The Ignition System and Operation

1

Purpose of Ignition System

- The ignition system includes those parts and wiring required to generate and distribute a high voltage to the spark plugs.
- The heart of the ignition system is the ignition coil which can deliver over 40,000 volts of electricity to the spark plugs from a 12 volt input.
- Early ignition systems used a mechanical switch known as contact points to trigger the spark.

2

2

Principle of Ignition System

- The basic principle of the electrical spark ignition system has not changed over the years.
- What has changed is the method by which the spark is triggered and how it is distributed
  - A Mechanical Ignition **System** was used prior to 1975 (conventional system)
  - An Electronic Ignition System started finding its way to production vehicles during the 1970s
  - Distributorless ignition was introduced in the mid 1980s

3

3

Circuit Components

Primary
Low Voltage

- Battery
- Ignition switch
- Primary wiring
- Ignition control device
- Ignition coil primary

Secondary
High voltage

- Ignition coil secondary
- Distributor cap and rotor
- Secondary wiring
- Spark Plugs
- Sensors and PCM (computer)

4

4

Primary Circuit Operation

- Current path is from the positive of the battery through the ignition switch to the ignition coil, through the coil to the ignition points.
- If the ignition points are closed the current flows through the points and back to the negative of the battery through chassis ground.

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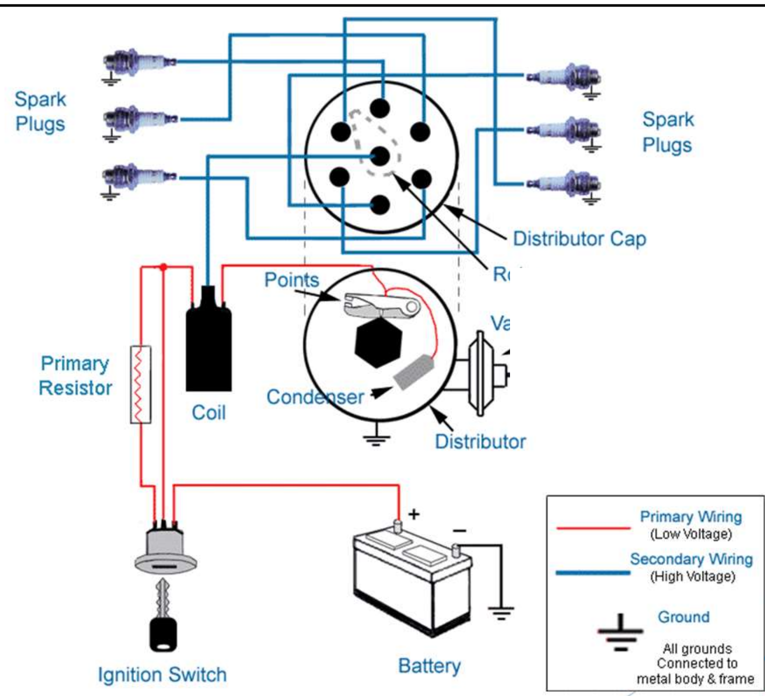

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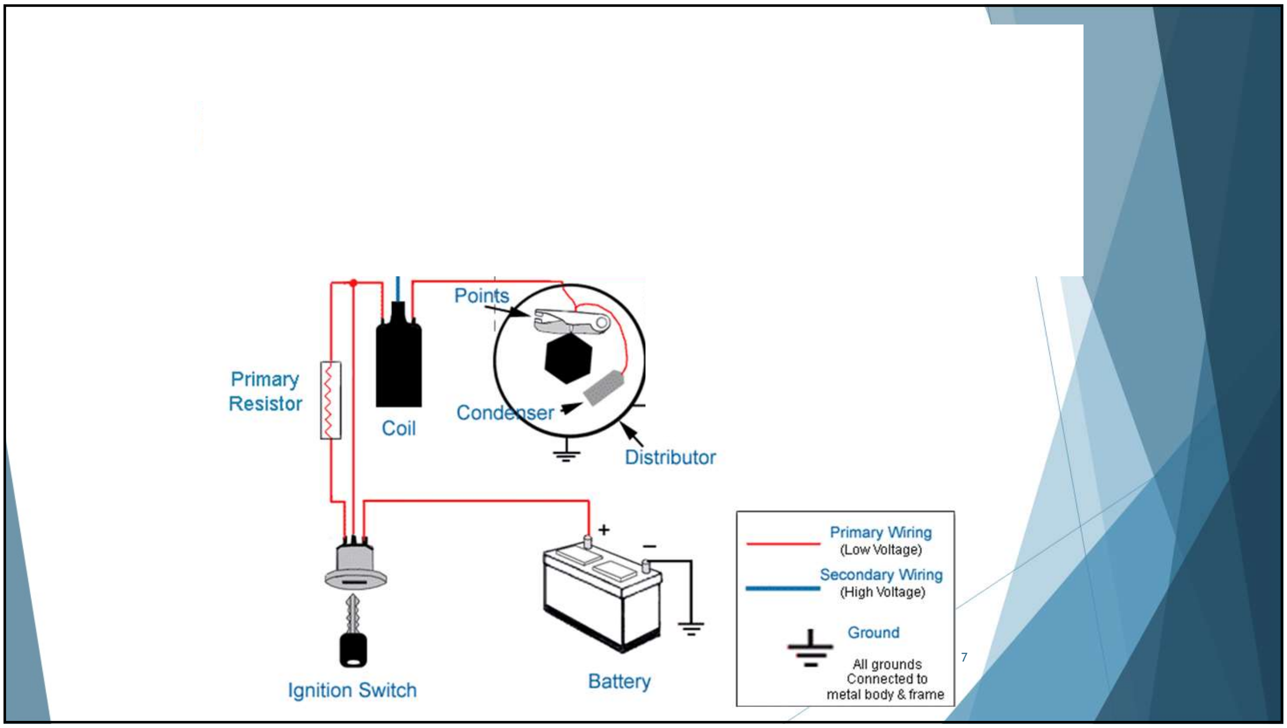
Points
Primary
Resistor
Coil
Condenser
Distributor
Ignition Switch
Battery
Primary Wiring
(Low Voltage)
Secondary Wiring
(High Voltage)
Ground
All grounds
Connected to
metal body & frame
7

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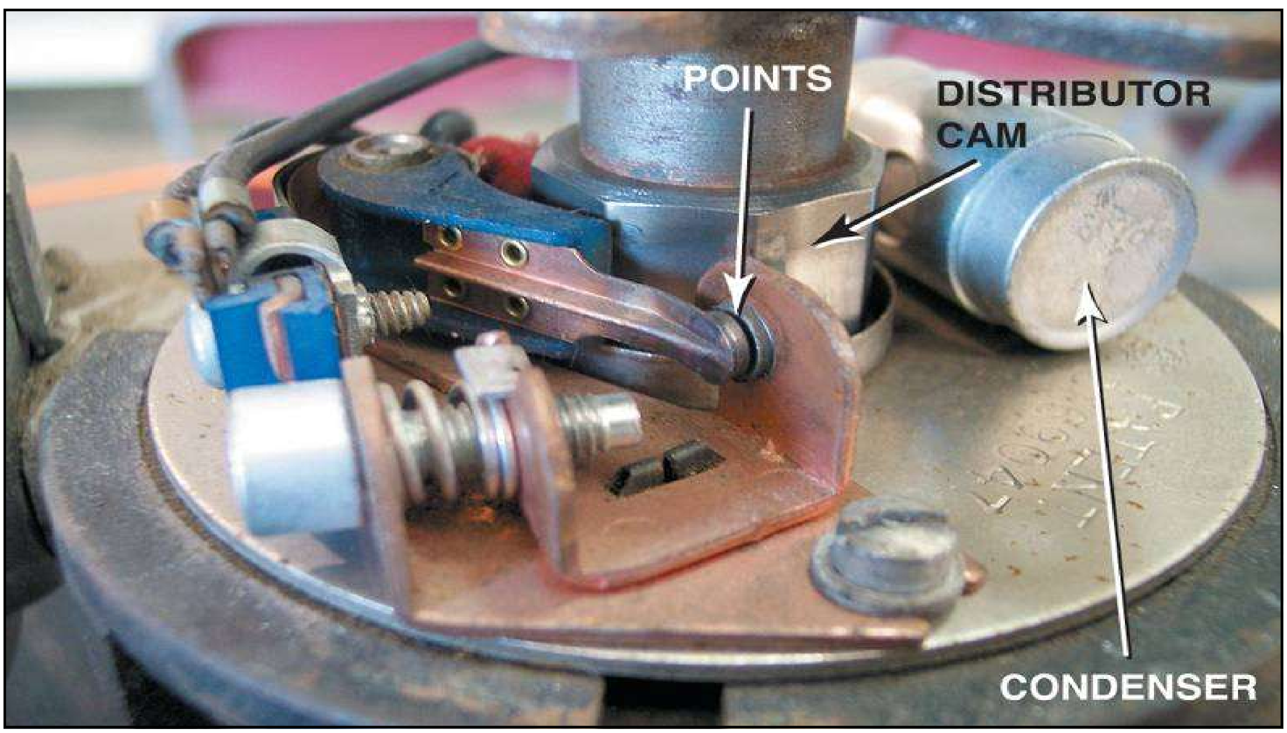
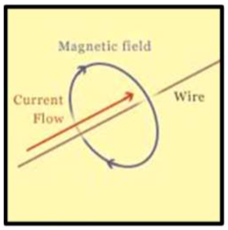
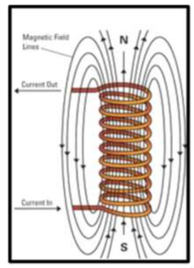

POINTS
DISTRIBUTOR
CAM
CONDENSER

8

Electricity and Magnetism

- When electric current flows through a wire it generates a magnetic field around the wire.
- By winding the wire in a coil (called turns) the strength of the magnetic field is increased. The higher the current flow the stronger the magnetic field.





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Electromagnetic Induction

- When the current flows through the coil wire is interrupted, the magnetic field around collapses.
- If a second coil of wire is placed inside the first one, the energy from the collapsing magnetic field will generates an electric current in the second coil wire.
- The current in the first coil is called the primary current and the current in the second wire is (surprise, surprise) secondary current.

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Electromagnetic Induction

- This principle causes electric current to pass through empty space from one coil of wire to another.
- Electromagnetic induction because the collapsing magnetic field in the first coil "induces" a voltage in the second coil.
- The electrical energy passes more efficiently from one coil to the other if the coils are wrapped around a soft iron bar (called a core).

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Electromagnetic Induction

- If the secondary coil windings (turns) have the same number of turns as the first coil, the voltage in the second coil will be virtually the same size as the one in the first coil.
- If there are more turns in the secondary coil than in the primary, the secondary voltage will be increase and secondary current will decrease.

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The Coil

- Heart of the ignition system
- Step-up transformer.
- Primary winding contains 100 to 150 turns of wire and are the path of current flow in the primary circuit
- Secondary winding circuit contains 15,000 to 30,000 turns of fine copper wire.
- The point at which the coil reaches its maximum magnetic strength is called saturation.
- This is when we want to discharge the coil.

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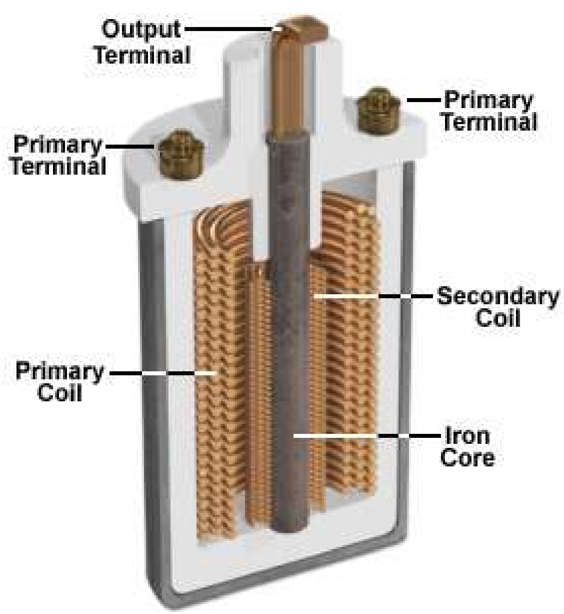

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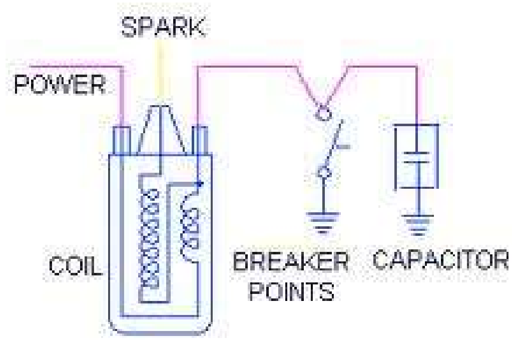
Coil Primary



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The Coil Secondary

- When the ignition points open, current flow in the primary circuit stops
- The magnetic field in the coil's primary windings collapses and induces a voltage in the secondary windings.
- The difference in the size and number of the secondary windings causes the voltage increase.
- Electricity always follows the path of least resistance to ground.
- Coil Voltage goes to ground by jumping the gap at the spark plug creating a high intensity spark.

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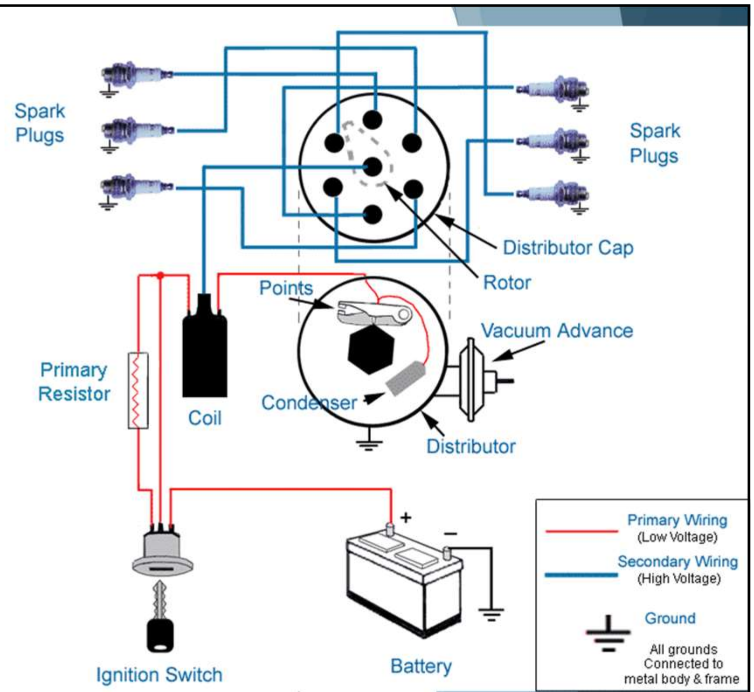

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Electronic Ignition

- Module replaces the ignition points as the switching device, to open the coils primary circuit.
- For any ignition system to function, the primary current must be turned on to charge the coil and off to allow the coil to discharge.
- An electronic switch, such as a power transistor is controlled by an ignition control module or the PCM.

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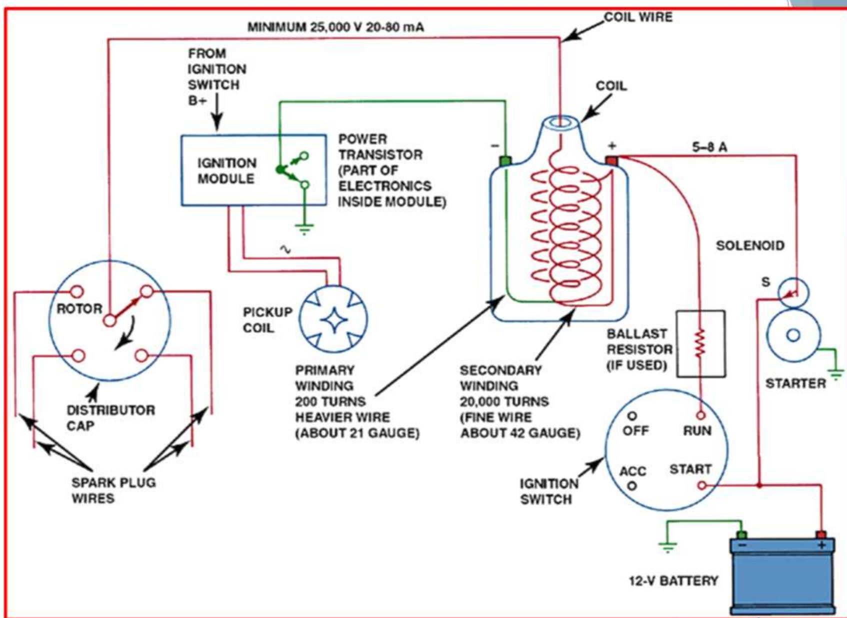
MINIMUM 25,000 V 20-80 mA
COIL WIRE
FROM IGNITION SWITCH B+
COIL
IGNITION MODULE
POWER TRANSISTOR (PART OF ELECTRONICS INSIDE MODULE)
5–8 A
SOLENOID
S
ROTOR
PICKUP COIL
BALLAST RESISTOR (IF USED)
STARTER
DISTRIBUTOR CAP
PRIMARY WINDING 200 TURNS HEAVIER WIRE (ABOUT 21 GAUGE)
SECONDARY WINDING 20,000 TURNS (FINE WIRE ABOUT 42 GAUGE)
OFF
RUN
ACC
START
SPARK PLUG WIRES
IGNITION SWITCH
12-V BATTERY

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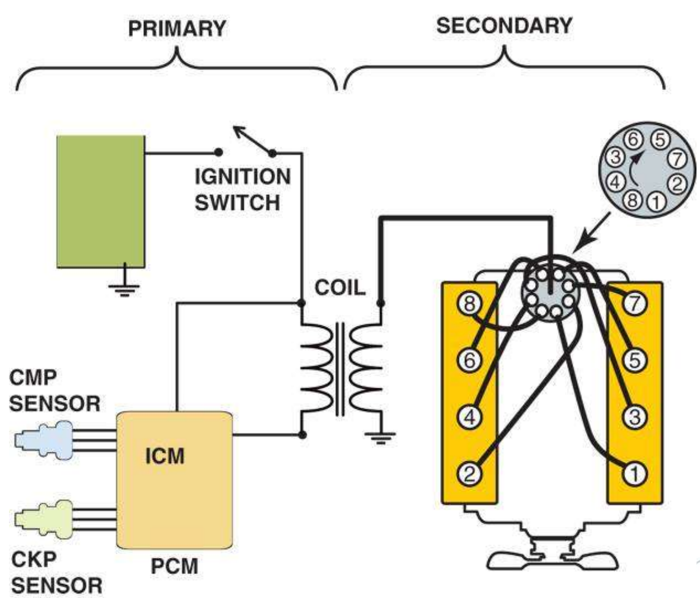
PRIMARY
SECONDARY
IGNITION SWITCH
COIL
CMP SENSOR
ICM
CKP SENSOR
PCM

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Trigger

- The device that signals switching of the coil
- Pickup coil in some distributor-type ignitions
- Crankshaft position sensor (CKP) on electronic (waste-spark and coil-on-plug) and many distributor-less ignitions

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Distributor-less Ignition

- Distributor is eliminated by a coil pack directly over the spark plug
- Spark is controlled by the PCM
- Advantages:
  - Increased voltage at the spark plug
  - No plug wires
  - Better timed spark
  - More efficient operation

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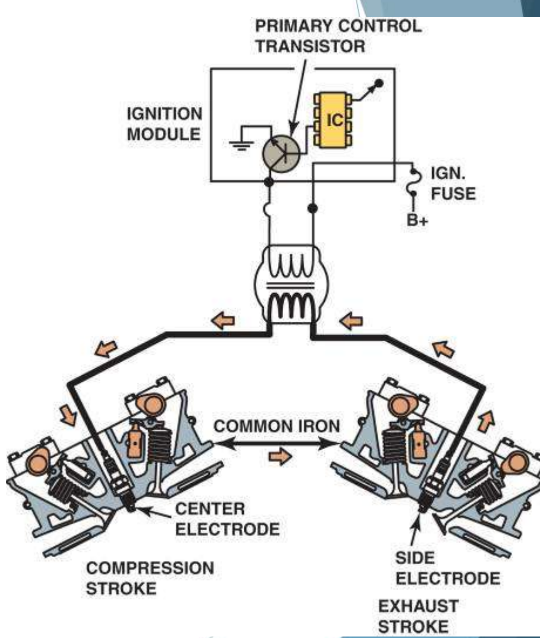
Waste Spark

Fires one cylinder on compression stroke and at the same time fires a companion cylinder on the exhaust stroke.

In a typical engine, it requires only about 2 to 3 kV to fire the cylinder on the exhaust stroke.

The remaining coil energy is available to fire the spark plug under compression (typically about 8 to 12 kV).



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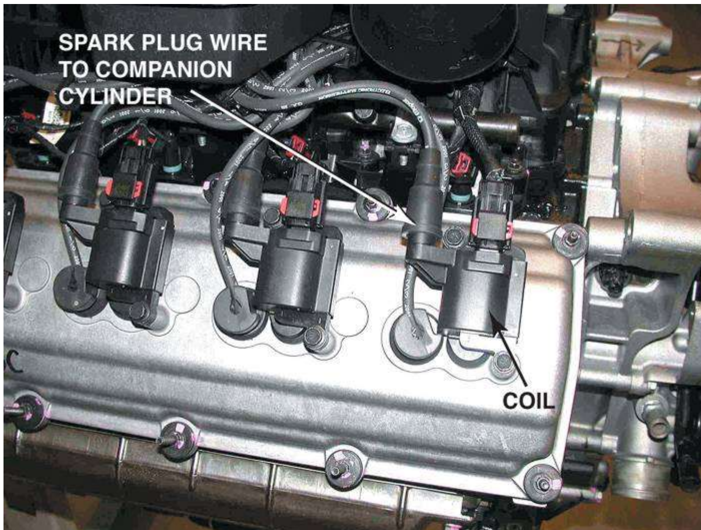
A Chrysler Hemi V-8 that has two spark plugs per cylinder. The coil on top of one spark plug fires that plug and, through a spark plug wire it simultaneously fires the plug in the companion cylinder.



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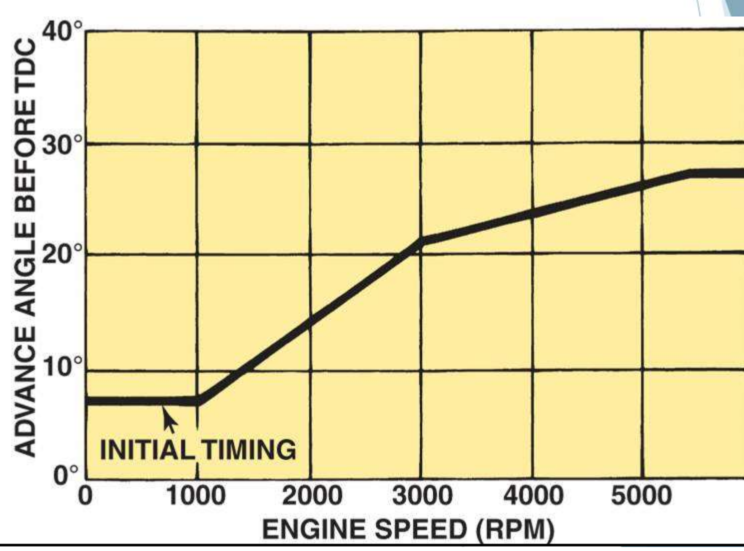
The initial (base) timing is where the spark plug fires at idle speed. Based timing must be advanced as engine speed increases.
Why?



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Normal Combustion

- Under ideal conditions the common internal combustion engine burns the fuel/air mixture in the cylinder in an orderly and controlled fashion
- Combustion is started by the spark plug before TDC
- This ignition advance allows time for the combustion process to develop peak pressure at the ideal time for maximum power from the expanding gases

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Normal Combustion

- The air and fuel mixture is compressed by piston
- When the piston reaches a predetermined point BTDC, the plug fires and starts the combustion process at the plug tip
- The burn should be steady and even as it moves across the chamber
- Pressure rises smoothly to a peak, as nearly all the available fuel is consumed reaching maximum pressure at TDC, then pressure falls as the piston descends
- At the end of the combustion process, all of the air fuel mixture has been burned
- There is no “explosion” – just an even and controlled ignition

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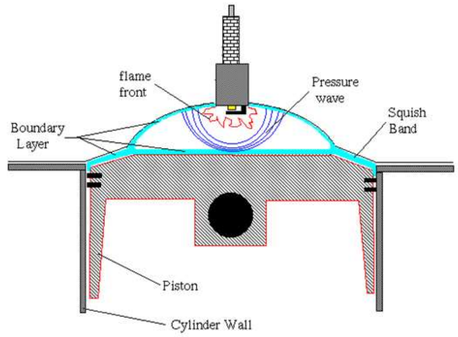

Fig. 2 – Combustion Chamber Side View

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Abnormal Combustion /Detonation

- Unburned fuel mixture beyond the boundary of the flame front spontaneously ignites
- Instantaneous, explosive ignition of a pocket of fuel mixture outside of the flame front

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Detonation / Spark-Knock

- Occurs AFTER the spark plug fires
- Due to pressure and heat usually created under a load
- Results in one or more competing flame fronts that collide
- Rattling noise / pinging
- Noise is caused by sharp spike in cylinder pressure and the rotating assembly of the engine absorbing it
- Causes rod bearing wear
- Caused by:
  - Incorrect octane rating
  - Incorrect ignition spark timing

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Spark Timing

- The need for advancing the timing of the spark is because fuel does not completely burn the instant the spark fires, the combustion gases take a period of time to expand.
- As the engine speed increases the must be advanced so the fuel has time to completely burn before the piston reaches TDC.
- Setting the correct ignition timing is crucial in the performance of an engine.
- Modern engines that are controlled in real time by an engine control unit use a computer to control spark timing.
- 1995 and older vehicles require spark timing be checked during a smog inspection, if the timing is adjustable.

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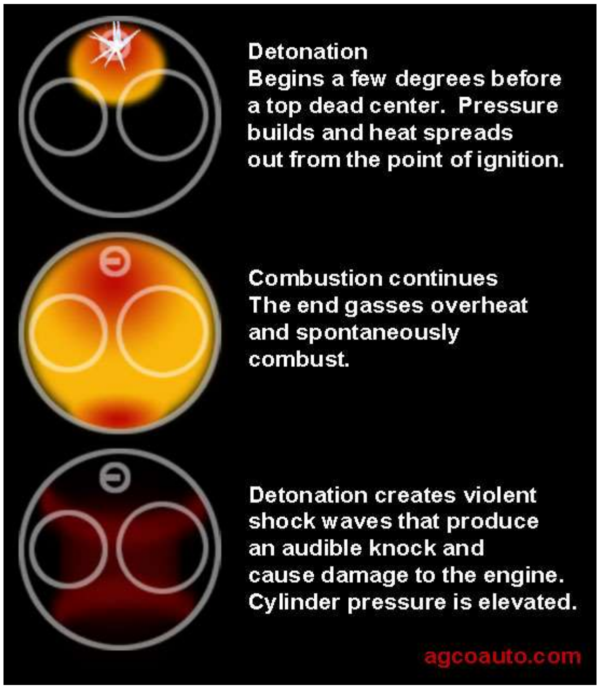

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Abnormal Ignition / Pre Ignition

- Air/fuel mixture ignites before the spark plug fires
- Initiated by an ignition source other than the spark
- Worst possible thing that can happen during the combustion process

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Pre-ignition Damage

35

Causes of Pre-ignition

- Carbon deposits form a heat barrier and can be a contributing factor to pre-ignition.
- Overheated spark plug (too hot a heat range for the application).
- Glowing carbon deposits on a hot exhaust valve
- A sharp edge in the combustion chamber or on top of a piston
- A lean fuel mixture
- An engine that is running hot

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Detonation induced pre-ignition

- Detonation breaks components in the cylinder, such as the spark plug electrode
- Components can start to get very hot over sustained periods of detonation and glow
- Glowing hot parts can cause pre-Ignition
- An engine can run for thousands of miles with mild detonation
- Pre-ignition can destroy an engine in just a few strokes of the piston

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Octane Rating

- Measure of a fuel's ability to resist auto ignition
- The higher octane rating the more compression the gas can withstand before detonating
- Rating of gasoline's Anti-knock properties
- 91 octane pump gas has a higher resistance to knock then 87 octane

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Octane Rating Methods

- Two methods
  - Research method (tested at 600 RPM)
  - Motor method (tested at 900 RPM)
- Anti-Knock Index (AKI) posted on pumps
  - Averages of both methods : (RON+MOM)/2

40

Controlling Spark Knock

- Ignition timing determined by fuel octane
- Timing must be advanced from base timing as RPM is increased to give the fuel time to burn
- At 3000 RPM the piston reaches TDC quicker than at idle, but the fuel still requires the same amount of time to burn
- Computer controlled vehicles
  - Knock sensor: senses pre-ignition and adjust ignition timing to eliminate the knock

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Hydrocarbon Chains

- The shortest chain is methane;   1 carbon atom surrounded by 4 hydrogen atoms
- With each successive hydrocarbon, 1 carbon atom and 2 more hydrogen atoms are added
- Resulting hydrocarbons are: ethane (C2H6), propane (C3H8), butane (C4H10) , pentane, hexane, heptane, and iso-octane.
- The two hydrocarbons molecules used in gasoline are heptane and iso-octane

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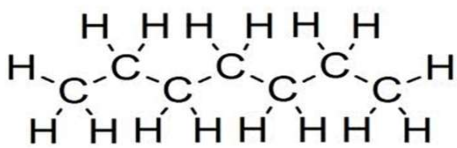
Gasoline Reference Fuels

Heptane

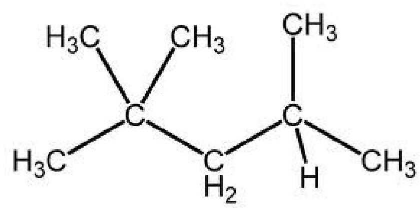
- 7 carbon & 16 hydrogen molecules
- Handles compression poorly
- Compress causes it ignite spontaneously



Octane rating of zero

Iso-octane

- 8 carbon & 18 hydrogen molecules
- Handles compression very well



Octane rating of 100

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Octane Ratings

- Regular: 87 (87% isoctane: 13% heptane)
- Midgrade: 89 (89% isoctane: 11% heptane0
- Premium: 91 (91% isoctane: 9% heptane)
- Aviation Gas (AvGas 100 octane)
- Racing gas: 105-119
- The higher the octane number, the less likely the fuel is to detonate under compression

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Leaded Gasoline

- Tetraethyl lead (TEL) added to gasoline improves octane rating above the isooctane/heptane combination
- Cheaper grades of gasoline could be made usable by adding TEL

45

Leaded Gasoline

- Phased out in 1973
- Banned in the 1986 buy the US Clean Air Act
- It will destroy a catalytic converter within minutes

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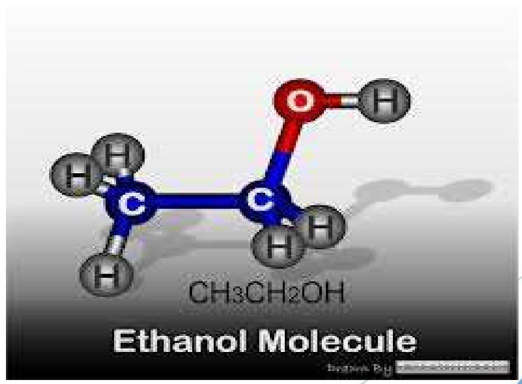
Reduced Emissions

- Ethanol is an oxygenate
- It has an oxygen atom
- Provides extra oxygen at combustion which reduces CO in the exhaust



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Ethanol

- Alcohol molecule from fermentation of grain
- **Added to fuel it increases the octane rating**
- Up to 10% ethanol can be blended with gasoline
- Ethanol is very corrosive, more ethanol than 10% increases risk of damaging fuel system components

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Regular vs. Premium

- Which produces a more power premium or regular gas?
- Why?
- Which burns faster?
- Can you use 87 octane in a vehicle requires 91 octane?

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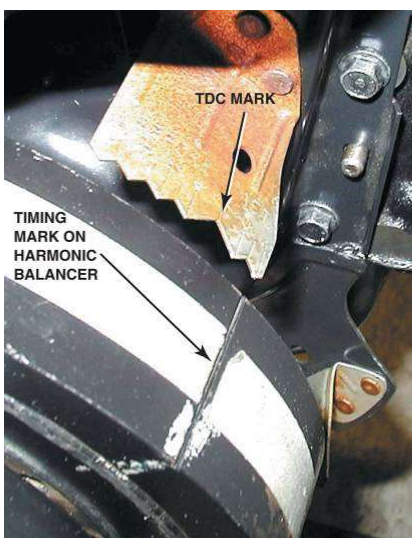
Ignition timing marks are found on the harmonic balancers on engines equipped with distributors that can be adjusted for timing.



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Timing Adjustment Problems During a Smog Inspection

- Functional timing test is required on all 1995 and older vehicles with adjustable timing
- Timing must be +/- 3 degrees of mfgs. recommended setting at idle
- Idle speed must set ant mfgs. recommended RPM +/- 100 RPM
- Inspectors shall check the base ignition timing using the vehicle manufacturer procedures.
- Timing cannot be adjusted during a smog inspection.
- Timing not testable:
  - Timing indicator missing
  - Harmonic balancer slipped on inertia ring
  - RPM too high / cannot be adjusted during a smog inspection
- Any of these will cause a vehicle to fail a smog inspection

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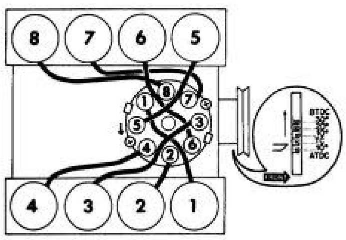
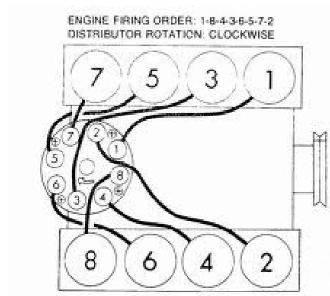
Firing order

- The order in which each cylinder fires starting with #1 cylinder
- Distributor can turn clockwise or counterclockwise



1975–88 8-460; 1979–88 8-302
firing order: 1-5-4-2-6-3-6-7-8
distributor rotation: counterclockwise
NOTE: Squares are the latches on 1975–76 models; circles are the latches on 1977–88 models



1984–86 HEI

53