Automotive Ignition – How it works

A high-level description of how an automotive ignition system (pre-computer controlled engine) operates.

Major Components of an automotive ignition system:

- Ignition coil – The ignition coil is a device that creates the high voltage pulse necessary to produce the electric arc in a spark plug.
- Ignition Resistor – A high power resistor used to limit electrical current. In an automotive ignition application the resistor is used to reduce the voltage supplied to the ignition coil. The resistor is bypassed during cranking in order to supply full battery voltage to the ignition coil in order to generate a “hotter” spark to help start the engine.
- Condenser/Capacitor – A device used to absorb voltage spikes. In an automotive ignition application, the condenser is used to prevent arcing across the points.
- Points – Electrical contacts that open and close based on the position of the cam in the distributor. The points control the ignition coil’s generation of the high voltage pulse.
- Distributor – An engine component that contains the points/electronic ignition and directs the high voltage from the ignition coil to a specific spark plug.
- Electronic ignition – A solid-state electronic device that replaces the points (pre-computer controlled engines).

Definitions:

- Open – The circuit is incomplete or broken, switches are off, no current is flowing in the circuit.
- Closed – the circuit is complete, switches are on, current will flow in the circuit.
- Coil – A coil of wire with multiple turns or windings. Not to be confused with an Ignition Coil.
- Magnetic field – Magnetic energy created by the flow of electric current (electro-magnet) or a permanent magnet.

Electro-magnetism

The ignition coil works on basic electro-magnetic physics, using electricity to create a magnetic field and conversely using a magnetic field to create electricity. Both of these events take place within the ignition coil. The rules are:

- Creating a magnetic field
    - When electrical current flows through a coil of wire, a magnetic field is created around the wire. Think electro-magnet.
    - The strength of the magnetic field is determined by the amount of electrical current flowing through the coil and the number of turns (windings) in the coil of wire.

- Generating electric current
    - When a coil of wire (just a coil of wire, not an ignition coil) moves through a magnetic field, electrical current flows in the wire. Think generator.
    - The amount of current that flows is determined by the strength of the magnetic field and the number of turns (windings) in the coil of wire.

Inside the ignition coil

The ignition coil consists of three main components; the primary coil, the secondary coil and the core.

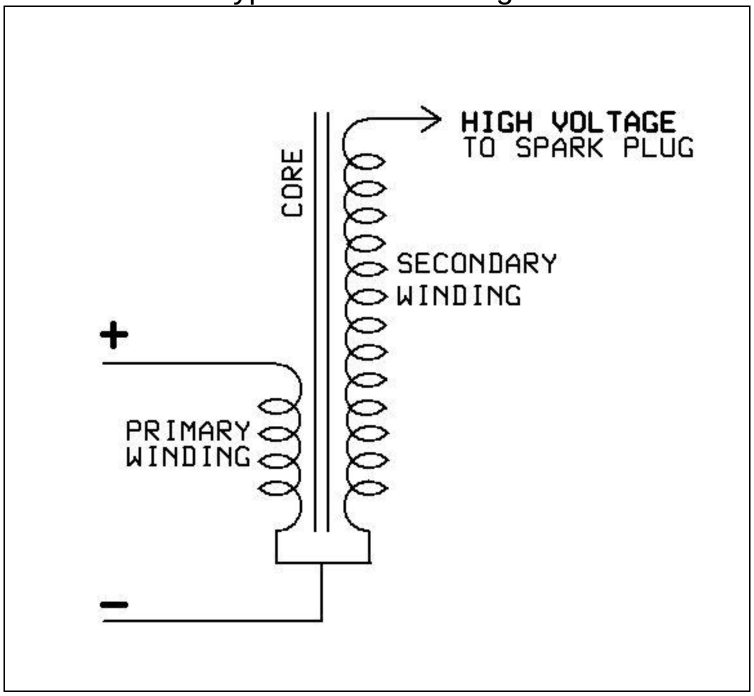
- The primary coil (or windings) creates the strong magnetic field within the ignition coil. Think electromagnet.
- The secondary coil (or windings) generates the high voltage output. Think generator.
- The metallic core magnetically couples the primary and secondary coil to maximize the transfer of magnetic energy between the coils within the ignition coil.

Relative properties of the primary and secondary coils inside the ignition coil

- Primary coil (low voltage, high current)
  - Hundreds of turns (windings)
  - Large gauge wire
  - Powered by vehicle's battery (12 volts)
  - High current (8 – 12 Amps)

- Secondary coil (very high voltage, very low current)
  - Thousands of turns (windings)
  - Extremely small gauge wire
  - Very high voltage output
  - Very low current

Schematic of a typical automotive ignition coil:



How the Ignition Coil works

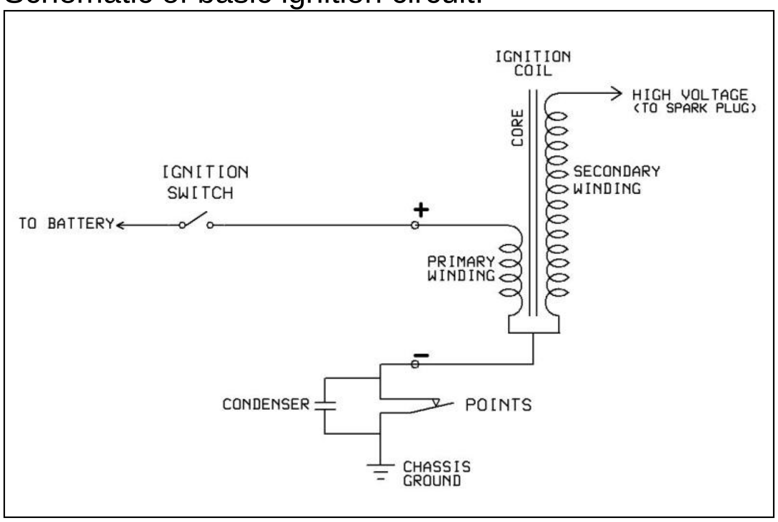
There are three components used to control the operation of the ignition coil:

1. Ignition switch – turns power on and off to the ignition coil
2. Points – Interrupts current flow in the primary coil when the coil needs to "fire"
3. Condenser – prevents the spark from arcing across the contacts of the points instead of the spark plug.

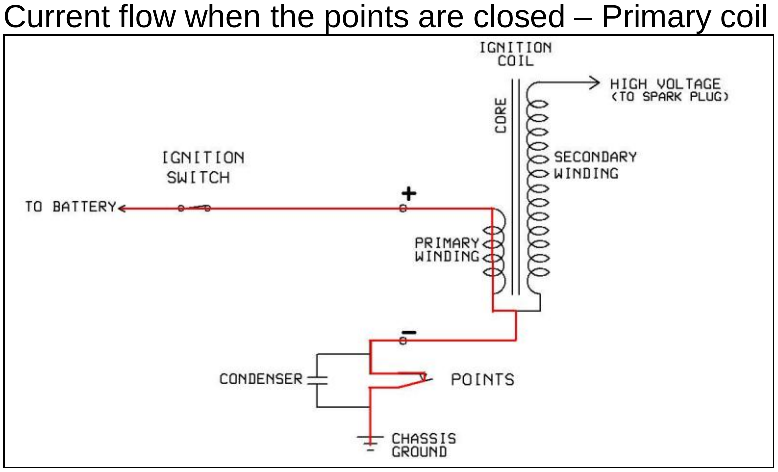
There are three steps in the operation of an ignition coil. They are:

1. Power the primary coil - Power the primary coil to create a strong magnetic field within the ignition coil.
    a. The ignition switch is closed (on). Battery voltage applied to the "**+**" terminal of the ignition coil.
    b. The points are closed. The "**-**" post of the ignition coil is connected to chassis ground via the points.
    c. Electric current from the battery is flowing through the primary coil creating a strong magnetic field within the ignition coil.
2. Open the points - Open the points when it is time to fire the spark plug. It may seem counter intuitive to open (turn off) the power to the primary coil to create the high voltage necessary to fire the spark plug, but that is how it works.
3. Generate high voltage – When the points open the current flow through the primary coil stops and the strong magnetic field created by the primary coil collapses. This collapsing magnetic field causes voltage to be created in the secondary coil. As the magnetic field collapses, it "moves" across the secondary coil. Because the secondary coil has a very large number of windings, this moving magnetic field creates the high voltage in the secondary coil that is connected, via the distributor, to the spark plug.

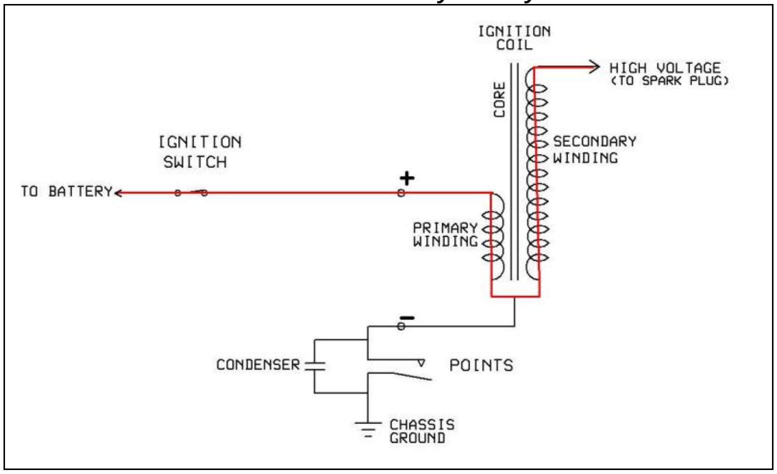
Schematic of basic ignition circuit:



Current flow when the points are closed – Primary coil creating magnetic field



Current flow when the points open – Magnetic field collapses creating high voltage in secondary coil. Current flow is momentary - only for the duration of the spark.



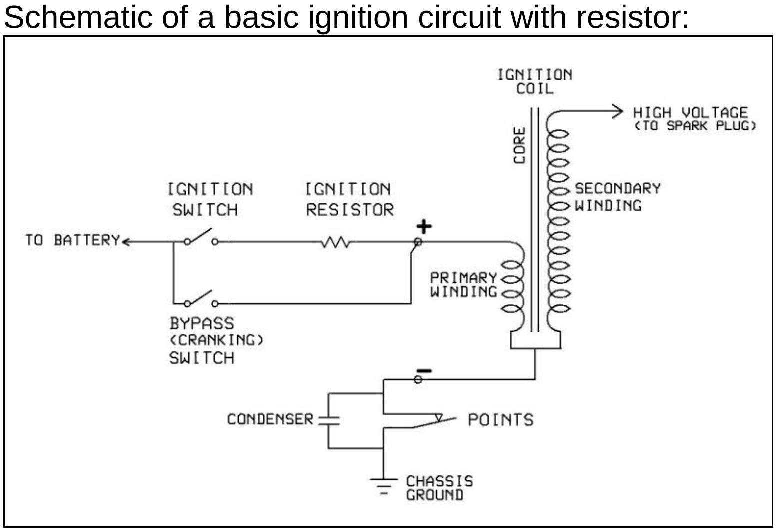
The Condenser

The condenser is actually a capacitor. The purpose of the condenser is to absorb energy (think shock absorber for electricity) and prevent arcing across the points when the points open. Without the condenser, the electricity in the secondary coil would create a path of least resistance by arcing across the points to chassis ground instead of going to the spark plug – and then to chassis ground. The condenser also causes a "ringing" condition with the secondary coil that increases the intensity of the spark.

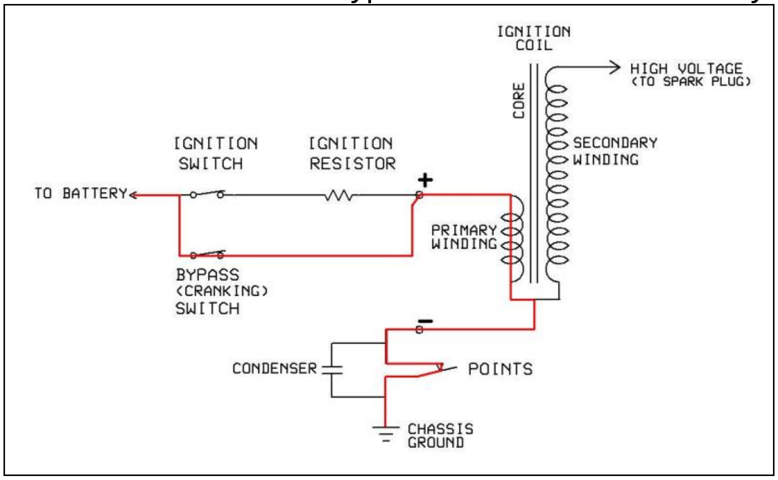
The Ignition Resistor

The purpose of the ignition resistor is to drop the voltage to the ignition coil (**+** terminal) to approximately 6 – 9 volts (varies with vehicle type/make/model). This is the proper operating voltage when the engine is running. During cranking, because the battery voltage is decreased because of the load on the battery from the starter and a "hotter" spark is desirable during cranking to help start the engine, the resistor is bypassed and full battery voltage (12 volts) is applied to the ignition coil. Typically, the ignition switch has an additional circuit that is used to provide the full battery voltage to the ignition coil while the ignition switch is in the crank/start position. Operating an ignition coil designed to be used with a resistor without a resistor will cause the ignition coil to overheat and burn out.

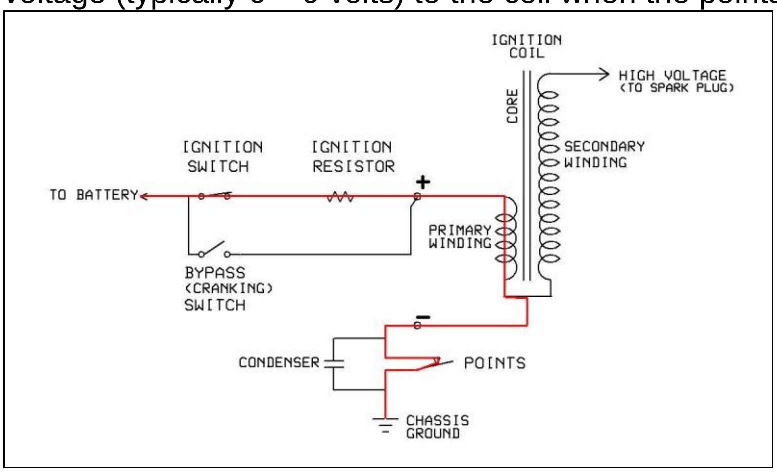
Schematic of a basic ignition circuit with resistor:



Current flow while cranking – Both switches closed (ignition and bypass) current takes the path of least resistance and bypasses resistor. Full battery voltage to coil



Current flow while running – Bypass switch off, current flows through the resistor reducing the voltage (typically 6 – 9 volts) to the coil when the points are closed

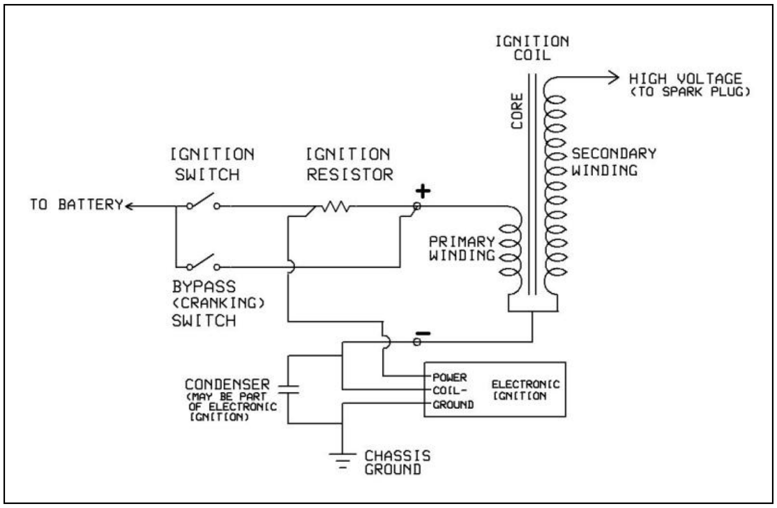


Note: When the points are open, no current is flowing through the resistor so there is no voltage drop. Consequently full battery voltage (12 volts) will appear at the "+" terminal of the coil when the points are open.

Electronic Ignition

The mechanical points in the vehicle's distributor are a high wear and high maintenance item. OEM or aftermarket electronic ignition devices are use to replace the points. Electronic ignitions use Hall Effect sensors to detect the presence of the cam on the distributor shaft and open the circuit to the ignition coil. High powered electronic switching devices are used to emulate the action of the points to turn on and off the ignition coil's "**-**" connection to chassis ground. In additional to the wire from the electronic ignition device to the "**-**" terminal on the ignition coil, and possibly a ground wire from the electronic ignition device to chassis ground, a power wire (+12 volts) is typically required to power the circuitry inside the electronic ignition device.

Typical electronic ignition circuit. The electronic ignition has the same functionality as the points (interrupt current flow in the primary winding) without the high maintenance and short life span of electro-mechanical points.



Troubleshooting

Possible component failures

- Coil
  - Primary coil burns out – can be caused by using the coil (that was designed to be used with a resistor) without a resistor.
  - Secondary coil shorts internally – With age the insulation breaks down on the secondary windings and the spark occurs inside the coil and never gets to the spark plug.
- Condenser
  - Fails internally so it does not prevent the point's contacts from arcing when the points open. Arcing occurs at the points instead of at the spark plug.
  - Condenser is internally shorted so there is no interruption of the current through the primary winding when the points open – current goes through condenser when the points are open.
- Ignition Resistor
  - Resistor can become intermittent with age and temperature.
  - An indicator of a failed resistor is the engine starting while cranking (power to coil via the bypass switch) and then the engine stalls when the ignition switch is returned to the run position (bypass switch is open and current to the coil is blocked by the open resistor.
- Ignition wires
  - With age and heat the insulation on the ignition wires breaks down. Wires that are in contact with metal parts can deteriorate allowing arcing to ground through the wire's insulation.
  - Resistor ignition wires (carbon fibers) are used to suppress ignition noise that can interfere with the vehicle's radio. With age the carbon can clump causing gaps that block the flow of the high voltage to the spark plug.
- Moisture
  - With age cracks develop in all of the high voltage components (coil, distributor cap, rotor, ignition wires, etc.). During high moisture/condensation conditions the moisture gets into these cracks and diminishes the insulation properties of the component causing arcs to find a path to ground before they get to the spark plug
- Hint - An in-line indicator light is useful to be able to see when the coil is creating a spark. A timing light can also be used.

WARNING

- Avoid "firing" a coil with out a load (spark plug). A coil should have a spark plug attached to it whenever it is fired. A tremendous amount of high voltage energy is generated inside the coil in order to create the spark at the spark plug. If there is no spark plug connected to the coil, the energy in the coil has no place to go – so it will try to find a path to ground in a way that is not good. This is one of the circumstances that causes the insulation on the secondary winding to break down resulting in internal shorts and ruining the coil.
- Automotive ignition coils can create thousands of volts. Getting shocked by an ignition coil hurts! Ask me how I know. Be careful.

Disclaimer

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If you try this at home (more likely on your vehicle), I am not responsible or liable for any damage you create or injuries you incur.