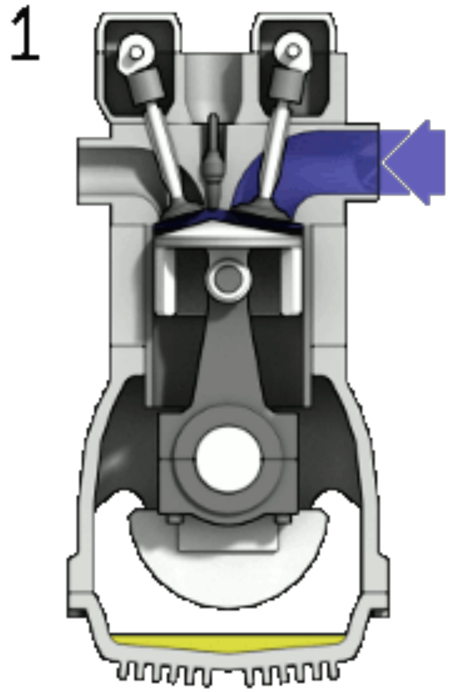
What has happened since the T-Ford?

History of Control, Spark-Ignition Engines

Overview

Spark-Ignition Engine Operation:



1 = Intake, **2** = Compression, **3** = Power, **4** = Exhaust

Compare the T-Ford engine-control system to a state-of-the art control system.

Consider the problem of controlling:

- Air Flow
- Fuel Flow
- Spark Timing

<u>On a very basic level</u>

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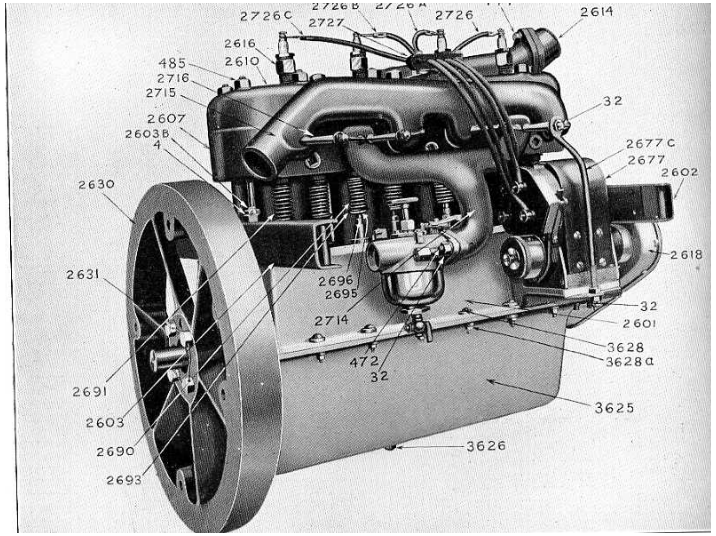
T-Ford Engine



- Simple, reliable and cheap
- Power: 20 hp, 15 kW (Ford Focus: 170 - 225 hp).
- Top speed: 72 km/h
- Produced from 1908 to 1941,
  exceeded the T-Ford vehicle (1908 to 1927).

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T-Ford Engine

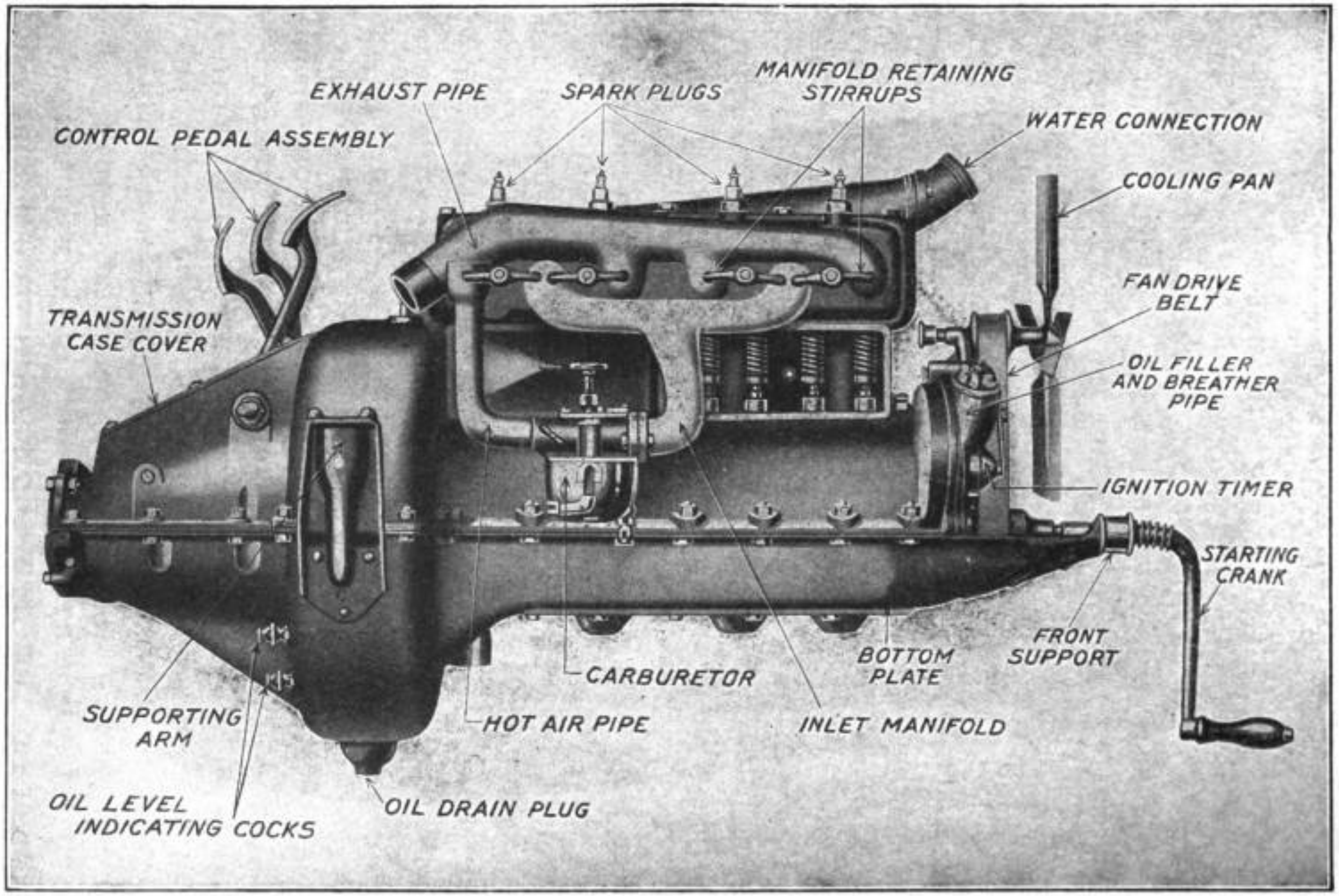

Fig. 8.—Valve Side of the Ford Model T Unit Power Plant Showing Manifolds, Carburetor and Interior of One of the Valve Spring Chambers.

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T-Ford Engine

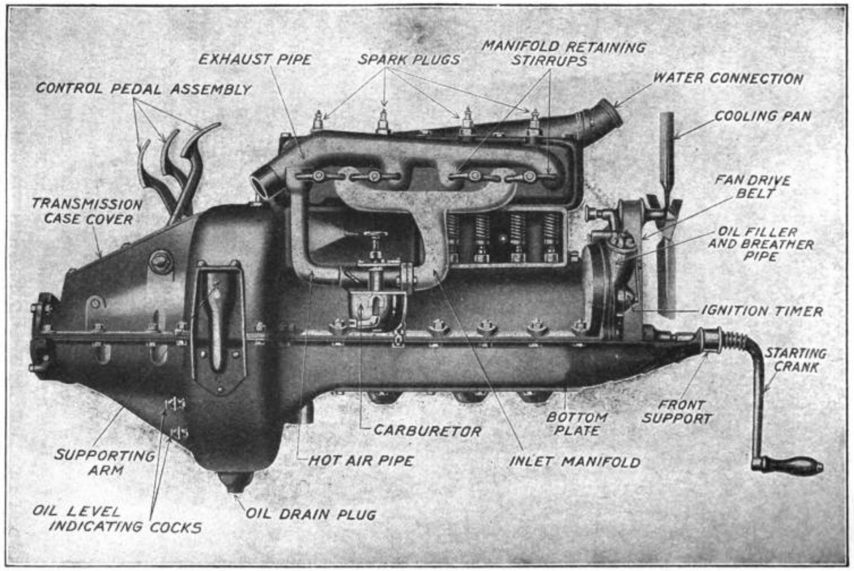


Fig. 8.—Valve Side of the Ford Model T Unit Power Plant Showing Manifolds, Carburetor and Interior of One of the Valve Spring Chambers.

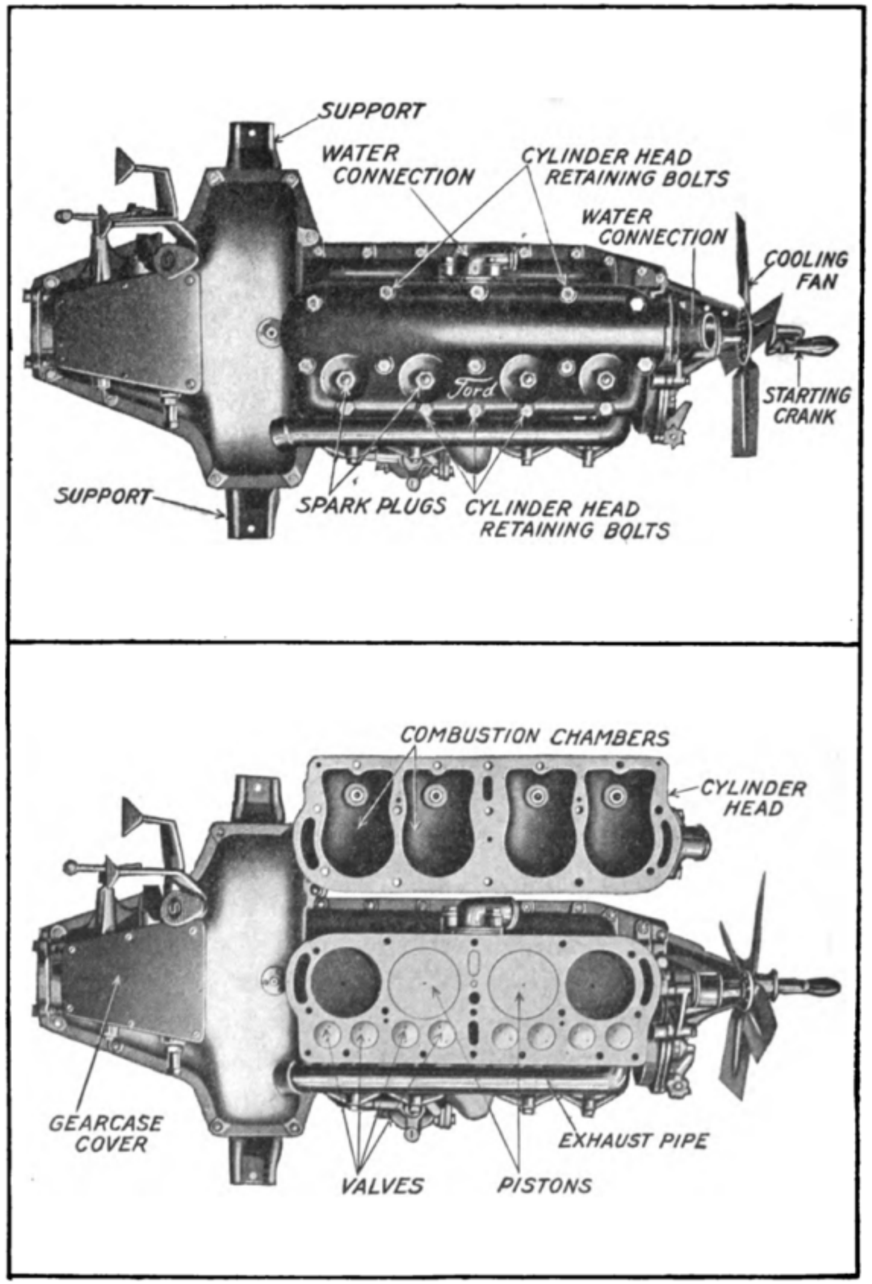


Fig. 12.—Depicting the Distinctive Design of the Ford Motor which Employs a Removable Cylinder Head to Permit Ready Access to the Combustion Chambers, Valves and Piston Parts.

Air & Fuel Flow

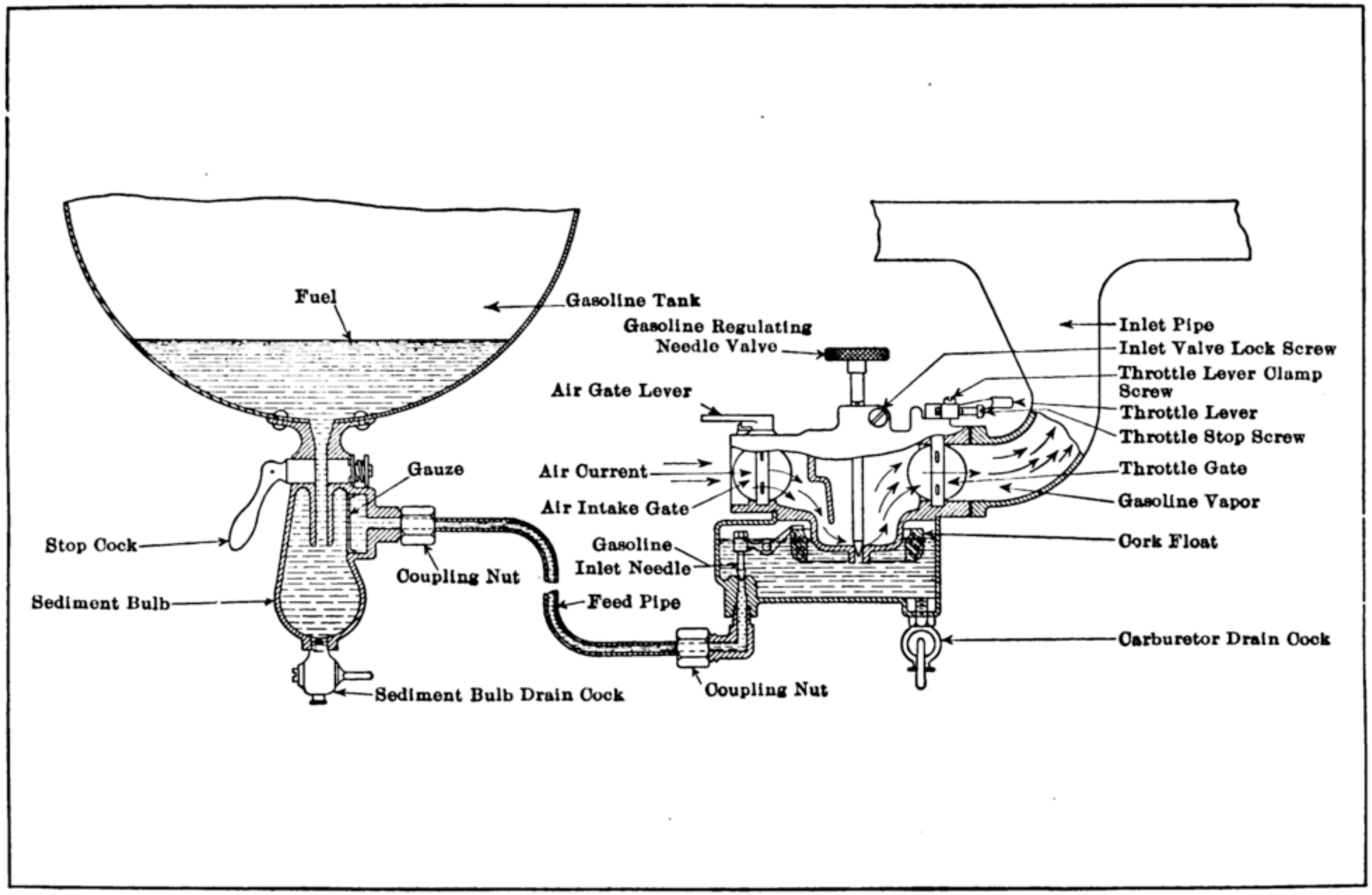


Fig. 14.—The Ford Model T Fuel Supply and Gas Making System.

Spark Ignition

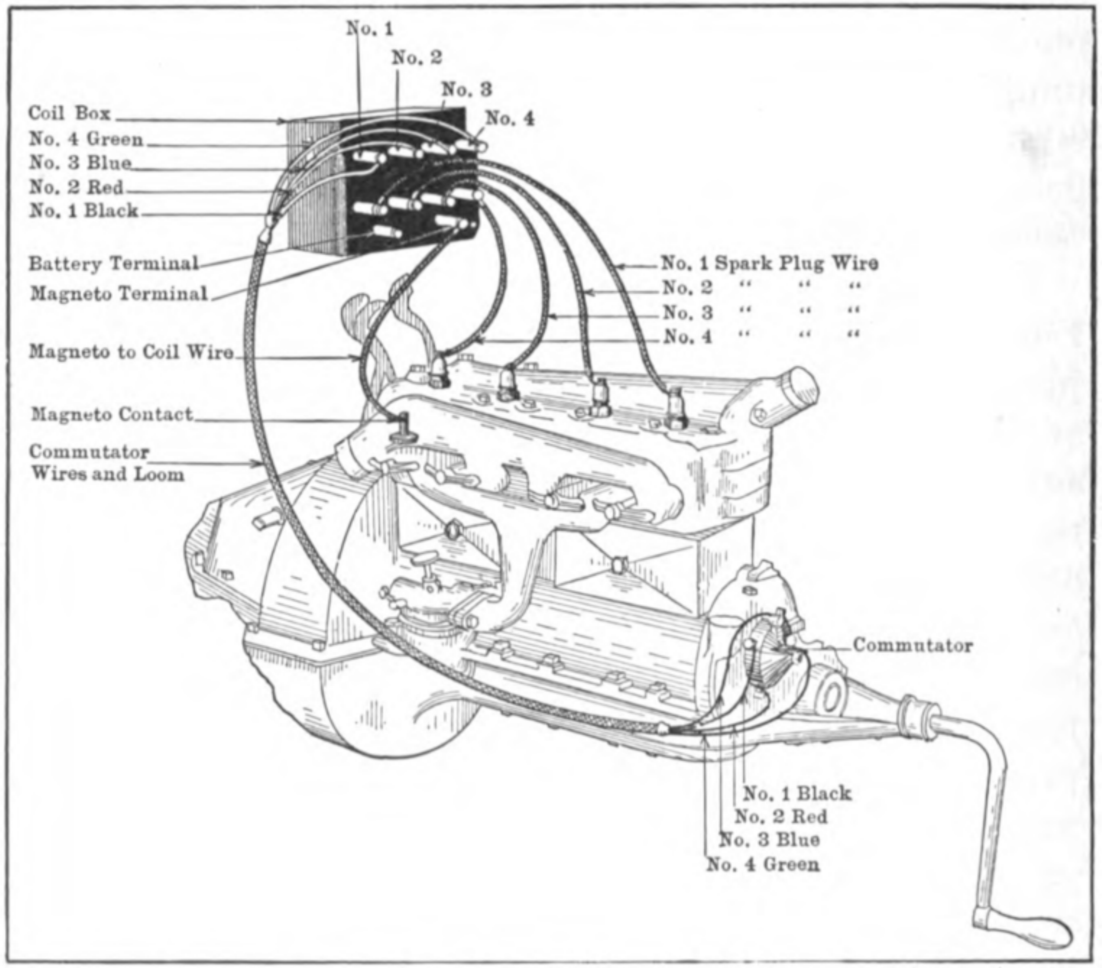
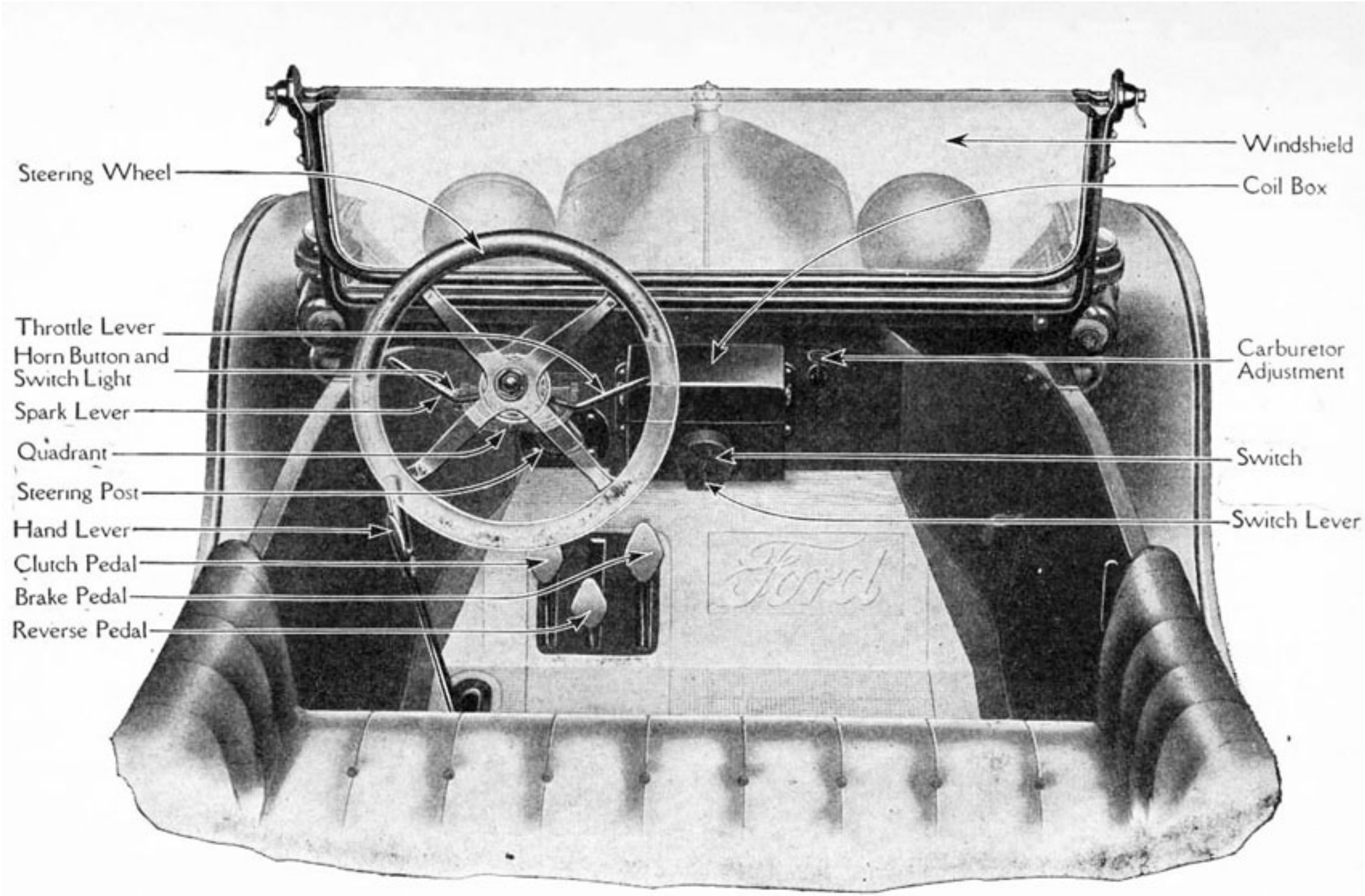


Fig. 16.—View of Ford Power Plant Showing Main Parts of the Ford Ignition System. Note Location of Timer and Induction Coil Box.

Manual Control



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Engine-Control Development

Manual control was soon exchanged by vacuum powered mechanical devices.

California passed laws regulating automotive exhaust emissions and Federal U.S. laws were introduced in the 1970’s. Current system could not meet the new legislations.

Progress examples:

- Three-way catalyst (TWC) + Zirconium oxide sensors → closed-loop Air/Fuel-ratio control with microcontrollers, (Volvo, late 70’s).
- Ignition-timing feedback with knock sensors and electrically controlled ignition systems, lowered fuel consumption, (Saab, 1985).
- Electronic fuel injection for increased precision, response and improved Air/Fuel-ratio control, (VW 1967).
- Drive by wire, BMW (1988).
- Closed-loop control for lower idle speeds for lower fuel consumption.

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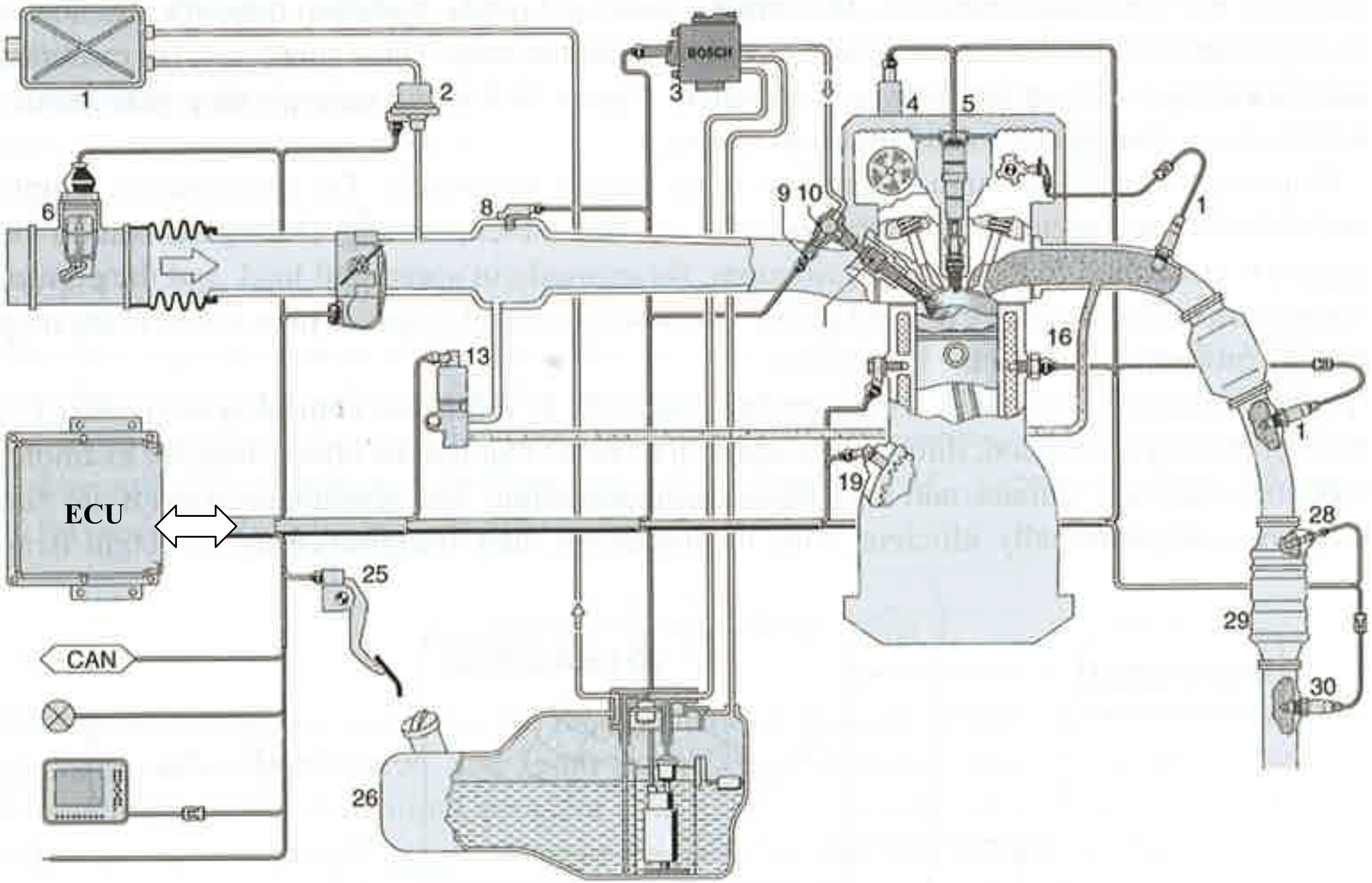
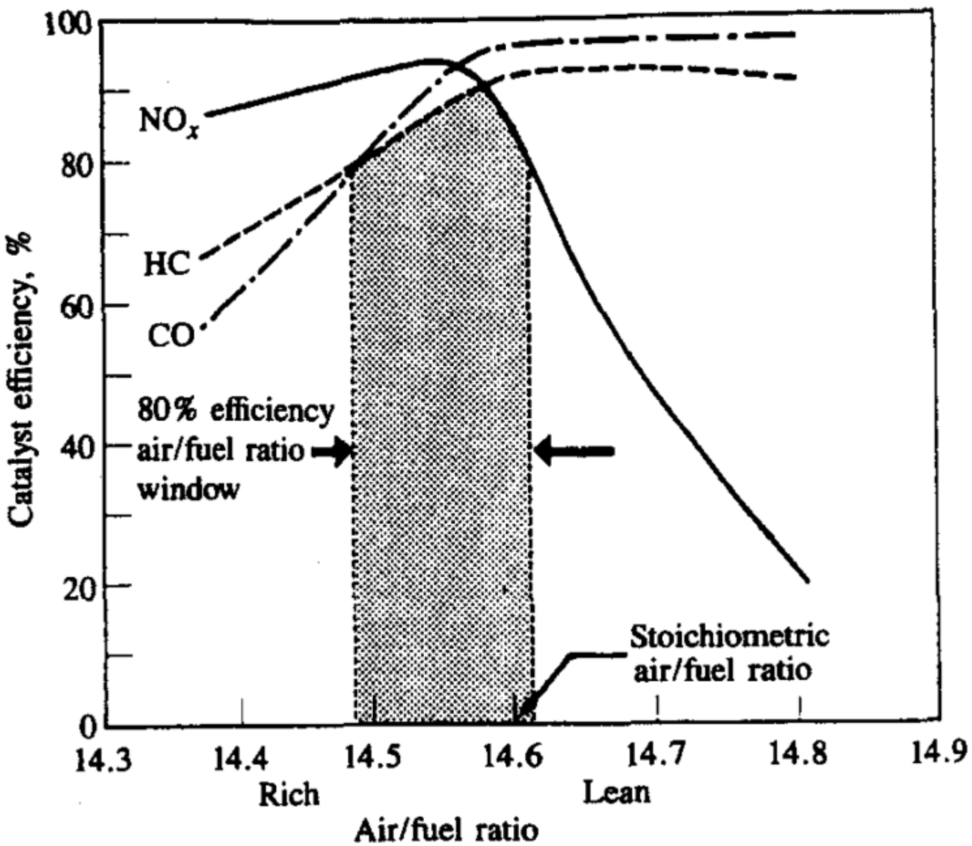
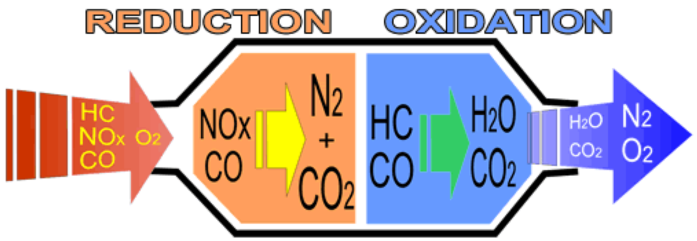
Modern-Engine Diagram



Three-Way Catalyst



Oxygen sensor



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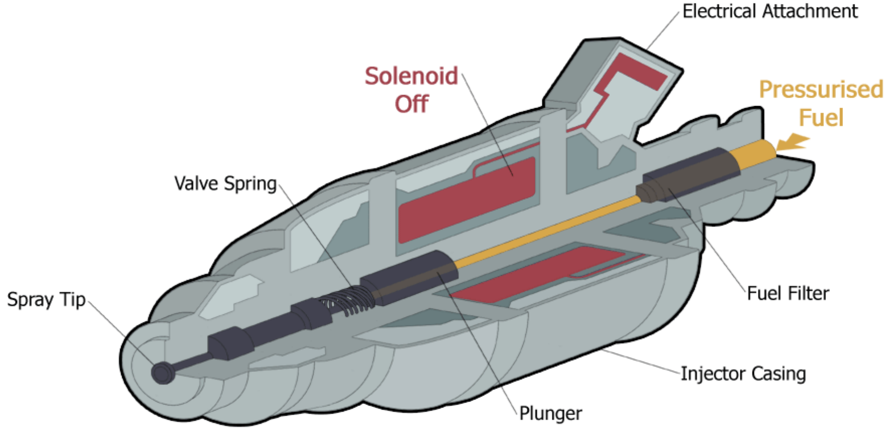
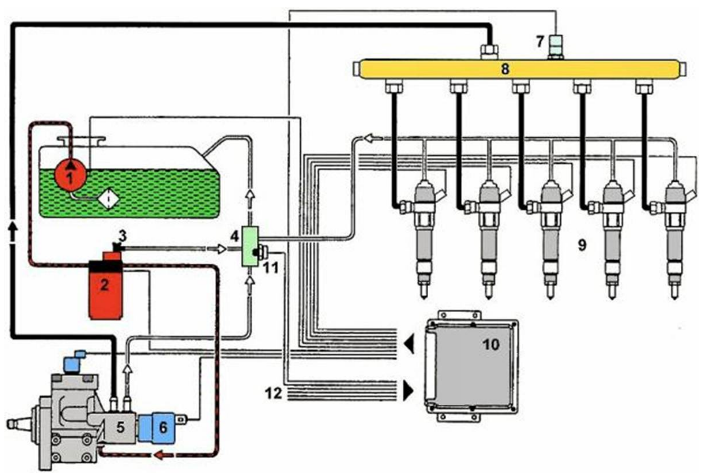
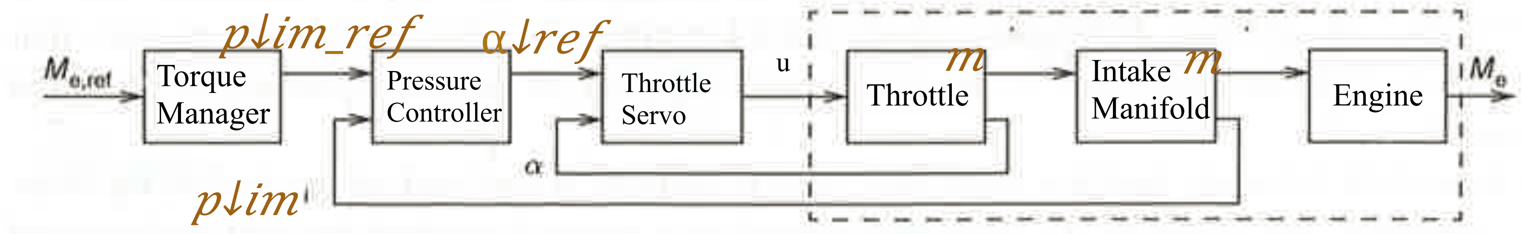
Electronic Fuel Injection



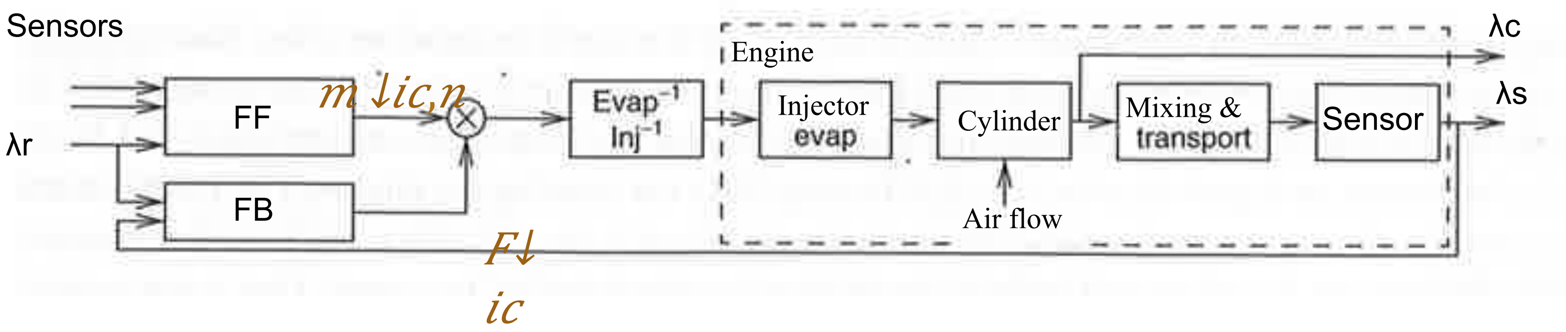


Basic Control of SI Engines

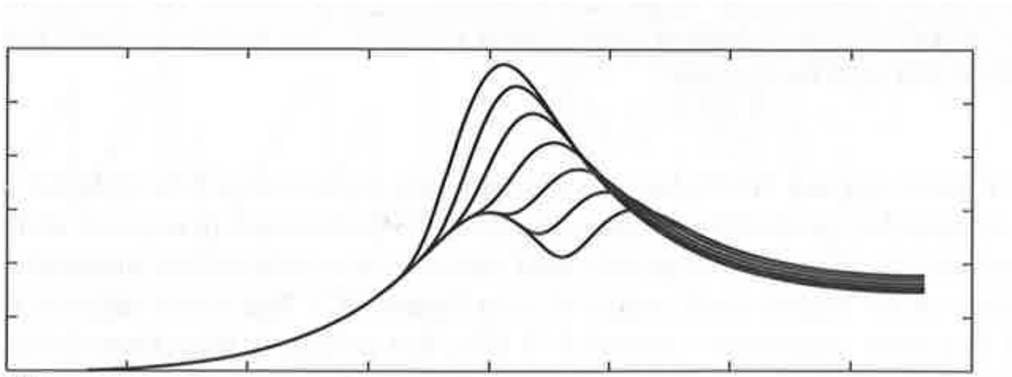
Torque is controlled with air flow:



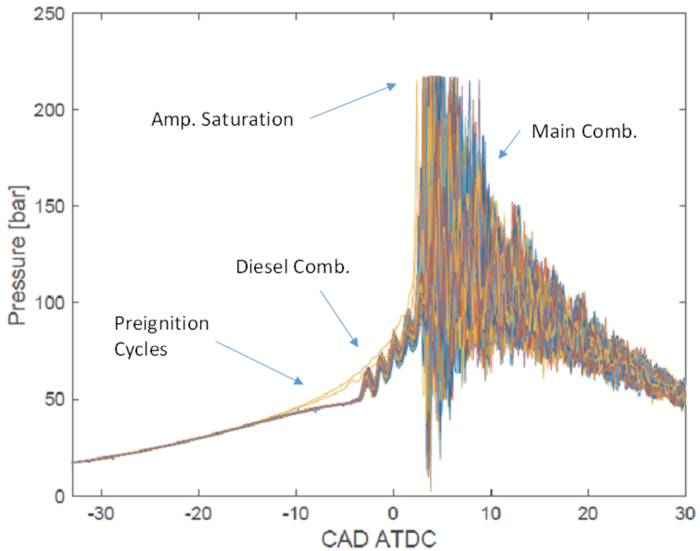
AFR is controlled with fuel flow:



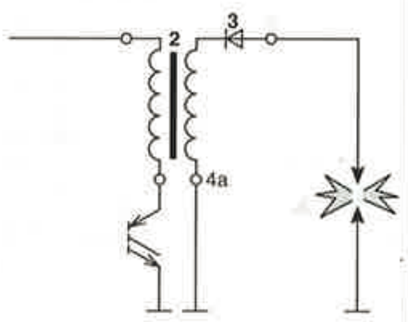
Ignition-Timing Control



Knock Sensor



Ignition Circuit



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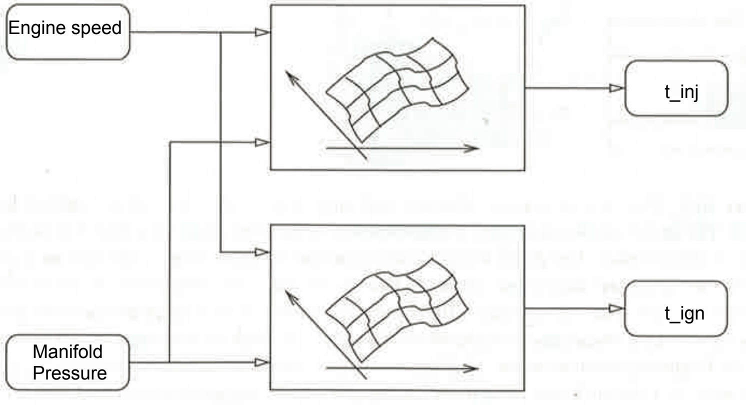
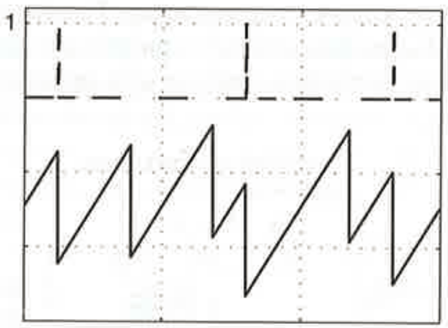
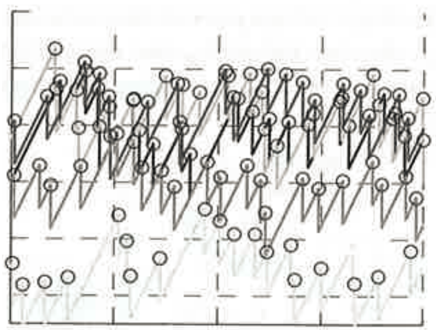
Ignition-Timing Control

```
If( knock detected )
  delay ignition timing with amount K1
else
  advance ignition timing with amount K2
```

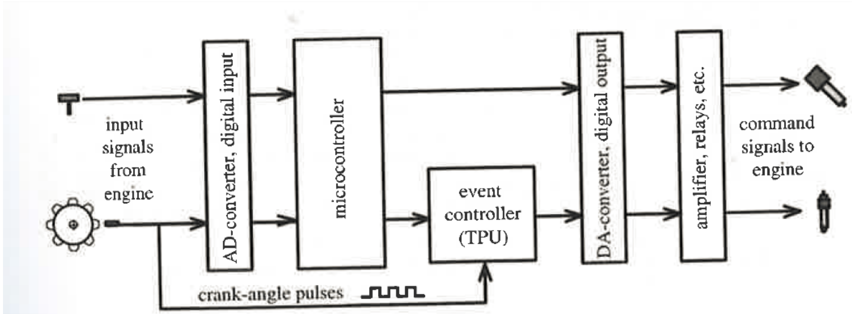






Engine Control Unit (ECU)

- Microcontroller (process interfaces, RAM/ROM, CPU, etc.)
- Time Processing Unit
- Lower clock rates



- Control other parts of the engine
  - Transmission, breaks, AC, etc..

The number of lines of code in a vehicle is increasing by a factor of 10 every eight years, and the development cost for software will exceed that of hardware before 2020.

Other Control Loops

- Variable-valve actuation
- Turbocharger
- Exhaust-gas recirculation
- Engine / Catalyst temperature
- RPM