open loop
  – Electronic fuel injection system does not use engine exhaust gas content as main indicator of air-fuel mixture

• Closed loop
  – Computer using information from oxygen sensor and other sensors
  – Forms imaginary loop from ECM, through fuel system, into exhaust system, and back to ECM
Narrow Band Oxygen Sensors

- Narrow band oxygen sensors
  - Can only measure combustion efficiency near stoichiometric
    - Chemically correct
- Zirconia oxygen sensors
  - Use zirconia and platinum to produce voltage output that represents oxygen in exhaust gases
Narrow Band Oxygen Sensors (Cont.)

• Planar zirconia oxygen sensors
  – Similar to conventional zirconia sensors
  – Zirconia element, electrodes, and heater combined in flat, laminated strip

• Lean burn oxygen sensor
  – Measures oxygen content in exhaust of lean-burn engines
Narrow Band Oxygen Sensors (Cont.)

- Titania oxygen sensor
  - Uses thick film of titania to detect amount of oxygen present in exhaust gases
  - Varies its internal resistance to signal ECM
Wide Band Oxygen Sensors

- Can change its output gradually and in direct proportion to oxygen content of exhaust gases
- Produces small $\text{O}_2$ sensor pump current representing oxygen content
Manifold Absolute Pressure Sensor

• Manifold absolute pressure (MAP) sensor
  – Measures pressure, or vacuum, inside engine intake manifold

• Excellent indicator of engine load

• Varies resistance with changes in engine load
  – Data is used by computer to alter fuel mixture
**Throttle Position Sensor**

- Throttle position sensor
  - Variable resistor connected to throttle plate shaft
- Different current levels produced for different throttle positions
Engine Coolant Temperature Sensor

• Engine coolant temperature sensor
  – Monitors operating temperature of engine
• Mounted so exposed to engine coolant
• When engine warms, sensor’s resistance changes so ECM knows to make mixture leaner
Sensors

- **Airflow sensor**
  - Used in many EFI systems to measure amount of outside air entering engine

- **Intake air temperature sensor**
  - Measures temperature of air entering engine

- **Crankshaft position sensor**
  - Used to detect engine speed
Sensors (Cont.)

- Fuel pressure sensor
  - Mounts on fuel rail
  - Sends electronic signal, proportional to pressure inside rail
- Fuel temperature sensor
  - Monitors temperature of fuel in fuel rail
Other Sensors

- Other sensors affect fuel injection system operation
  - A/C compressor sensor
  - Transmission sensors
  - EGR sensor
  - Engine knock sensor

- Provide additional data about operating conditions affecting engine fuel needs
Engine Idle Speed Control

- Idle air control motor
  - Solenoid, or servo motor-operated air bypass valve
  - Used to help control engine idle speed
- Works like thermo or temperature-sensitive mechanical valve but ECM controlled

(Honda)