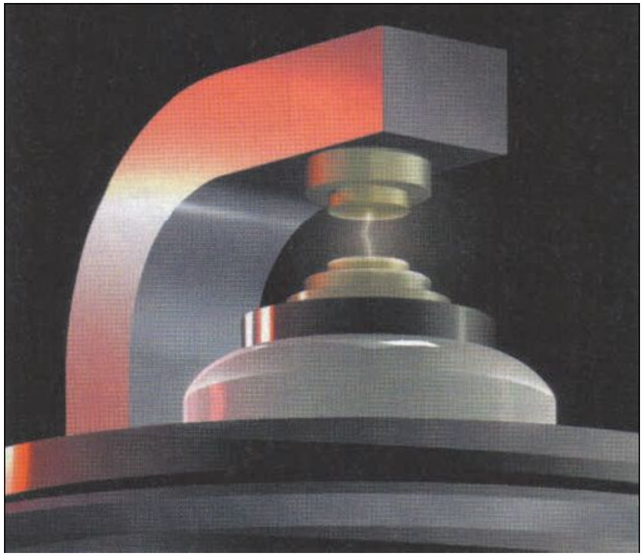
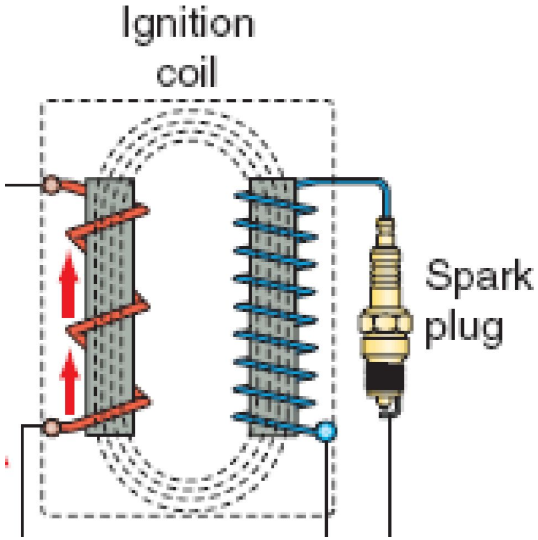
Internal Combustion Engine



Ignition Systems

Aleksey Terentyev

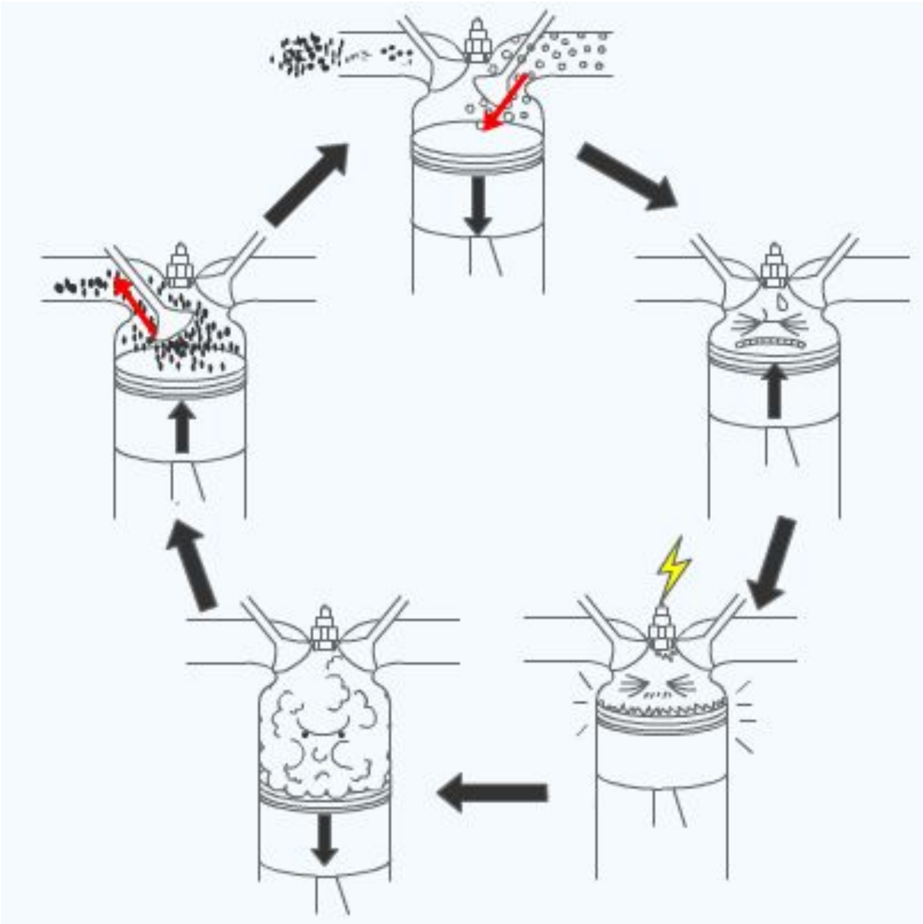


INTRODUCTION

Do you remember the stages of operation in a two-stroke and a four-stroke engine?

In each cylinder of the engine, the piston rises during the compression stage to compress the air–fuel mixture in the combustion chamber. Just before the piston reaches the top-dead center (TDC), a spark plug fires in the cylinder and ignites the compressed air–fuel mixture. The ignition of the air–fuel mixture forces the piston down in the cylinder, producing the power stage.

The power produced by the ignition of the air–fuel mixture turns the crankshaft, which in turn keeps the piston moving and the engine running.



One of the requirements for an efficient engine is the correct amount of heat, delivered at the right time. This requirement is met by the ignition system. The ignition system supplies properly timed, high-voltage surges to the spark plug(s). These voltage surges cause combustion inside the cylinder.

The ignition system must create a spark, or current flow (Figure 1), across each pair of spark plug electrodes at the proper instant, under all engine operating conditions.

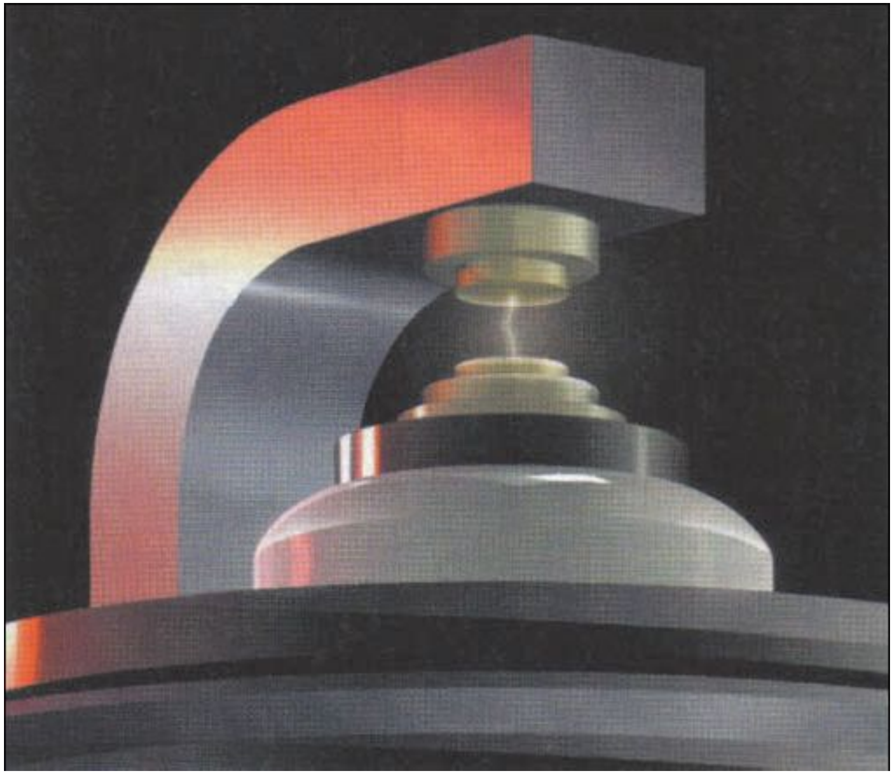


Figure 1 The spark in combustion chamber

POWER EQUIPMENT ENGINE IGNITION SYSTEMS

The sole purpose of an ignition system is to provide a spark that will ignite the air–fuel mixture in the combustion chamber. The spark must be timed to occur at a precise point relative to the position of the piston as it reaches TDC on the engine’s compression stroke. The difference between various ignition systems lies in how the spark is activated. In some of today’s larger power equipment engines, ignition systems are used in unison with electronic fuel injection systems.

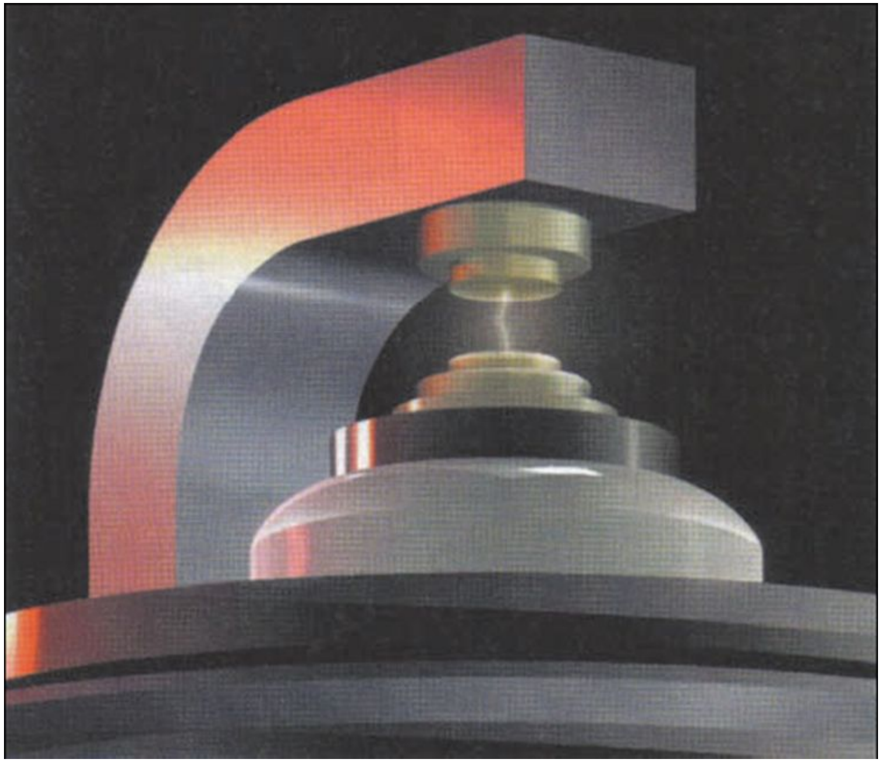


Figure 1 The spark in combustion chamber

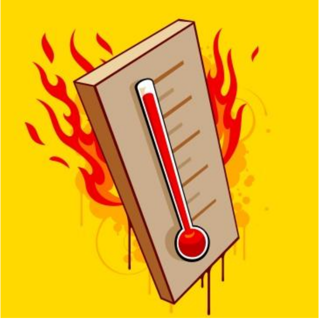
Three main functions of the ignition system

For each cylinder in an engine, the ignition system has the following three main functions:

1. It must generate an electrical spark that has enough heat to ignite the air–fuel mixture in the combustion chamber;

2. It must maintain that spark long enough to allow for the combustion of all the air and fuel in the cylinder;

3. It must deliver a spark so that combustion can begin at the right time during each compression stroke of the piston.



The ignition advance

For an engine to produce the maximum amount of power it can, the maximum pressure from combustion should be present when the piston is at 10–23° after top-dead center (ATDC). Because combustion of the air–fuel mixture within a cylinder takes a short period of time, usually measured in thousandths of a second (milliseconds), the combustion process must begin before the piston is on its power stroke.

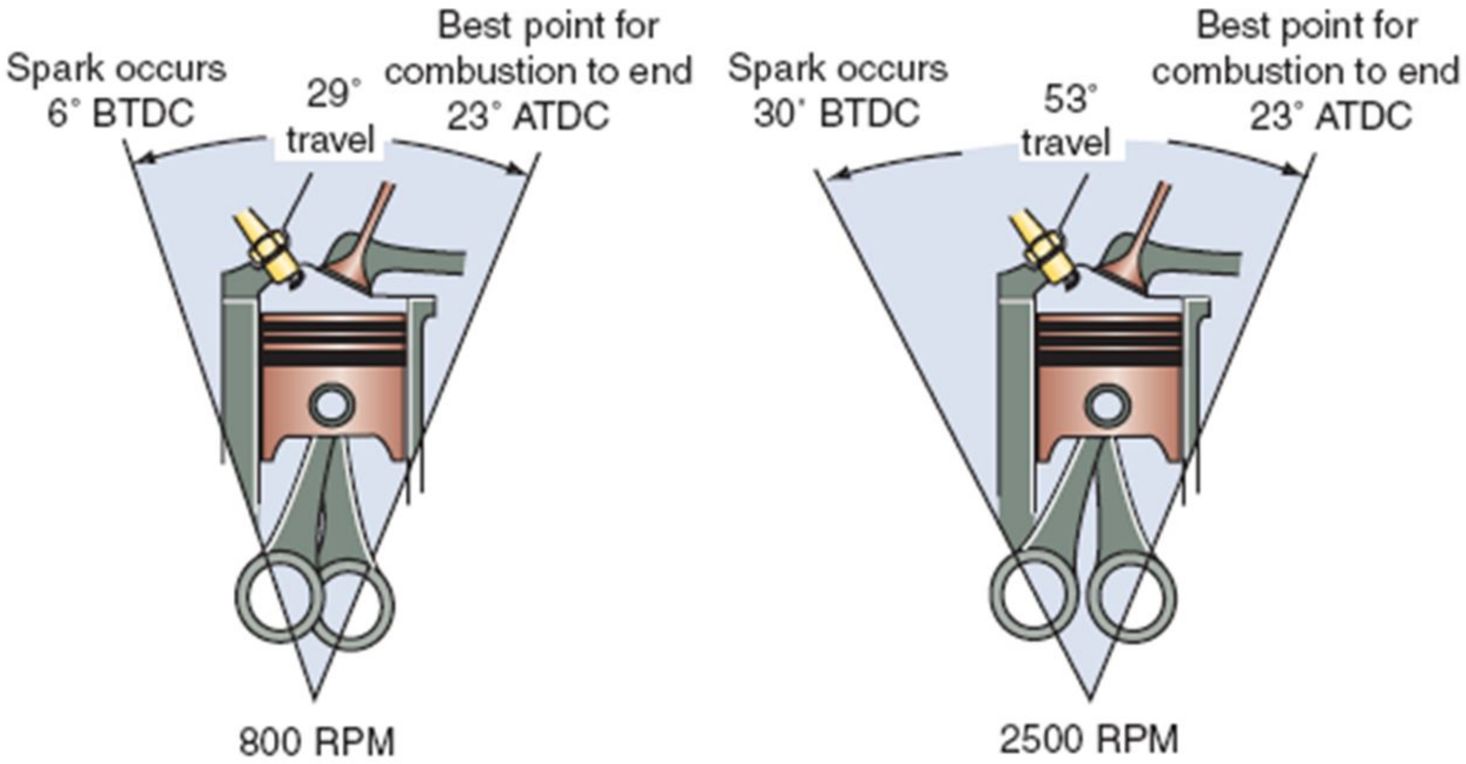


Figure 2 As an engine's speed increases, a spark must be delivered sooner to allow for complete combustion of the air–fuel mixture. This is known as ignition advance.

The ignition advance

Therefore, the delivery of the spark must be timed to arrive at some point just before the piston reaches TDC. Determining how much time before TDC the spark should begin is complicated. This is because even as the speed of the piston moving from its compression stroke to its power stroke increases, the time needed for combustion stays about the same. This means that, as the engine's speed increases, the spark should be delivered earlier (Figure 2).

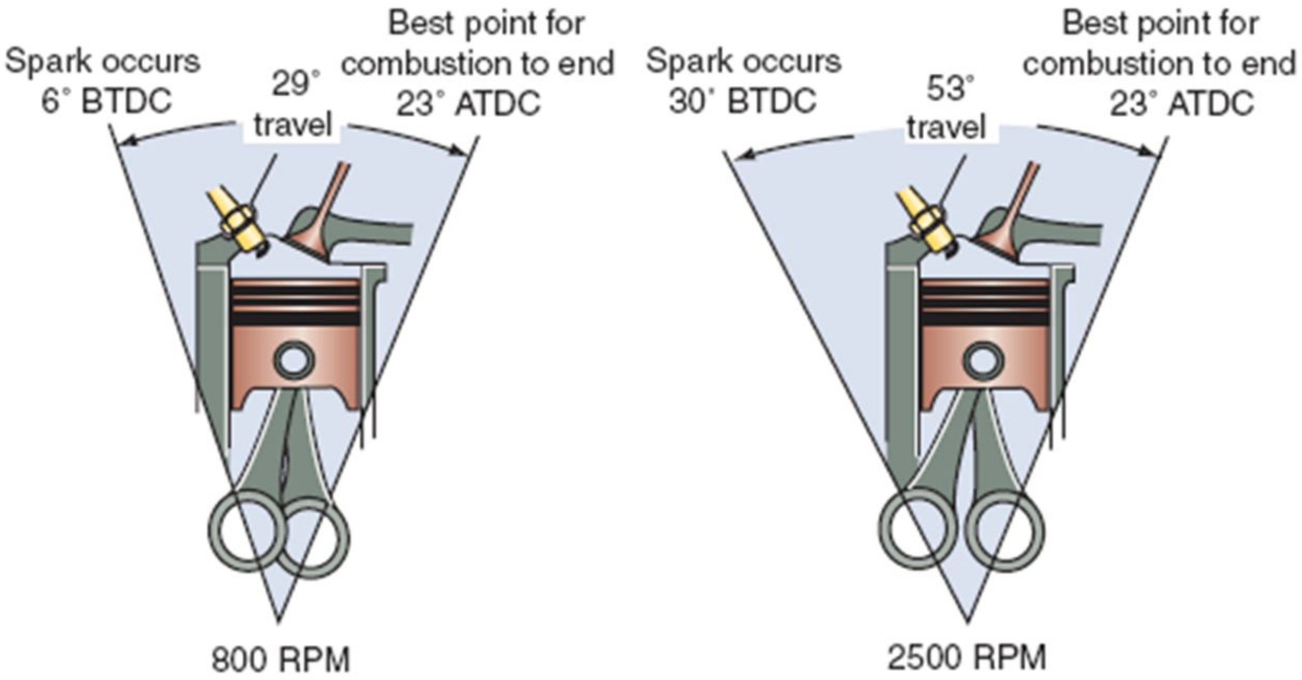


Figure 2 As an engine's speed increases, a spark must be delivered sooner to allow for complete combustion of the air–fuel mixture. This is known as ignition advance.

However, at high speeds, as the engine has to provide more power to do more work, the high load on the crankshaft tends to slow down the acceleration of the piston, in which case the spark needs to be accordingly delayed.

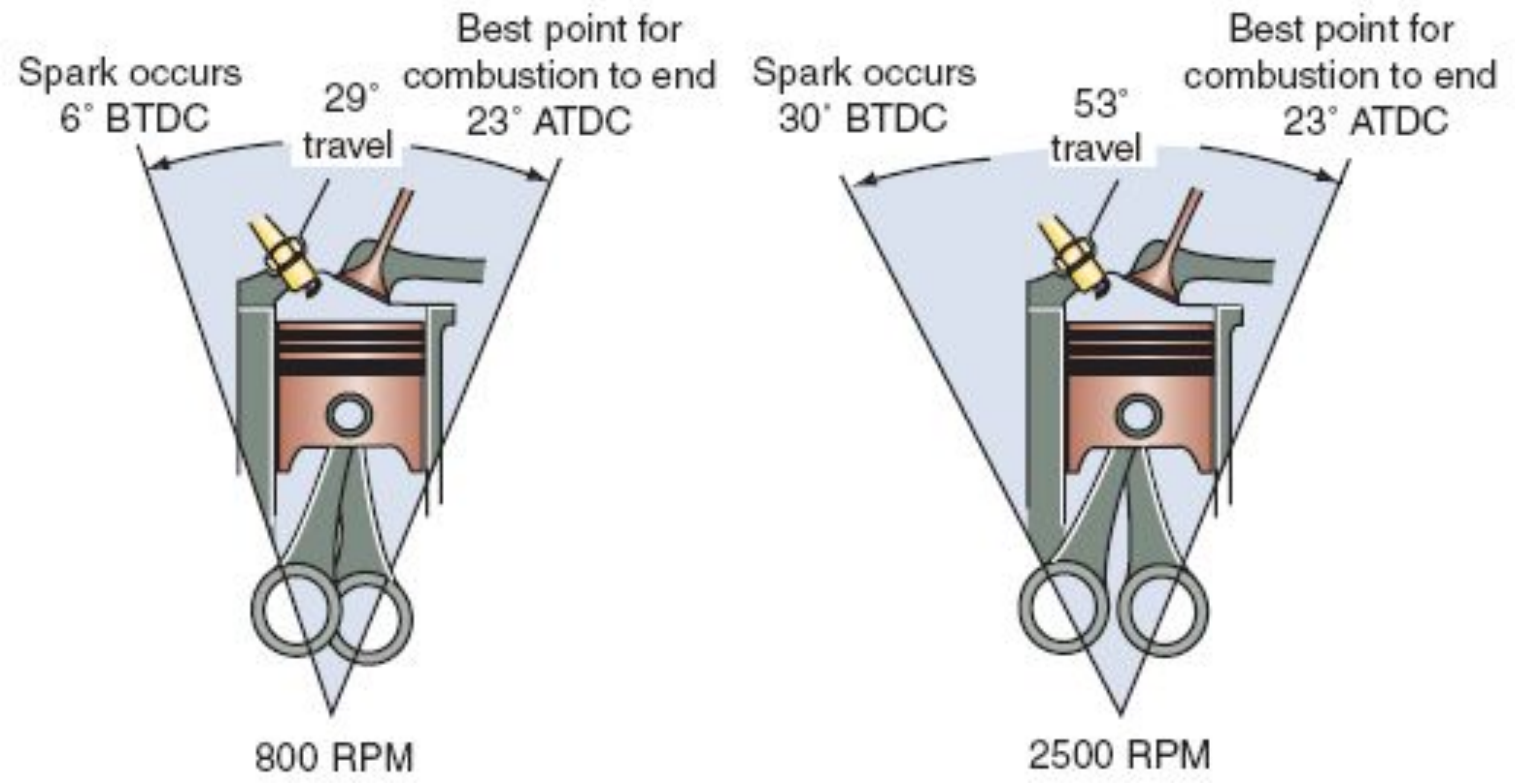
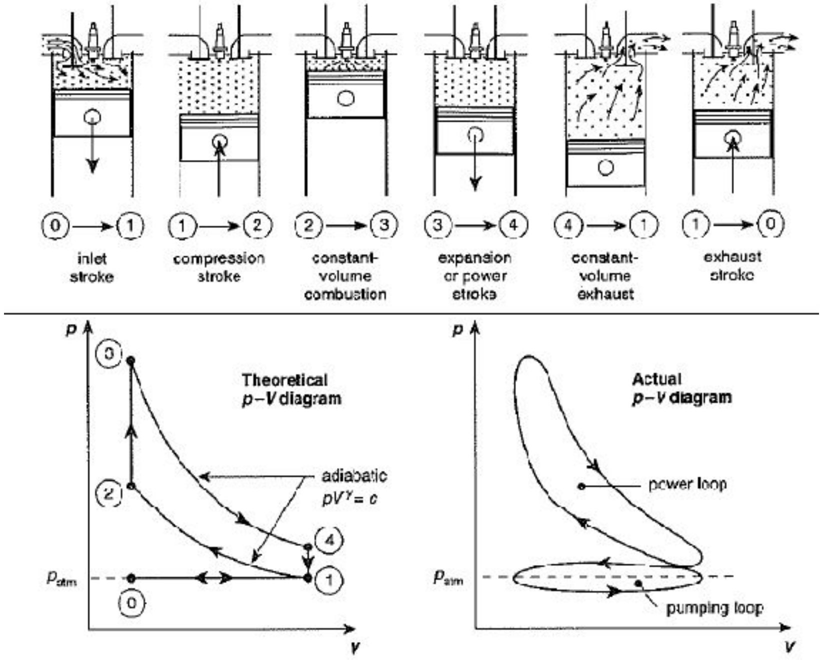


Figure 2 As an engine's speed increases, a spark must be delivered sooner to allow for complete combustion of the air–fuel mixture. This is known as ignition advance.

Factors of the combustion

Figuring out when the spark should begin gets more complicated because the rate of combustion varies, depending on certain factors. Higher compression pressures tend to speed up combustion. A higher-octane gasoline ignites less easily and requires more burning time. Increased vaporization and turbulence tend to decrease combustion times. Other factors, including intake air temperature, humidity, and barometric pressure, also affect combustion. Because of all of these complications, delivering the spark at the right time is a difficult task.



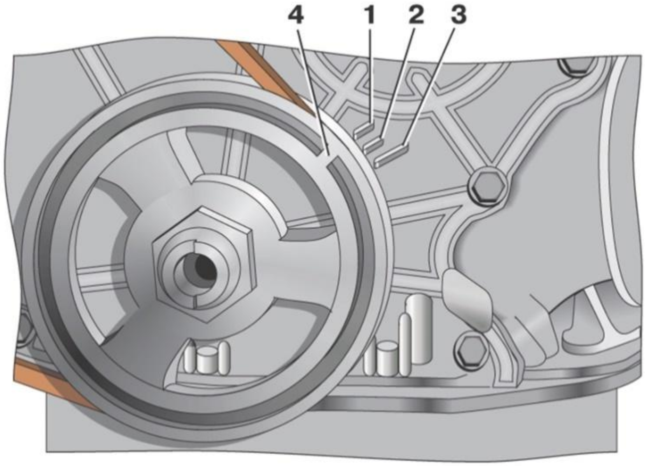
How does an ignition system produce a spark, time it perfectly, and keep making sparks over and over again?

Let's find out.

Ignition Timing

Ignition timing refers to the precise time spark occurs. It’s specified by referring to the position of a manufacturer-determined piston (generally the No. 1 piston on the crankshaft in multicylinder engines) in relation to crankshaft rotation. Ignition timing reference marks are sometimes located on the engine’s crankshaft flywheel/rotor to indicate the position of the piston.

Power equipment engine manufacturers specify initial or base ignition timing. Some engines don’t require such markings because the ignition systems are fixed in one position and are not adjustable.



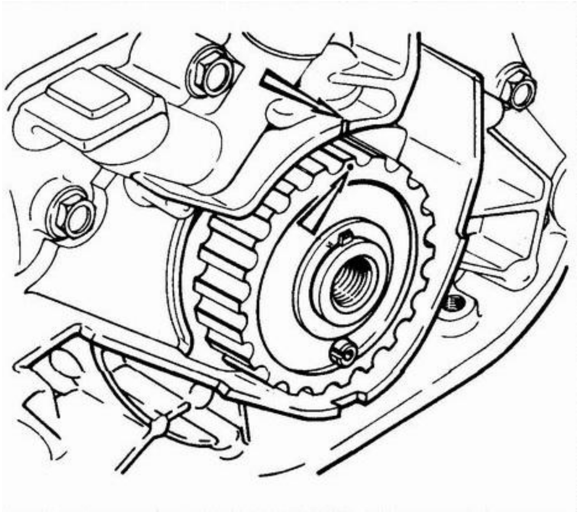


Figure 2a Marks on crankshaft pulley and crankshaft sprocket.

Primary factors of ignition timing

When the marks are aligned at TDC, the piston is at the TDC of the engine's stroke. Additional marks indicate the required number of degrees of crankshaft rotation before top-dead center (BTDC) or ATDC. In a majority of engines, the initial timing is specified at a point between TDC and 12…15° BTDC, depending on the manufacturer's predetermined specification.

Although most power equipment engines are designed to run over a relatively small engine rpm range (for instance, 600–6000 rpm), if optimum engine performance is to be maintained, the ignition timing of the engine must change as the operating conditions of the engine change.

These conditions affect the speed of the engine and the load on the engine. Therefore, all ignition timing changes are made in response to these primary factors.

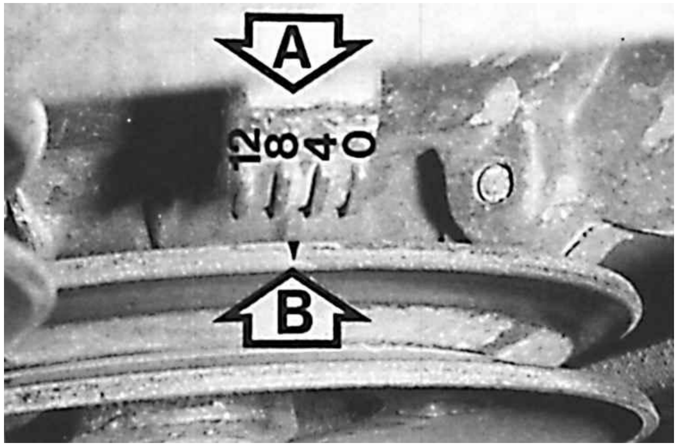


Figure 2b Marks on crankshaft pulley and front cover of engine

Ignition Timing Advance

Power equipment engines generally run at relatively stable engine speeds, and so ignition advance isn't required. But in some engines, speed varies a lot and ignition timing needs to be varied accordingly. In such cases, it's necessary to advance or retard ignition in some engines. Two methods are used in power equipment engines to advance ignition (Figure 3).

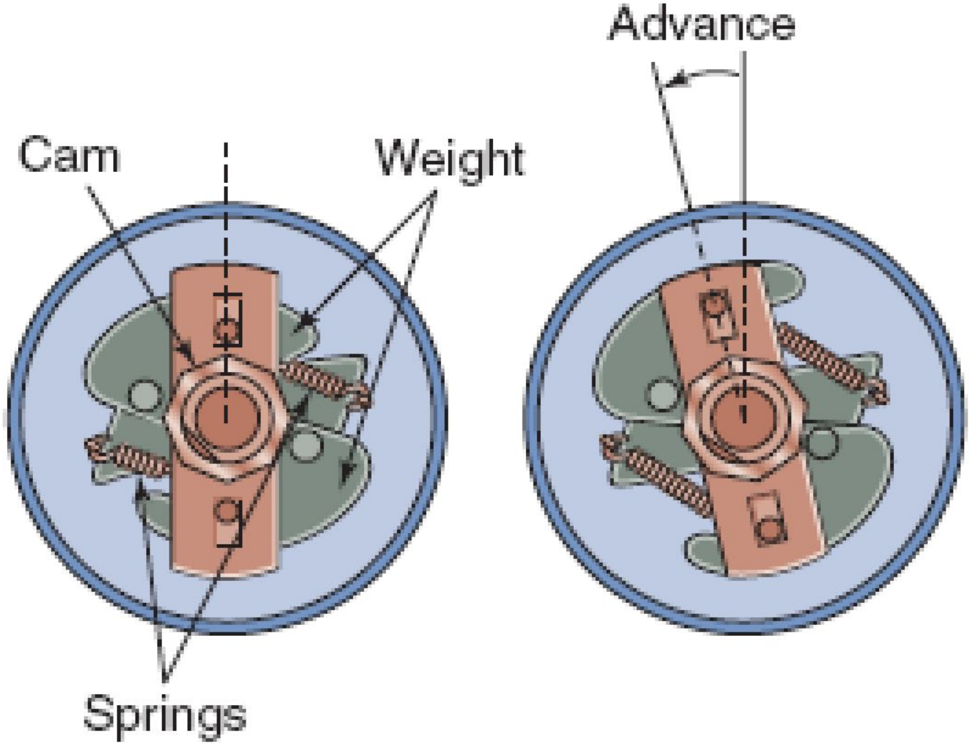


Figure 3 The centrifugal advance mechanisms

Ignition Timing Advance

Ignition systems in older power equipment engines that require ignition timing advance are equipped with centrifugal advance mechanisms, which advance or retard ignition timing in response to engine speed. Centrifugal advance uses a set of pivoted weights and springs connected to a shaft with the point cam (crankshaft or camshaft) attached to it.

When engine speed increases, the weights move outward, shifting the plate where the triggering device is mounted.

This shifting of the plate causes the triggering device to receive its signal earlier, causing an advance in the ignition timing.

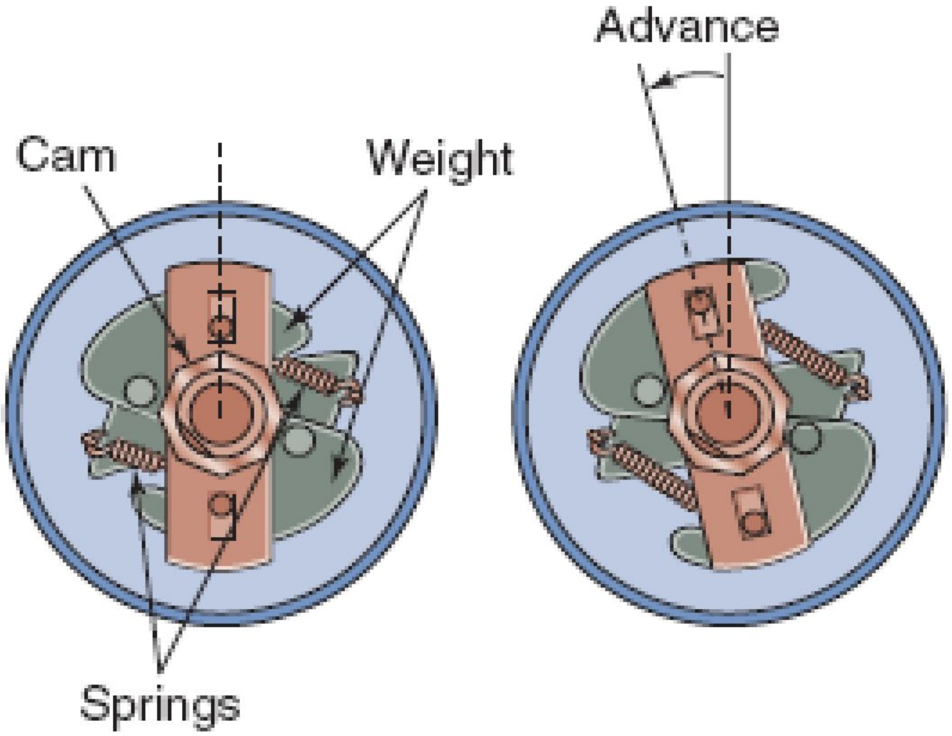


Figure 3 The centrifugal advance mechanisms

Electronic advance systems

Most all modern day power equipment engines that require advance use an electronic advance system to control the ignition. Electronic advance systems require no adjustment, have no mechanical parts, and therefore don’t wear out.

The design eliminates the need for maintenance. Electronic advance systems use multiple sensors to determine the correct timing advancement for any given condition. They offer a greater variety of timing choices for different engine running conditions instead of basically only two, as is case with centrifugal advance systems.

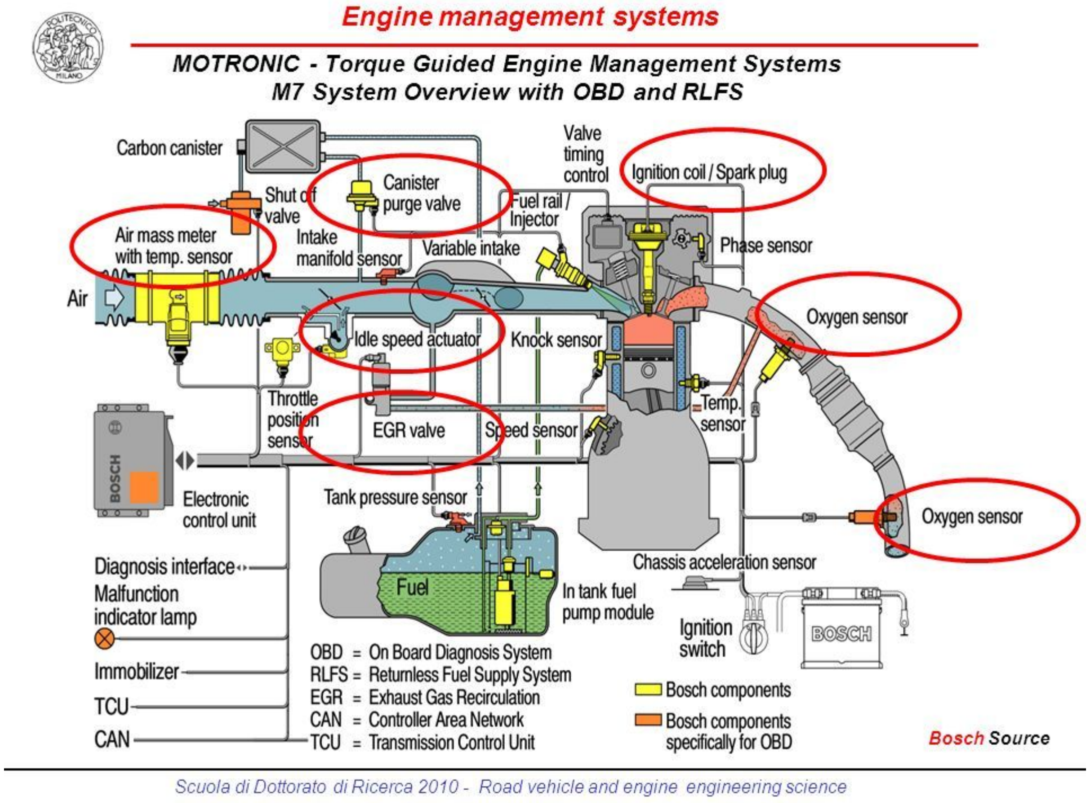


Figure 3a The electronic advance system

Engine rpm and Turbulence

At higher rpm, the crankshaft turns through more degrees in a given period of time. If combustion is to be completed by a particular number of degrees ATDC, ignition timing must occur sooner—or be advanced—by the use of a mechanical or electrical advancer. The advancer is generally attached on the crankshaft.

Another complication that arises at high rpm is the turbulence (swirling) of the air–fuel mixture, which increases with rpm. This causes the mixture inside the cylinder to turn faster. Increased turbulence requires that ignition must occur slightly later—or be slightly retarded—by the use of the advancer.

These two factors—high rpm and increased turbulence—must be balanced for optimum engine performance. Therefore, although ignition timing must be advanced as engine speed increases, the amount of advance must be decreased to compensate for the increased turbulence.

Engine Load

The load on an engine is related to the work it must do. For example, cutting deep grass or pulling extra weight increases engine load. At higher loads, there is greater resistance on the crankshaft; therefore, the piston has a harder time moving through their strokes.

Under light loads and with the throttle partially open, a high vacuum exists in the intake manifold. The amount of air–fuel mixture drawn into the manifold and cylinders is small. On compression, this thin mixture produces less combustion pressure, and combustion time is increased. To complete combustion by the desired degrees ATDC, ignition timing must be advanced.

Under heavy loads, when the throttle is open fully, a larger mass of air–fuel mixture is drawn in, and the vacuum in the manifold is low. High combustion pressure and rapid burning result. In such cases, ignition timing must be retarded to prevent completion of burning before the crankshaft has reached the desired degrees ATDC.

Firing Order in Multi-Cylinder Engines

Up to this point, we’ve focused primarily on ignition timing as it relates to any one cylinder. However, the function of an ignition system extends beyond timing the spark in a single cylinder. In multi-cylinder engines, it must perform this task for each cylinder of the engine in a specific sequence.

In the case of a multi-cylinder four-stroke engine, each cylinder of the engine must produce power once in every 720° of crankshaft rotation. Each cylinder must have a power stroke at its own appropriate time. To make this possible, the pistons and connecting rods are arranged in a precise fashion called the engine’s **firing order.**

The firing order is arranged to reduce rocking and imbalance problems. Because the potential for this rocking depends on the design and construction of the engine, the firing order varies from engine to engine. Engine manufacturers simplify cylinder identification by numbering each cylinder. Regardless of the firing order used, the No. 1 cylinder always starts the firing, with the rest of the cylinders following in a fixed sequence.

The ignition system must be able to “monitor” the rotation of the crankshaft and the relative position of each piston to determine which piston is on its compression stroke. It must also be able to deliver a high-voltage surge to each cylinder at the proper time during its compression stroke. How the ignition system does these things depends on the design of the system.

BASIC IGNITION SYSTEM COMPONENTS

Figure 4 shows a simplified drawing of a basic ignition system. The main components of the system are the following:

- ■ Power source
- ■ Ignition switch
- ■ Ignition coil
- ■ Spark plug
- ■ Triggering switch
- ■ Stop switch

All ignition systems contain these components. The difference is how the components function.

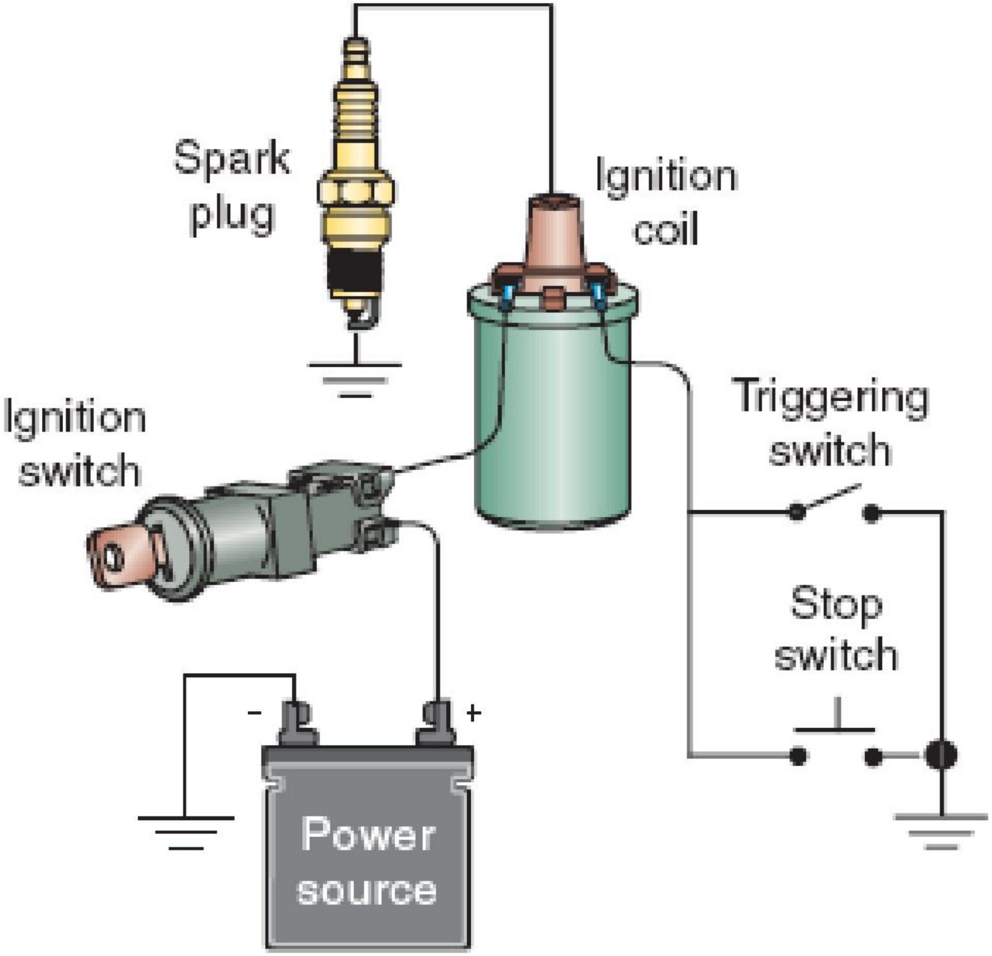


Figure 4 The basic components of an ignition system.

Power Sources

In power equipment engine ignition systems, there are just two power source options. These power sources are the battery [for direct current (DC)] or the AC generator [for alternating current (AC)].

In a battery ignition system, a battery is connected to the ignition coil. A triggering switch device is used to alternately turn the DC voltage on and off for its operation.

AC generator power sources are far more common than battery systems for power equipment engines, and in most cases, they're designed to be run without a battery. The AC-powered ignition system uses the principles of magnetism to produce a voltage.

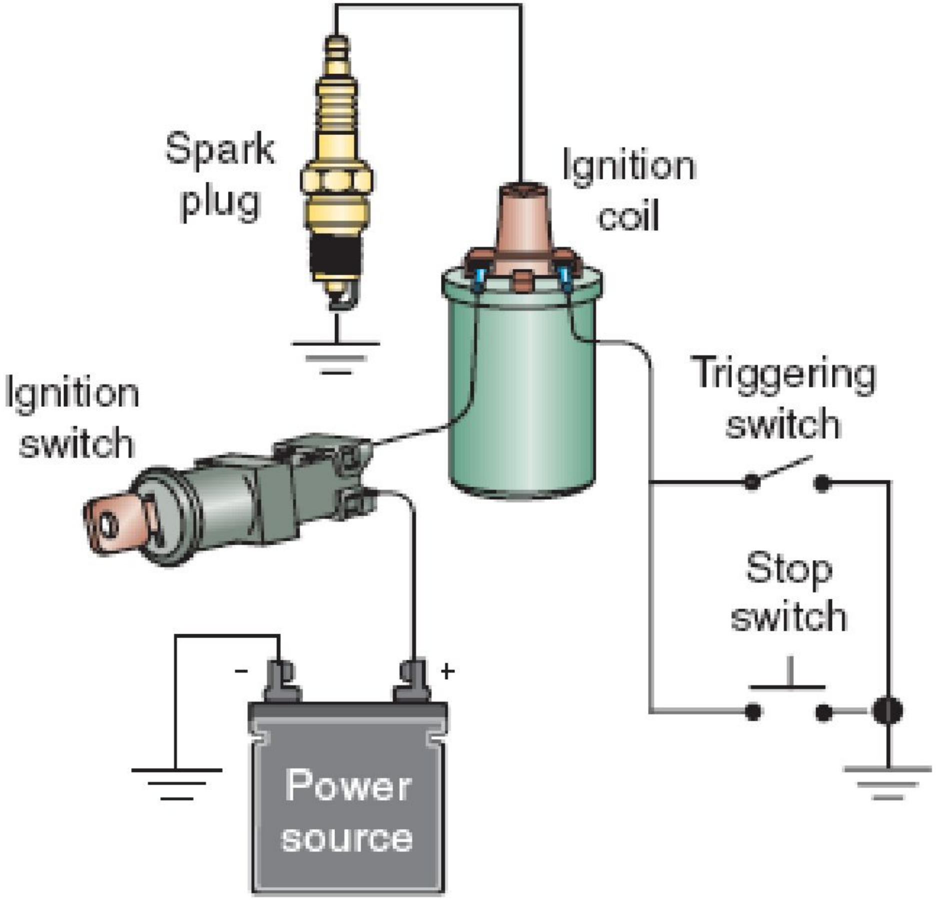


Figure 4 The basic components of an ignition system.

Power Sources

Remember that when a conductor wire is moved through a magnetic field, a voltage is induced in the conductor. It's also true that if a magnet is moved near a conductor, a voltage is induced in the conductor. If this conductor wire is connected to a complete circuit, current will flow in the circuit.

In an AC ignition system, permanent magnets are installed in the engine's flywheel/rotor. As the flywheel/rotor turns, the moving magnets cause a voltage to be induced in the ignition coil.

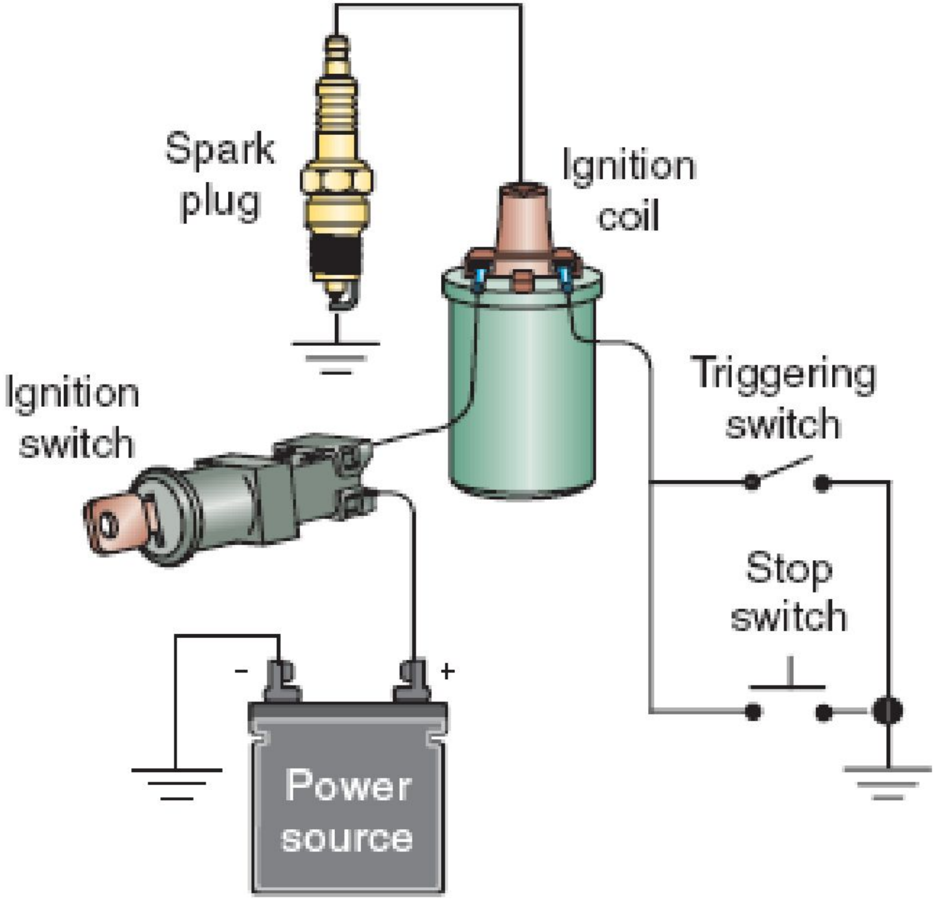


Figure 4 The basic components of an ignition system.

Ignition Switch

The ignition switch allows the power source to provide electrical power to the ignition system. It’s generally a key-type switch that also powers all components that use a power source, such as lights and accessories.

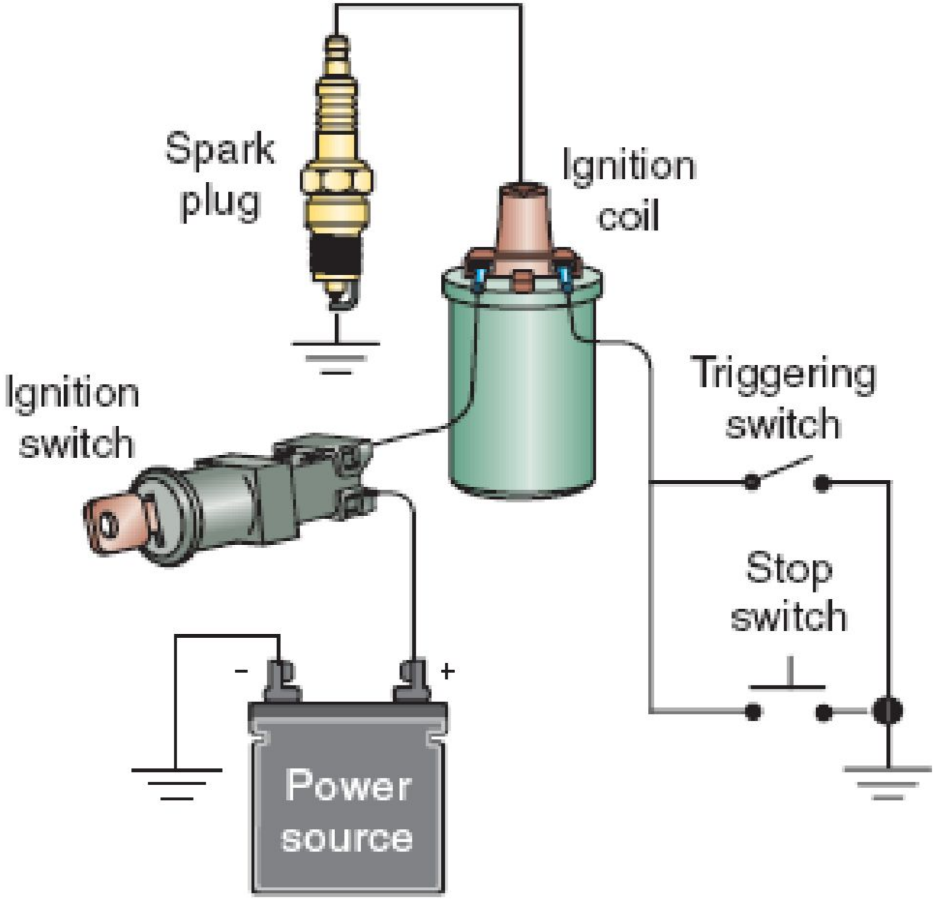


Figure 4 The basic components of an ignition system.

Ignition Coil

An **ignition coil** is essentially a transformer that consists of two wire windings wound around an iron core (Figure 5). The first winding is called the primary winding, and the second winding is called the secondary winding. The secondary winding has many more turns of wire than the primary winding.

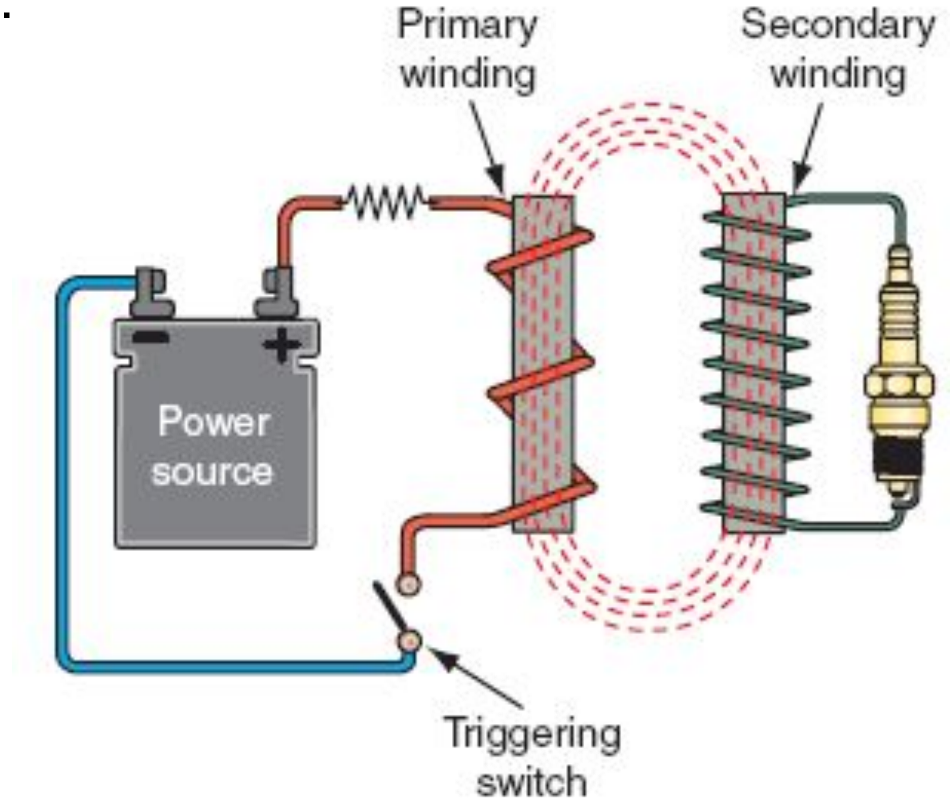


Figure 5 A basic transformer.

Ignition Coil

In an ignition coil, one end of the coil's primary winding is always connected to a powersource. Depending on the type of ignition system, the power source may be a battery (providing DC (direct current)) or a flywheel/rotor with a permanent magnet (providing AC (alternating current)). Either type of power source can be used to apply a voltage to the primary winding of the coil.

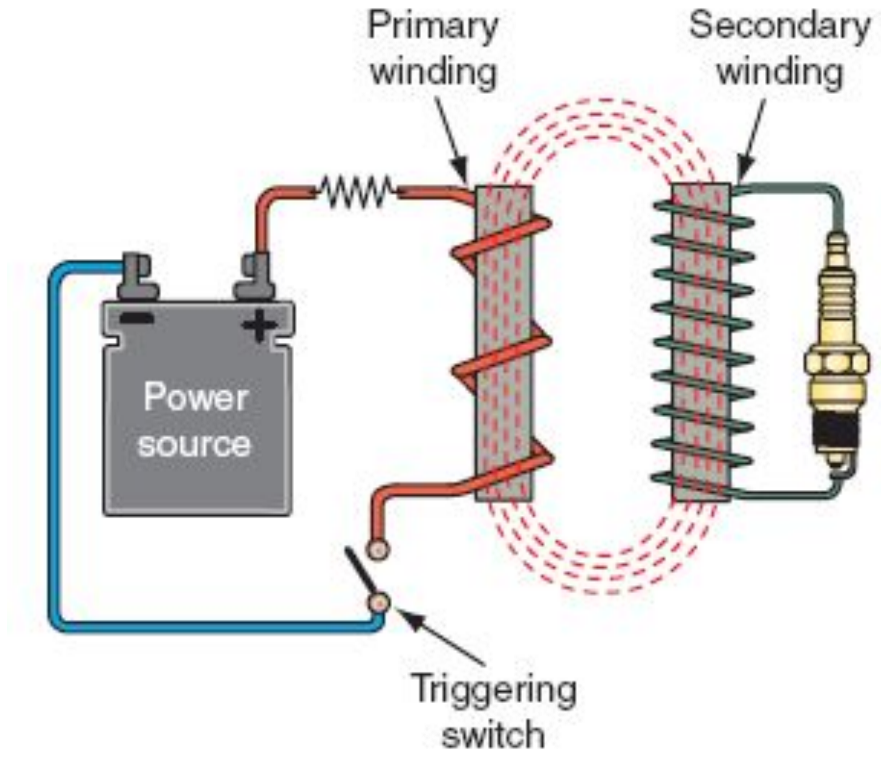


Figure 5 A basic transformer.

When a voltage is applied to the primary winding, a voltage is induced into the secondary winding that's many times greater than the voltage in the primary winding.

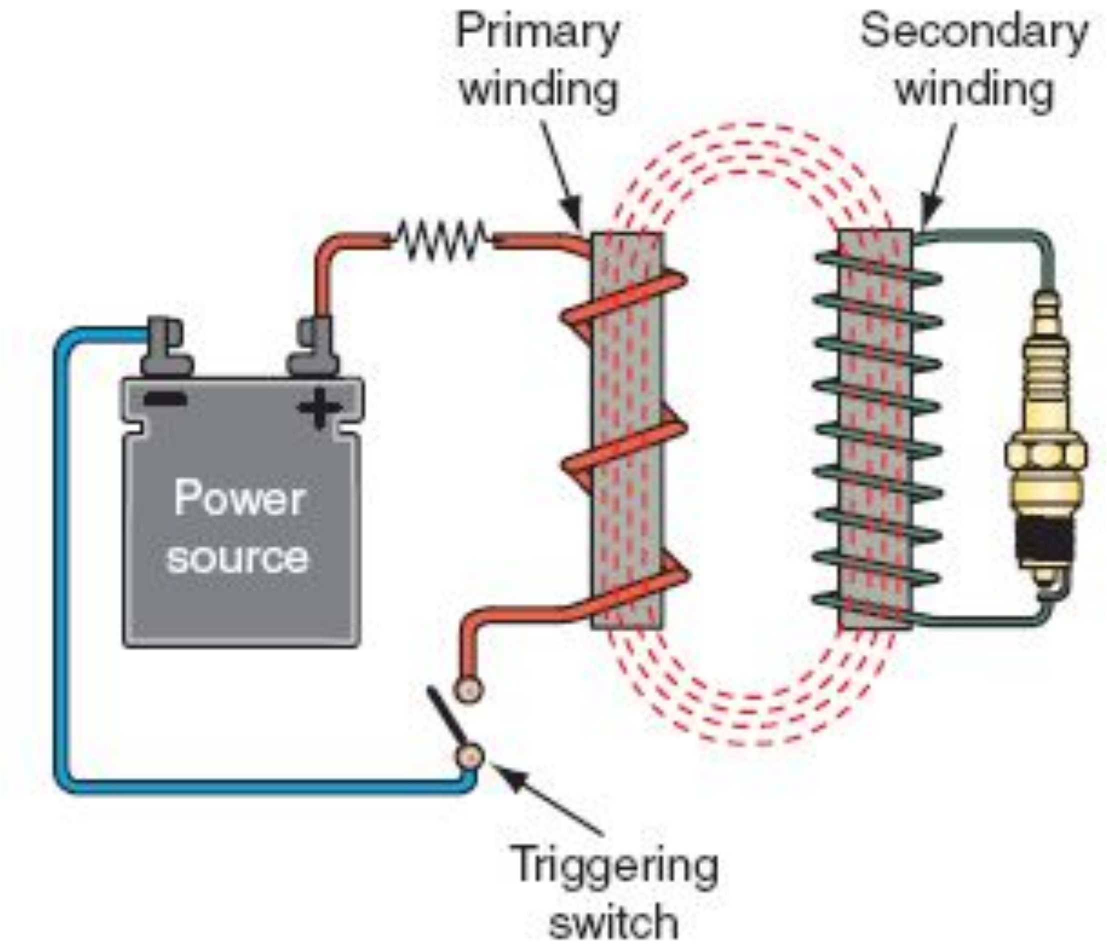


Figure 5 A basic transformer.

20,000–60,000 volts

When current passes through the primary winding of the coil, a magnetic field is created around the iron core. As the magnetic field expands, the magnetic lines of flux cut through the wires of the secondary winding and induce a voltage in the secondary winding.

If the current in the primary winding is switched off, a voltage is again induced into the secondary winding by the magnetic lines of flux, which again cut through the secondary winding. The direction of current induced into the secondary winding is reversed each time the current in the primary is turned on and off. This is because the magnetic lines of force around the iron core cut through the secondary winding in opposite directions as the magnetic field expands and collapses.

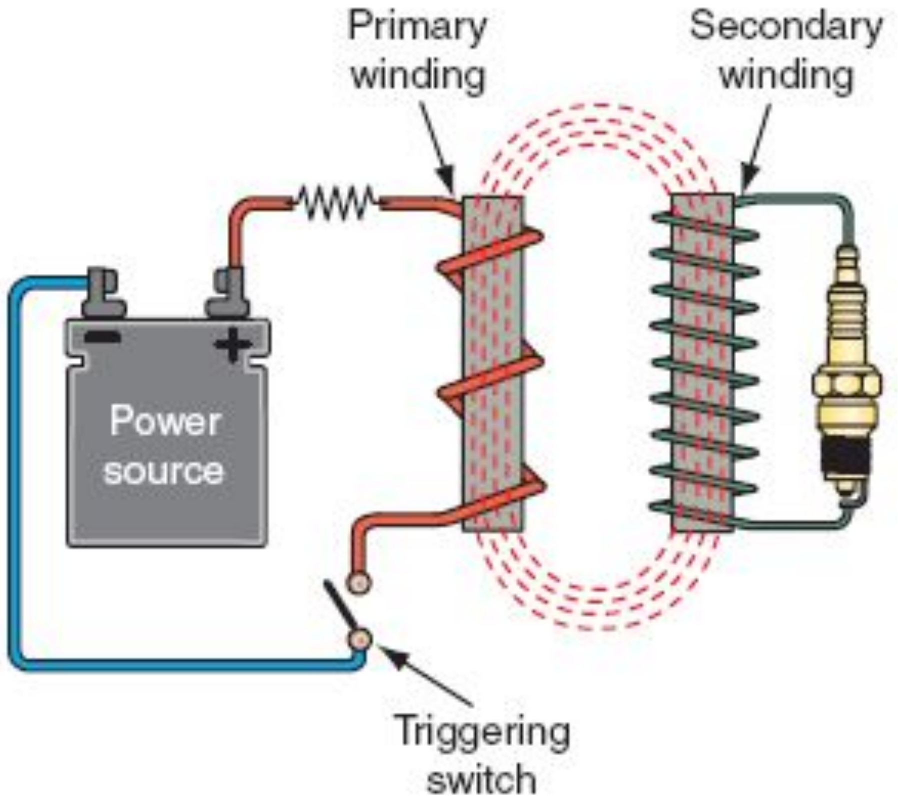


Figure 5 A basic transformer.

20,000–60,000 volts

Because the secondary winding of the coil has many more wire coils than the primary, the voltage produced in the secondary winding is much higher than the original voltage applied to the primary winding. In a typical power equipment engine ignition system, the power source supplies about 12 volts to the primary winding of the ignition coil. From this 12-volt input, the ignition coil produces 20,000–60,000 volts or even more at the secondary coil.

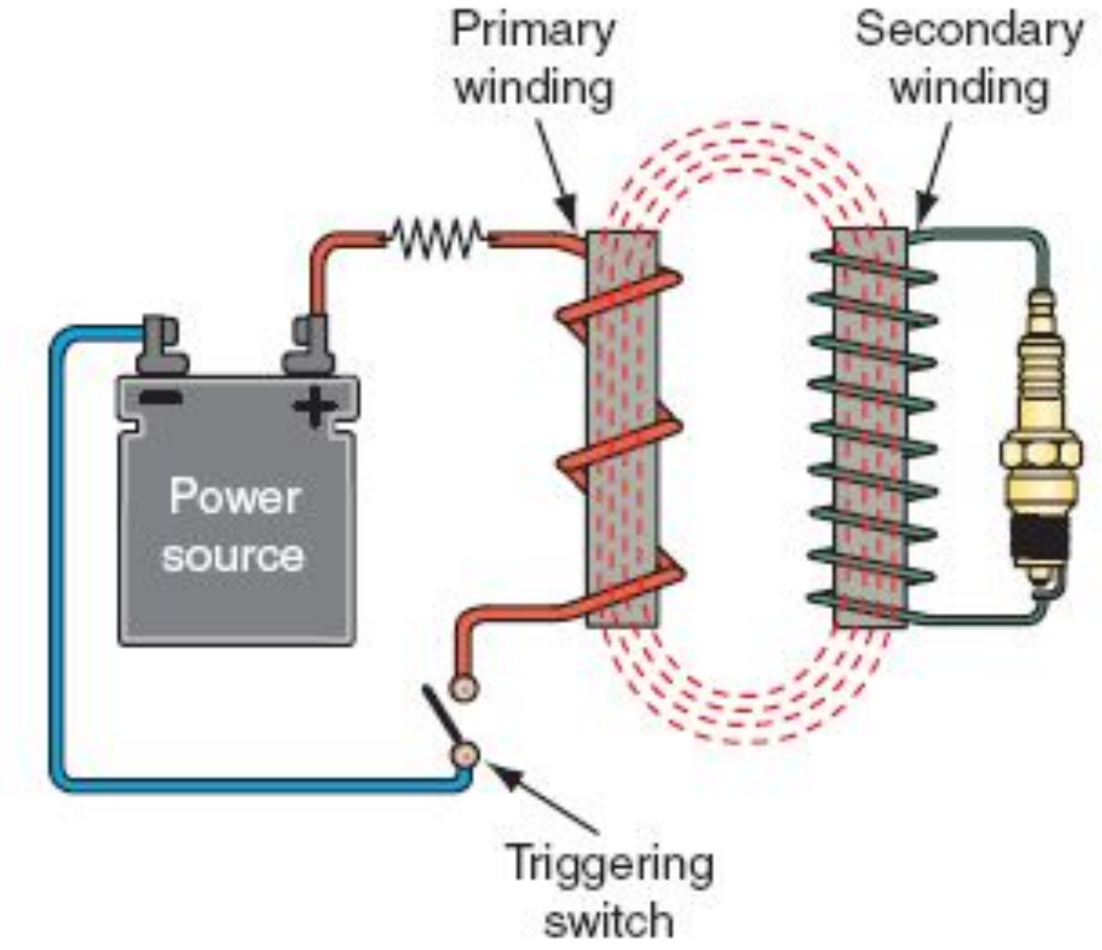


Figure 5 A basic transformer.

Different Ignition systems

The secondary winding of the coil is always connected to the spark plug through the spark plug wire. Because the spark plug wire needs to carry the high voltage and prevent it from arcing to ground, it's heavily insulated.

When the magnetic field in the ignition coil expands or collapses (coils are designed to do one or the other), the high voltage in the secondary is applied to the spark plug and causes a spark to jump across the spark plug gap. The spark ignites the air–fuel mixture, enabling the power equipment engine to run.

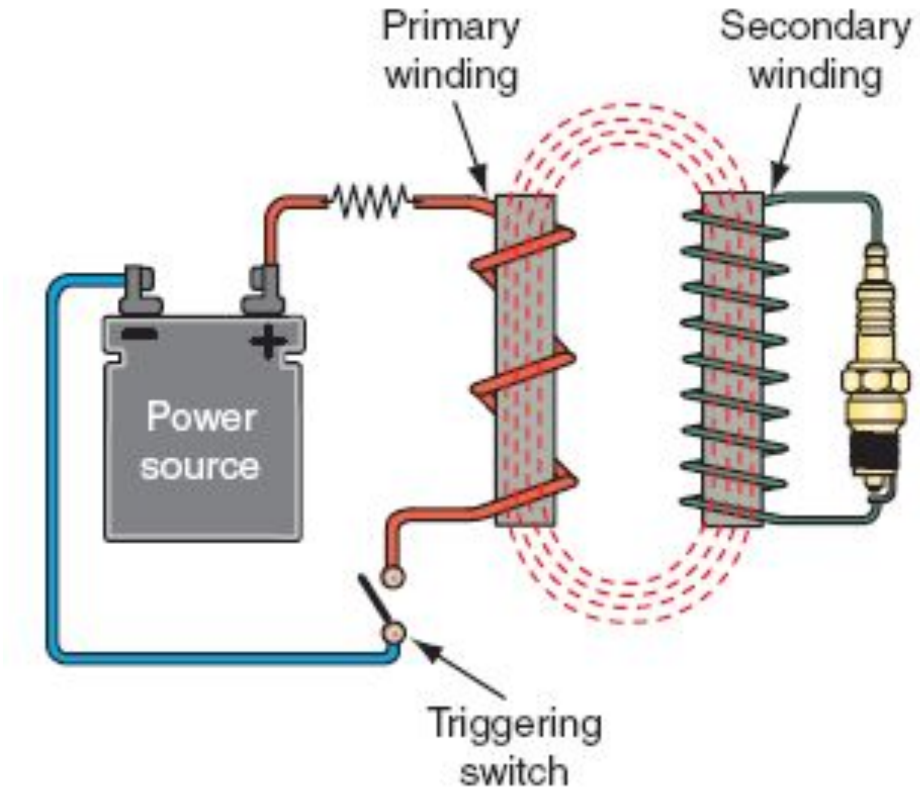


Figure 5 A basic transformer.

Different Ignition systems

It's important to remember that the high voltage in the secondary winding of the coil is produced each time the primary current is turned on or off.

In a collapsing-field ignition system, the high voltage from the secondary winding is used when the current to the primary winding is switched off.

In a rising-field ignition system, the high voltage from the secondary winding is used when the current to the primary winding is switched on. This means that all ignition systems need some type of a device that will keep turning the current from the power source on and off.

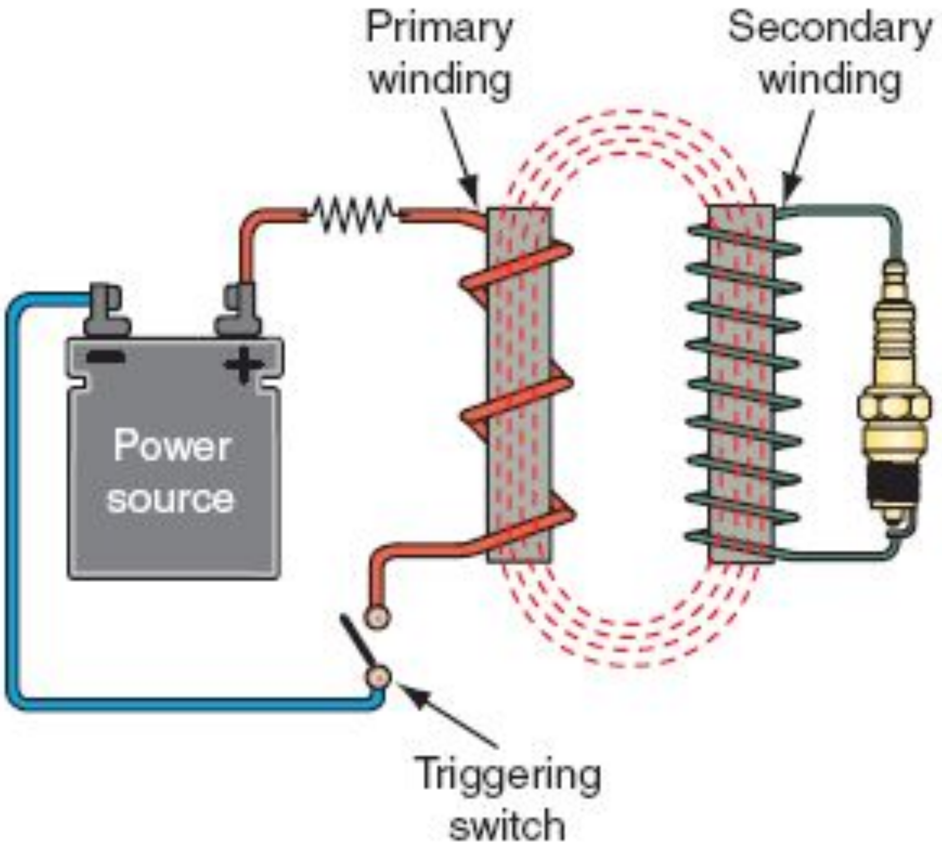


Figure 5 A basic transformer.

Spark Plug

The spark plug provides the crucial air gap across which the high voltage from the secondary coil causes an arc or spark.

The main parts of a **spark plug** are

- a steel shell;

- a ceramic core or insulator, which acts as a heat conductor; and

- a pair of electrodes, one insulated in the core and the other grounded on the shell.

The shell holds the ceramic core and electrodes in a gastight assembly and has threads for plug installation in the engine (Figure 6).

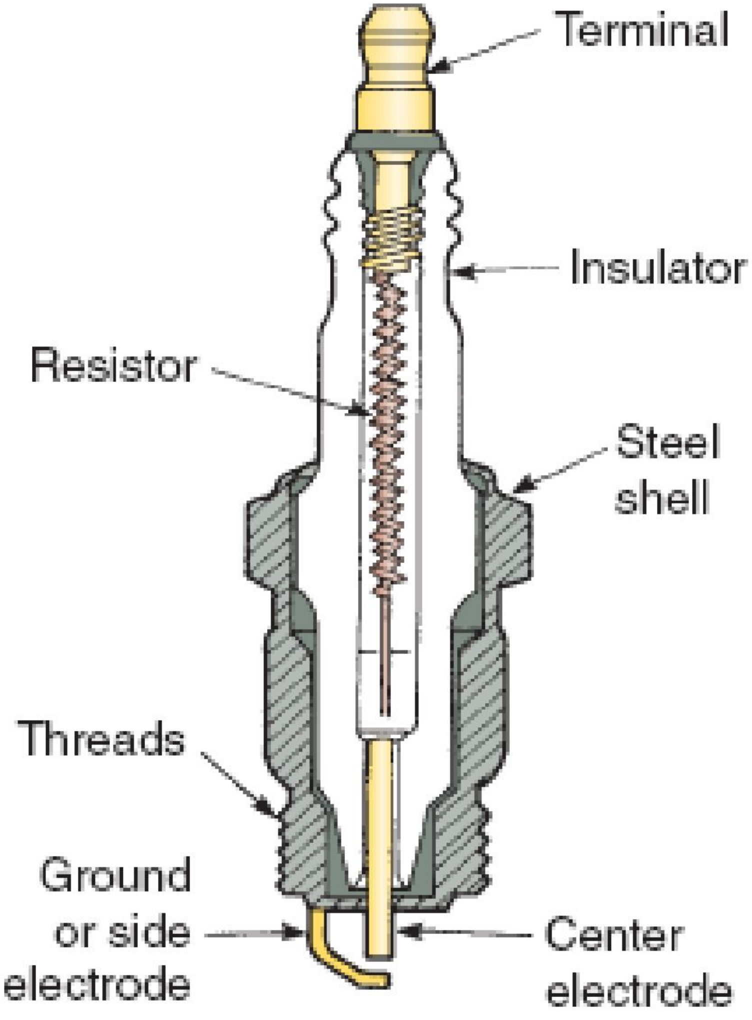


Figure 6 The parts of a typical spark plug.

The parts of a typical spark plug

The insulator is made of ceramic materials to provide for increased durability and strength. Most of today's spark plugs have a resistor (generally about 5,000 or 5K ohms) between the top terminal and the center electrode.

Some spark plugs use a semiconductor material to provide for this resistance.

The resistor reduces radio frequency interference (RFI), which can interfere with, or damage, radios, computers, and other electronic accessories.

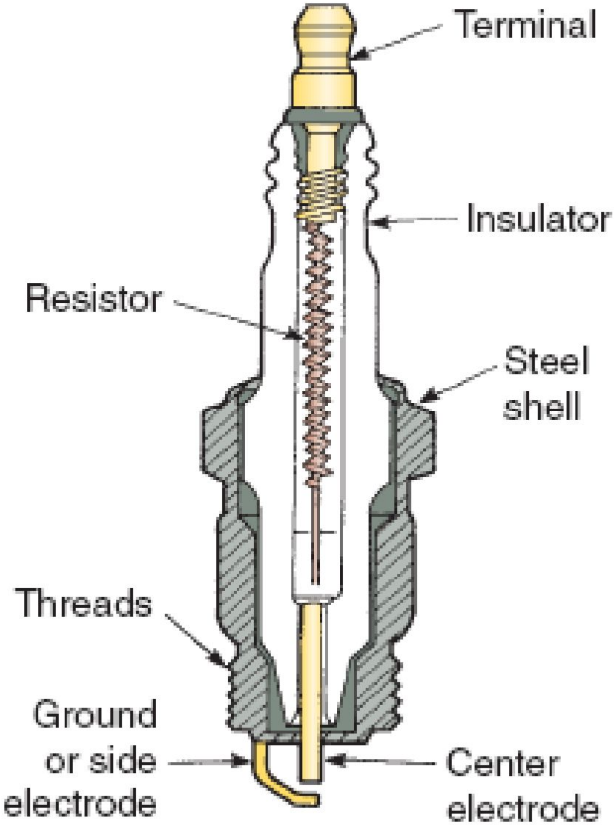


Figure 6 The parts of a typical spark plug.

The parts of a typical spark plug

The terminal post on top of the center electrode is the connecting point for the spark plug cable. Current flows through the center of the plug and arcs from the tip of the center electrode to the ground electrode. The center electrode is surrounded by the ceramic insulator and is sealed to the insulator with copper and glass seals.

These seals prevent combustion gases from leaking out of the cylinder. Ribs on the insulator increase the distance between the terminal and the shell, to help prevent electric arcing on the outside of the insulator. The steel spark plug shell is crimped over the insulation, and a ground electrode, on the lower end of the shell, is positioned directly below the center electrode. There is an air gap between these two electrodes.

Spark plugs come in many sizes and designs to accommodate different engine designs.

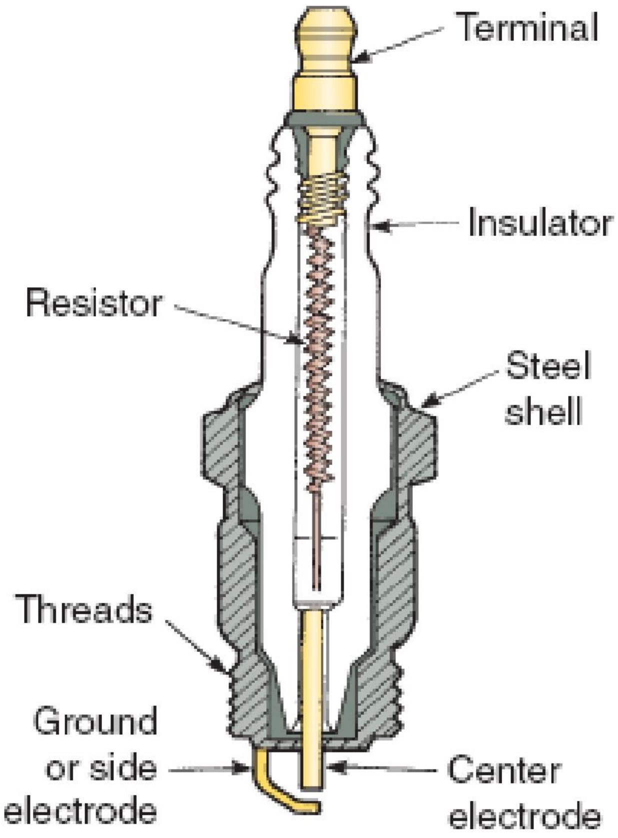


Figure 6 The parts of a typical spark plug.

Spark Plug Reach

One important design characteristic of spark plugs is spark plug reach (Figure 7). This refers to the length of the shell from the contact surface at the seat to the bottom of the plug.

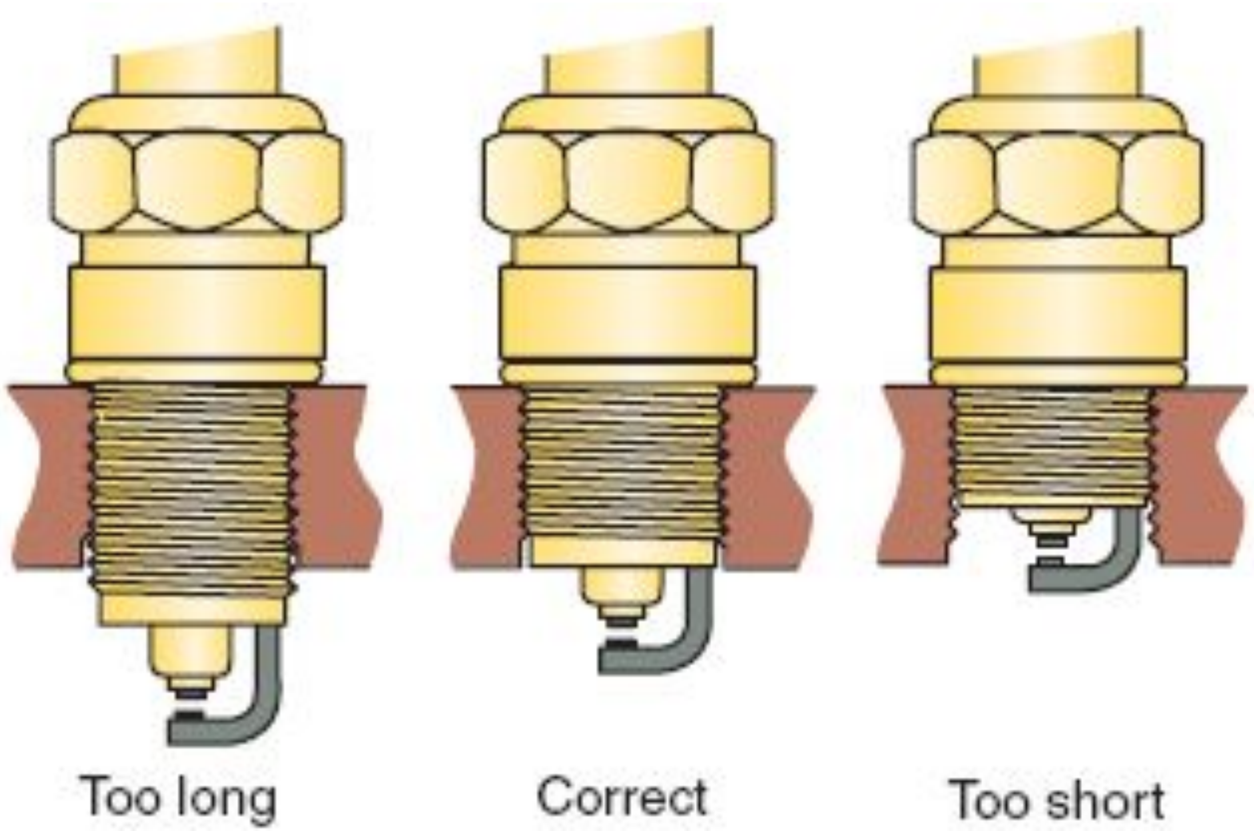


Figure 7 Spark plug reach

Abnormal combustion

Preignition is a term used to describe abnormal combustion, which is caused by something other than the heat of the spark. Spark plug reach is crucial because the plug's air gap must be properly placed in the combustion chamber to produce the correct amount of heat.

If a plug's reach is too short, its electrodes are in a pocket, and the arc does not adequately ignite the mixture. If the plug's reach is too long, the exposed plug threads can hit the piston or get so hot they will ignite the air–fuel mixture at the wrong time.

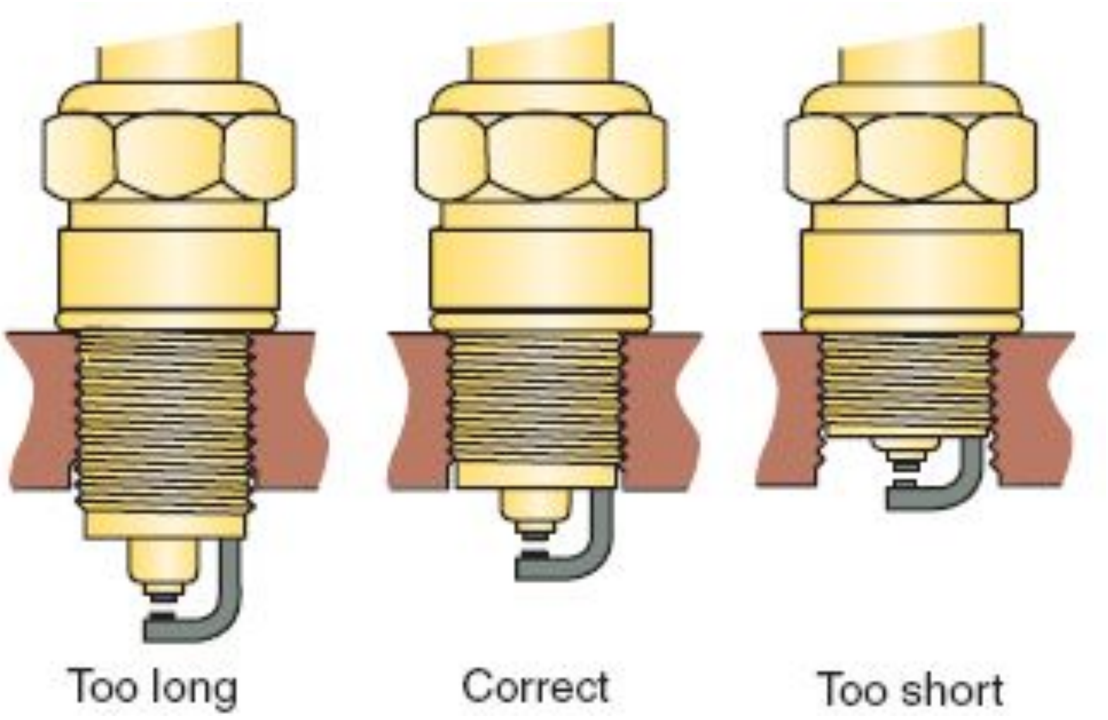


Figure 7 Spark plug reach

Heat Range

When the engine is running, most of the spark plug's heat is concentrated on the center electrode. Heat is quickly dissipated from the ground electrode because it's attached to the shell, which is threaded into the cylinder head (Figure 8) .

In liquid-cooled engines, coolant circulating in the head absorbs the heat and moves it through the cooling system.

In air-cooled engines, the heat is absorbed through the cylinder head.

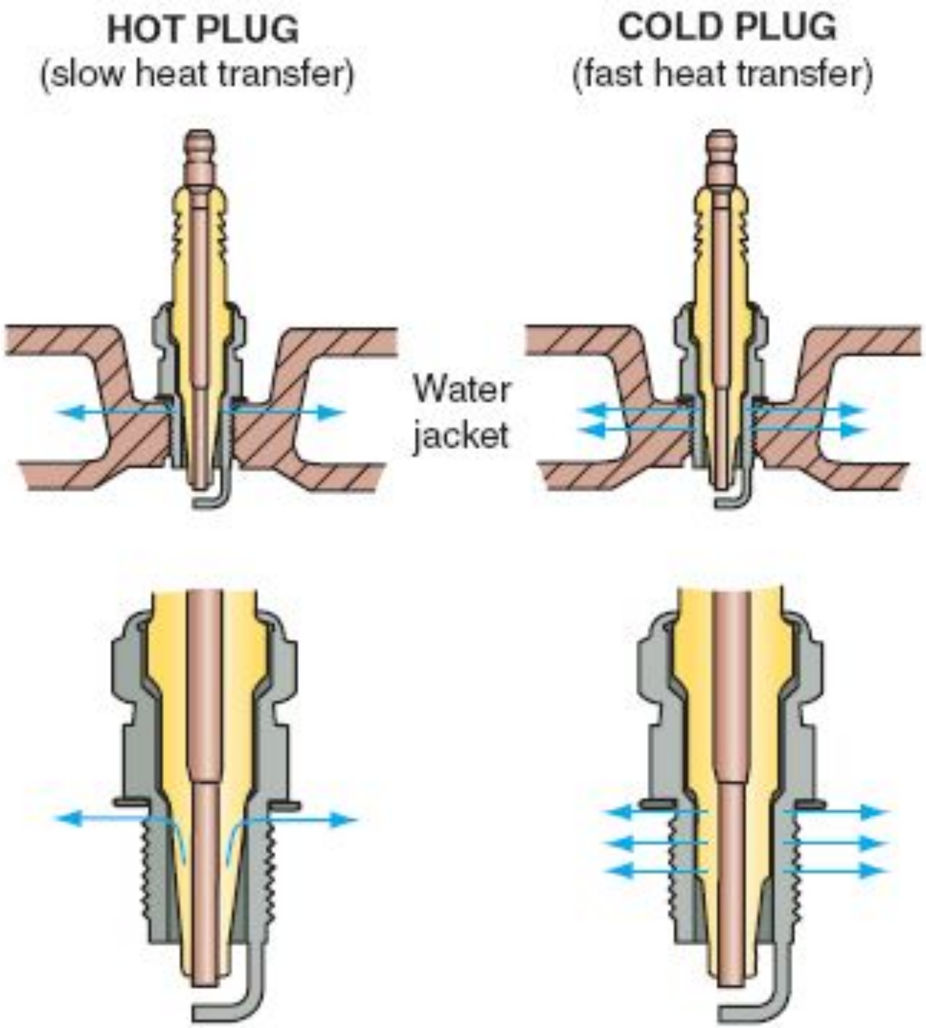
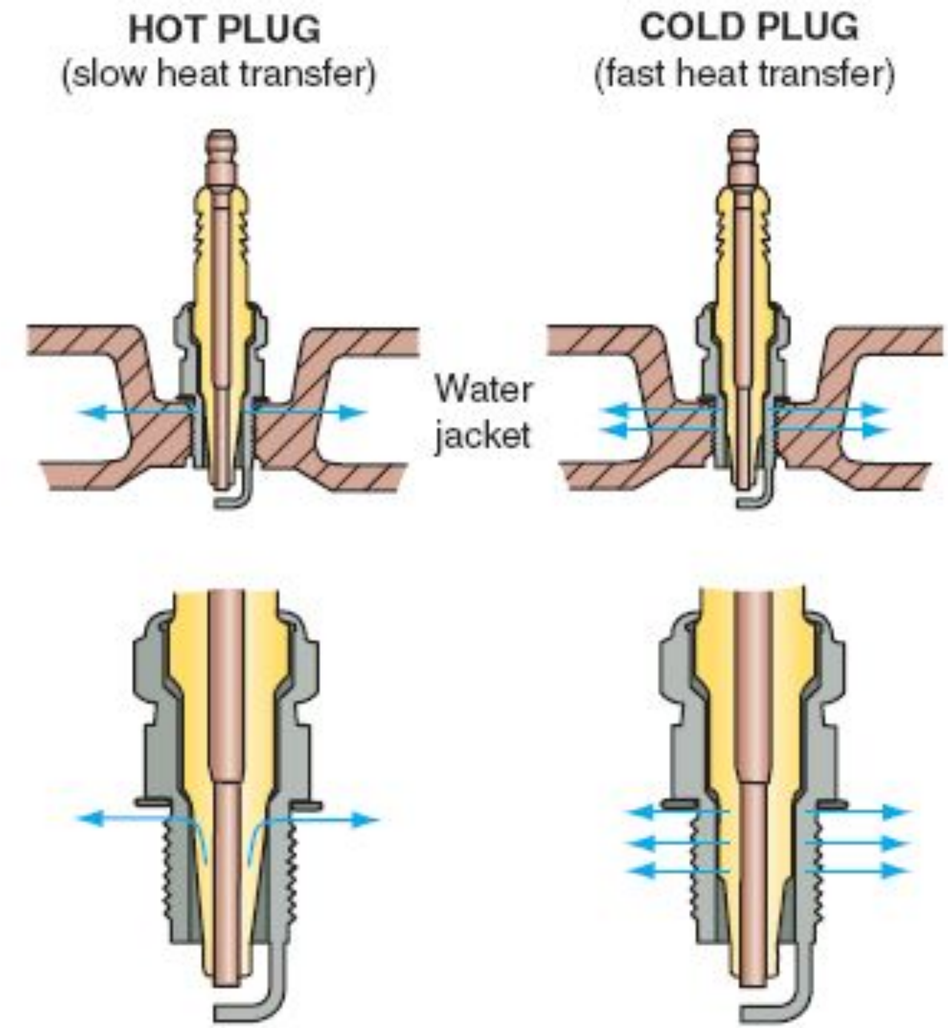


Figure 8 Spark plug heat range: hot versus cold.

Heat Range

The heat path for heat in the center electrode is through the insulator into the shell and then to the cylinder head. The heat range of a spark plug is determined by the length of the insulator before it contacts the shell.

In a **cold spark plug (Cold Plug)**, there is a short distance for the heat to travel up the insulator to the shell. This short path for heat means the electrode and insulator maintain little heat between firings.



Heat Range

In a **hot spark plug (Hot Plug)**, the heat travels farther up the insulator before it reaches the shell. This provides a longer heat path and the plug retains more heat. A spark plug needs to retain enough heat to clean itself between firings, but not so much that it damages itself or causes premature ignition of the air–fuel mixture in the cylinder.

The heat range is indicated by a code imprinted on the side of the spark plug, usually on the porcelain insulator.

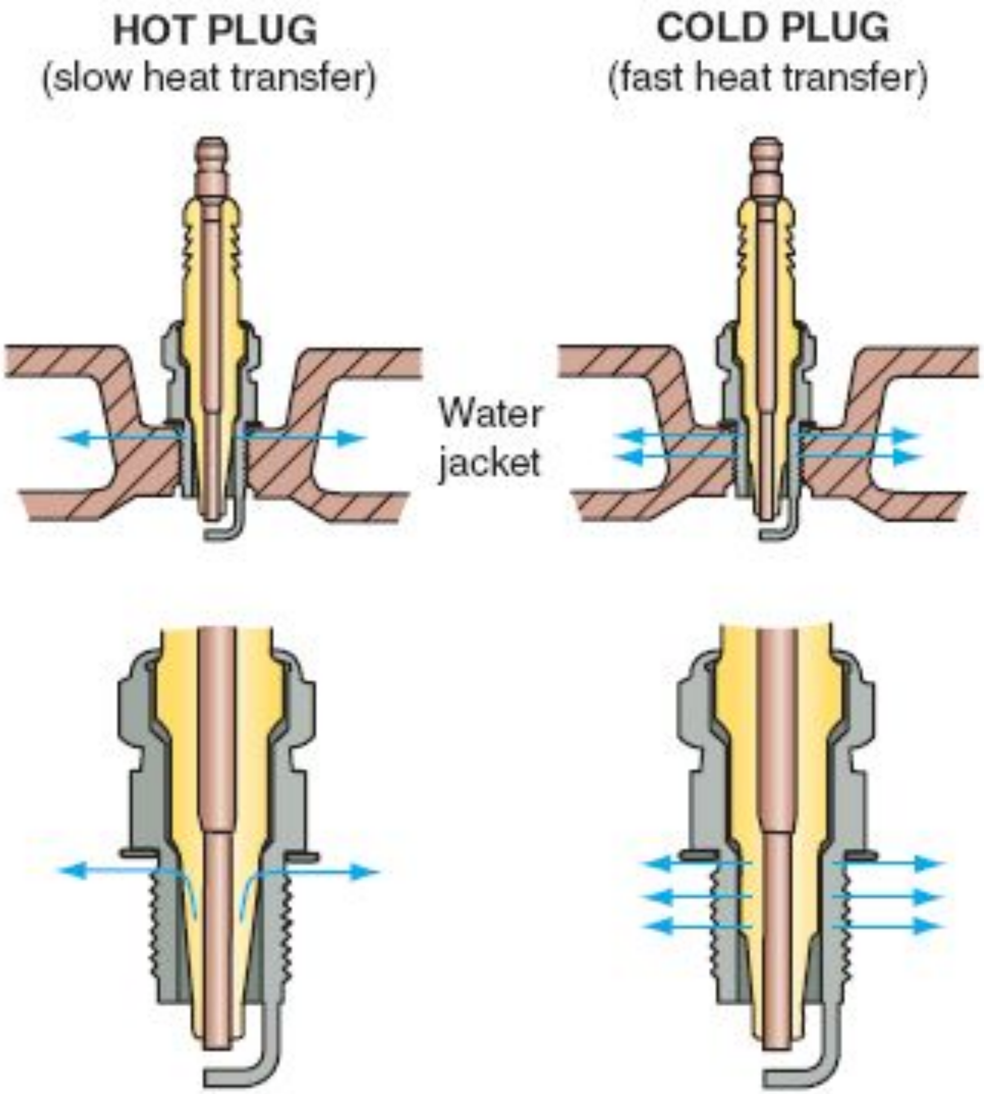


Figure 8 Spark plug heat range: hot versus cold.

Spark Plug Gap

Correct spark plug air gap (Figure 9) is essential for achieving optimum engine performance and long plug life. A gap that is too wide requires a higher voltage to jump the gap.

If the required voltage is greater than what is available, misfiring results. Misfiring occurs because of the inability of voltage generated at the secondary coils to jump the gap or maintain the spark. Alternatively, a gap that is too narrow requires lower voltages and can lead to rough idle and prematurely burned electrodes, due to higher current flow. Also, a misfire may occur if a spark plug terminal is loose.

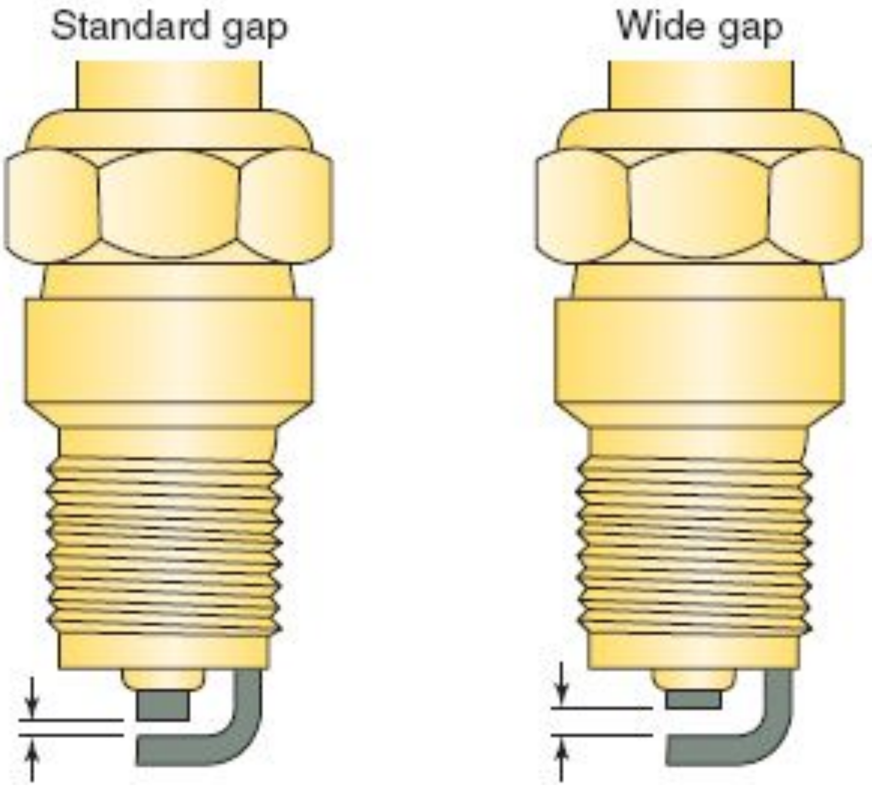


Figure 9 Spark plug gaps.

Electrodes

The materials used in the construction of a spark plug's electrodes determine the longevity, power, and efficiency of the plug. The construction and shape of the tips of the electrodes are also important.

The electrodes of a standard spark plug are made out of copper, and some use a copper–nickel alloy. Copper is a good electrical conductor and offers resistance to corrosion.

Platinum electrodes are used to extend the life of a spark plug (Figure 10).

Figure 10 A platinum-tipped spark plug.

Platinum alloy spark plugs

Platinum has a much higher melting point than copper and is highly resistant to corrosion. Although platinum is an extremely durable material, it’s an expensive precious metal; therefore, platinum spark plugs cost more than copper spark plugs. Also, platinum isn’t as good a conductor as copper.

Spark plugs are available with only the center electrode made of platinum (called single-platinum) and with the center and ground electrodes made of platinum (called double-platinum). Some platinum plugs have a very small center electrode combined with a sharp-pointed ground electrode designed for better performance.

Figure 10 A platinum-tipped spark plug.

Iridium alloy spark plugs

Until recently, platinum was considered the best material to use for electrodes, because of its durability. However, another material with several advantages is iridium alloy. Iridium is six times harder, eight times stronger, and has a melting point that is 1,200° higher than that of platinum. Iridium is a precious, silver-white metal and one of the densest materials found on earth.

A few spark plugs use an iridium alloy as the primary metal complemented by rhodium to increase oxidation wear resistance. This iridium alloy is so durable that it allows for an extremely small center electrode. A typical copper–nickel plug has a 2.5-mm-diameter center electrode, whereas a platinum plug has a diameter of 1.1 mm. An iridium plug can have a diameter as small as 0.4 mm (Figure 11), which means firing voltage requirements are decreased. Iridium is also used as an alloying material for platinum.

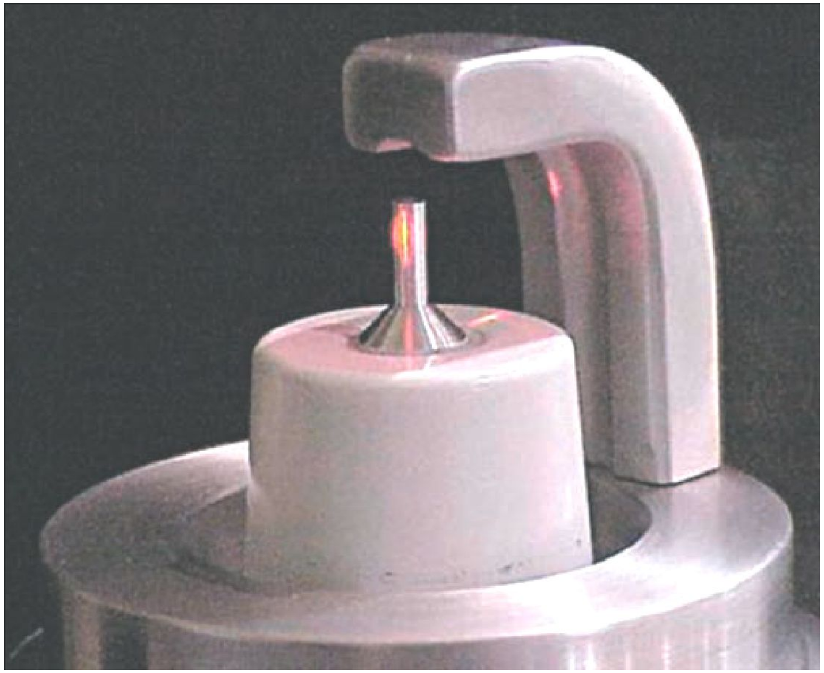


Figure 11 This spark plug has a small-diameter iridium center electrode and a grooved ground electrode.

Electrode Designs

Spark plugs are available with many shapes and numbers of electrodes. When trying to ascertain the advantages of each design, remember the spark is caused by electrons moving across an air gap. The electrons will always flow in the direction of least electrical resistance.

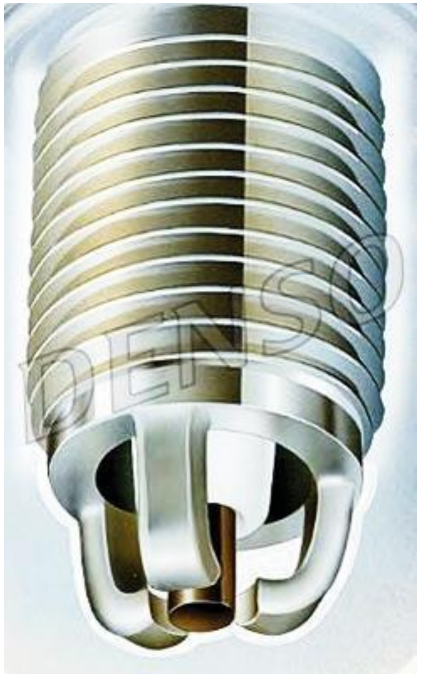


Figure 11a Electrode designs.

Electrode Designs

The shape of the ground electrode may also be altered. A flat, conventional electrode tends to crush the spark, and the overall volume of the flame front is smaller. A tapered ground electrode increases flame front expansion and reduces the heat lost to the electrode.

Ground electrodes in many power equipment engine spark plugs have a U-groove machined into the side that faces the center electrode. The U-groove allows the flame front to fill the gap formed by the U-shape. This ball of fire develops a larger and hotter flame front, leading to a more complete combustion.

Figure 11b U-groove ground electrode.

Triggering Switch Devices

Different types of ignition systems use different types of switching devices. There are two basic types of trigger switching devices used in power equipment engine ignition systems.

1. Older ignition systems use a set of electrical contacts called breaker points and a condenser to do the switching. Although rarely used by any major manufacturer today, breaker points and condensers continue to be in use in millions of older power equipment engines.

2. All modern power equipment engine systems, however, use electronic components to do the switching.

In either system, the construction of the ignition coil and the spark plug remain the same.

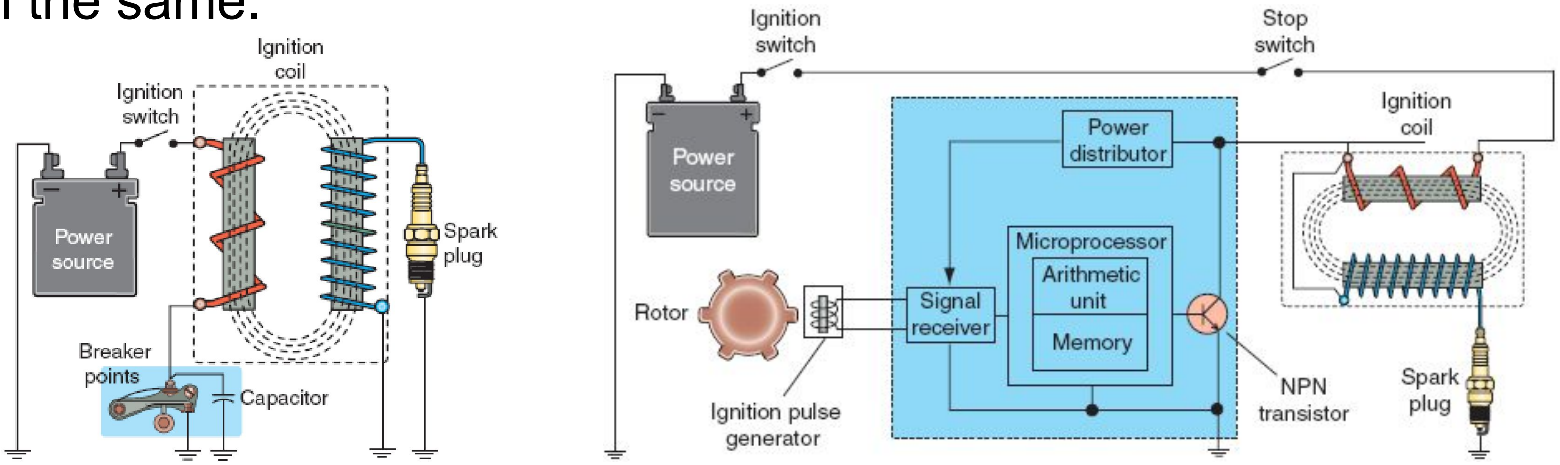


Figure 11c A basic transformer and digitally controlled transistorized ignition system

Breaker Points and Condenser

Breaker points are mechanical contacts that are used to stop and start the flow of current through the primary windings of the ignition coil. The points are usually made of tungsten, a very hard metal that has a high resistance to heat.

One breaker point is stationary (fixed), and the other point is movable and insulated from the stationary point. The movable contact is mounted on a spring-loaded arm, which holds the points together.

Figure 12 shows a simplified drawing of a set of breaker points.

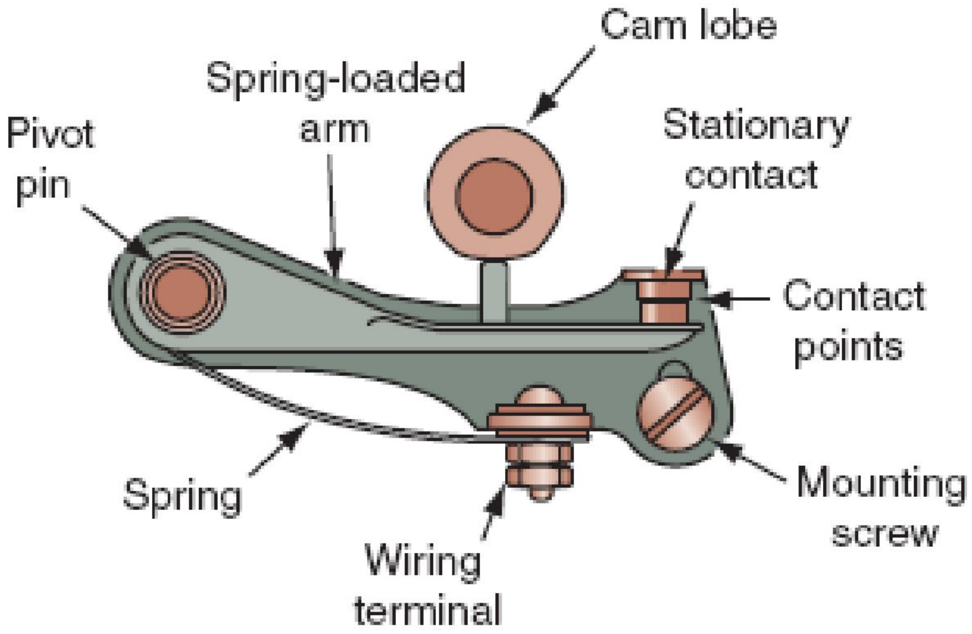


Figure 12 A set of breaker points.

Breaker Points and Condenser

When the two breaker points touch, the ignition circuit is complete and the primary winding of the ignition coil is energized. When the end of the spring-loaded movable breaker point is pressed, its contact end moves apart from the stationary breaker point. This opens the circuit and the flow of current stops. Each time the breaker points move apart, the spark plug fires. This action is shown in Figure 13.

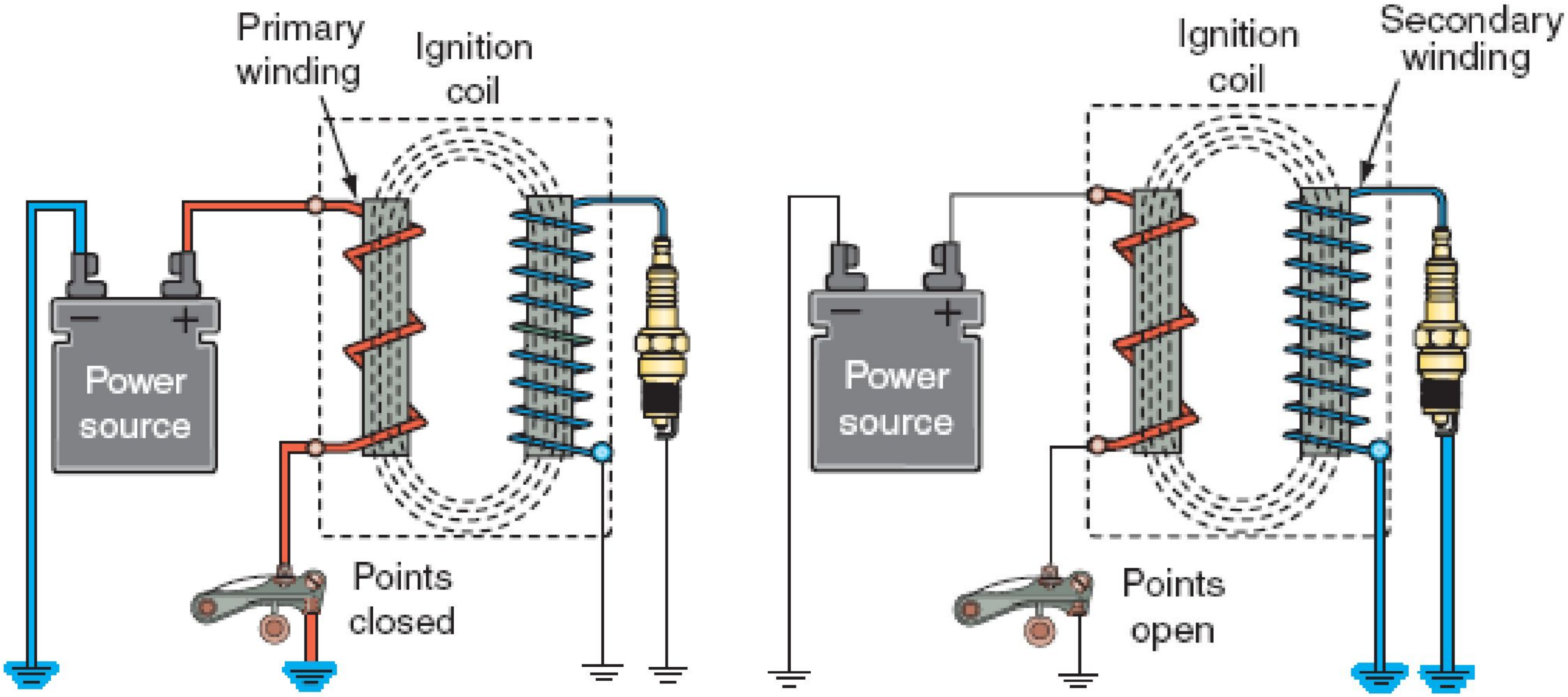


Figure 13 Shown is the action of breaker points in a simple ignition circuit.

When the breaker points are closed, current flows through the ignition coil’s primary winding. When the points open, the circuit is broken, and the magnetic field in the coil collapses, which induces a voltage into the coil secondary to fire the spark plug.

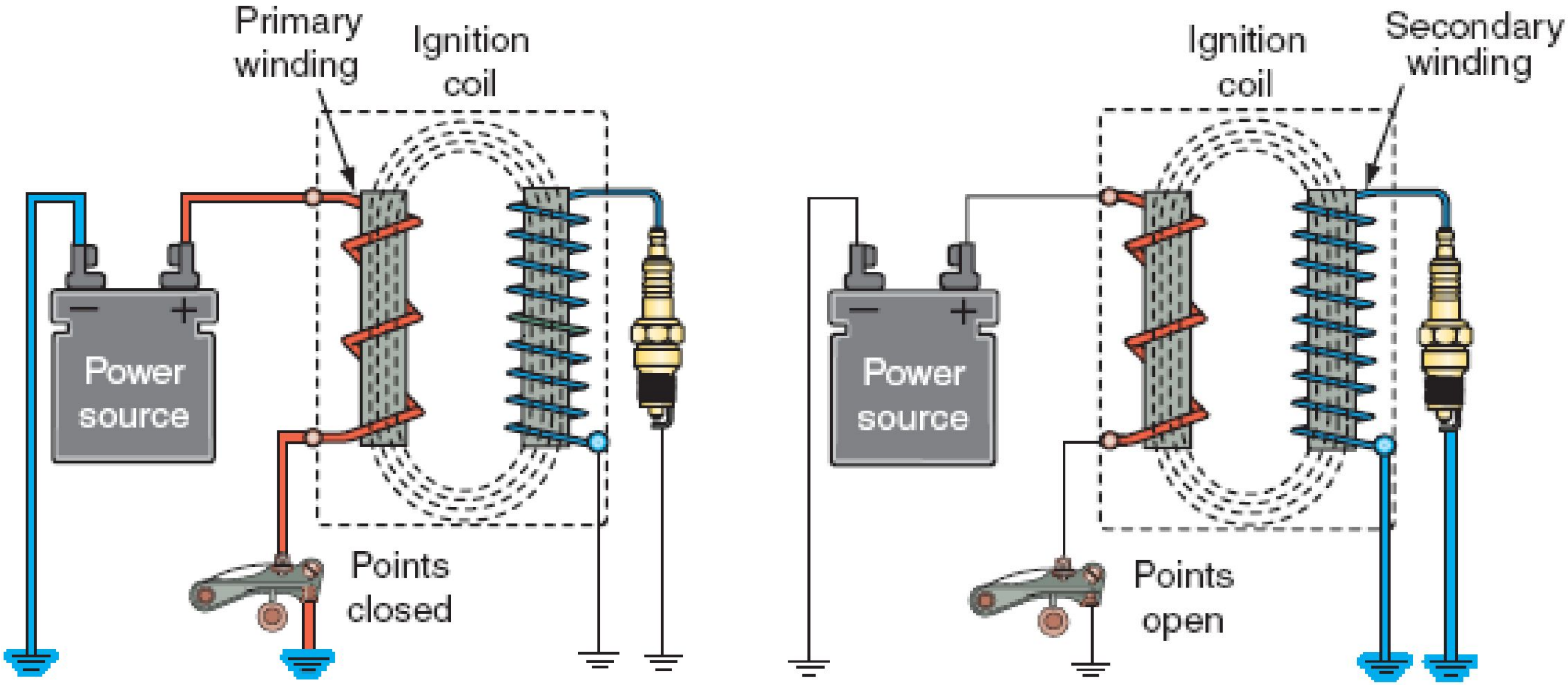


Figure 13 Shown is the action of breaker points in a simple ignition circuit.

Breaker Points and Condenser

The spring mounted under the movable point holds the movable breaker point against the cam. The movable breaker point is moved to the open position by a turning cam with a lobe. In most cases, the cam is located on the crankshaft. The lobe on the cam forces the movable breaker point away from the stationary point, and the spark plug fires.

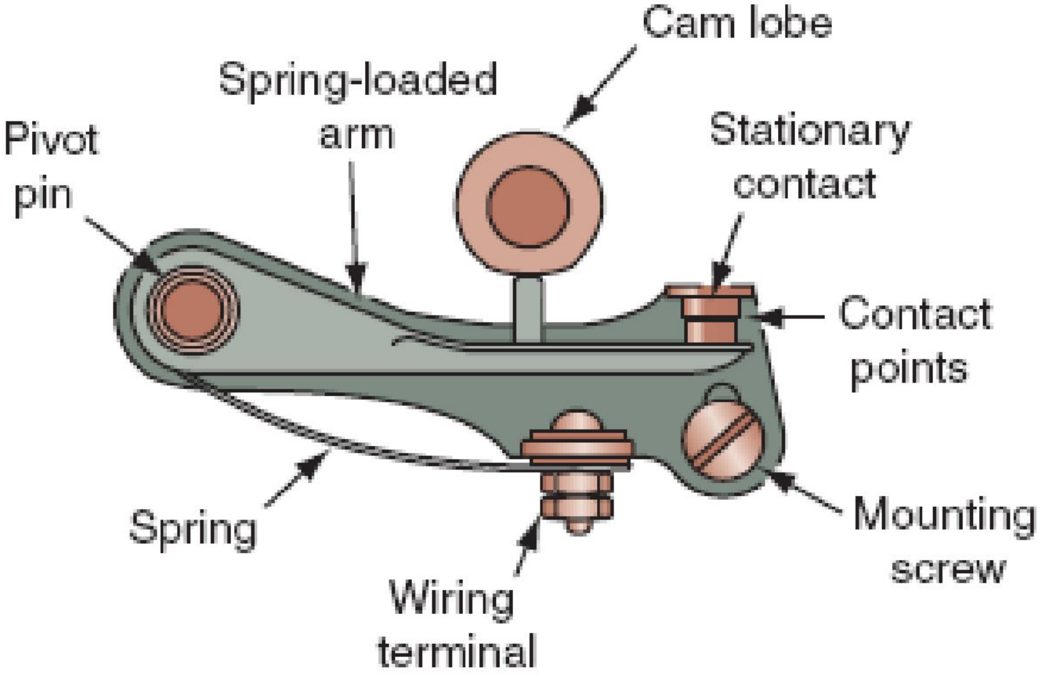


Figure 12 A set of breaker points.

The condenser

Another important component of a breakerpoints system is the condenser (also called a capacitor). Remember that each time the breaker points touch, current flows through them.

Unless this current flow is controlled in some way, a spark or arc will occur across the breaker points as they move apart. If this sparking is allowed to occur, the breaker points will arc, burn, and fail to operate properly. The points would also absorb the electrical energy and reduce the output voltage of the ignition coil.

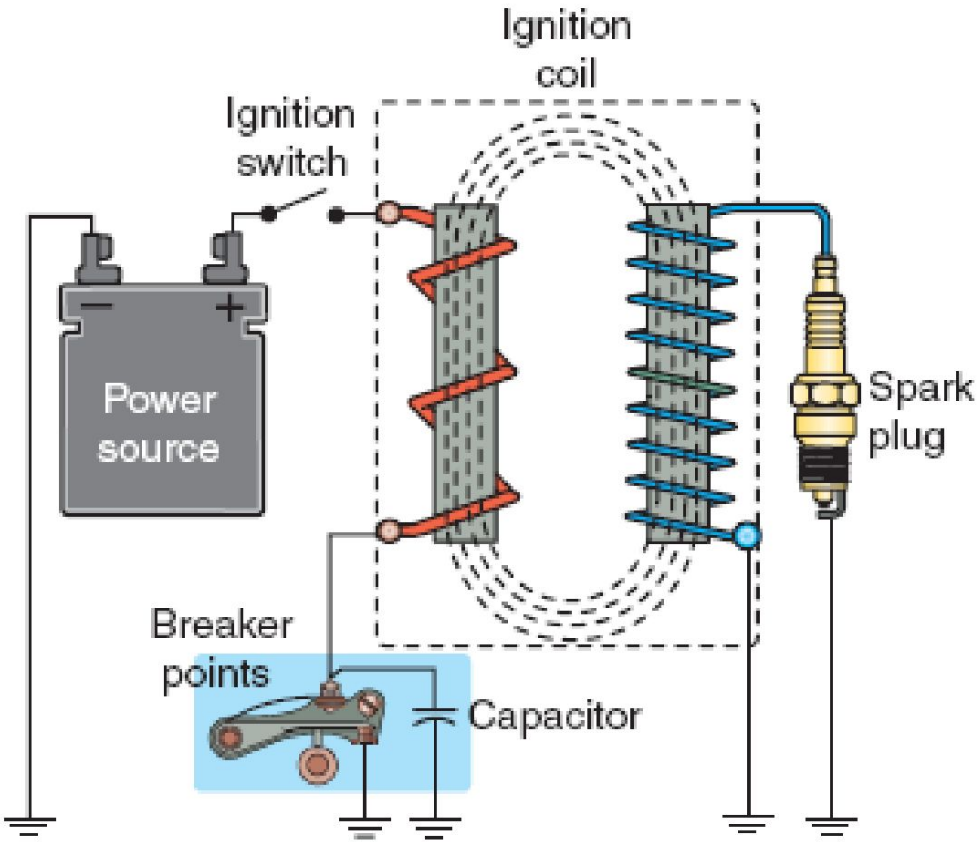


Figure 14 A typical battery-powered breaker point system.

For these reasons, a condenser is used to control the current as it flows through the breaker points. A condenser absorbs current and stores it, like a miniature battery. In an ignition circuit, the condenser is connected across—or parallel to the breaker points. As the breaker points begin to separate, the condenser absorbs the current created by the collapsing magnetic field around the primary winding of the coil so that it can't jump between the points and make a spark.

The breaker-points-and-condenser switching system can be used in both AC and battery powered ignition systems.

Figure 14 shows a breaker-points system. Note the location of the breaker points and condenser in the circuit.

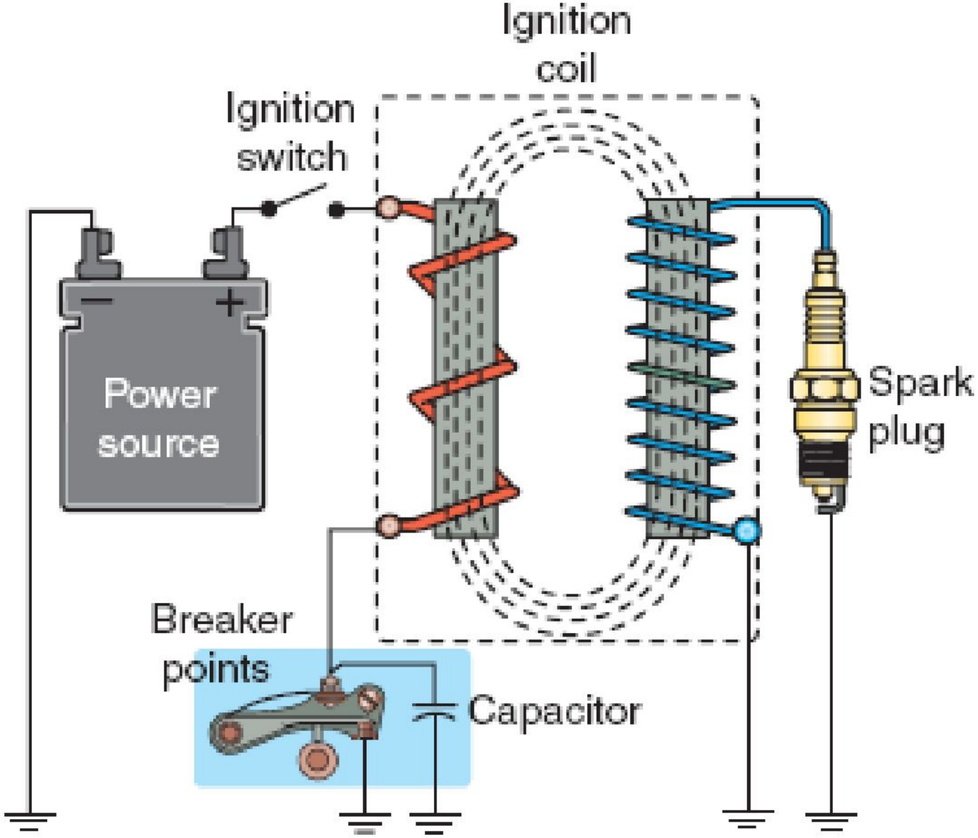


Figure 14 A typical battery-powered breaker point system.

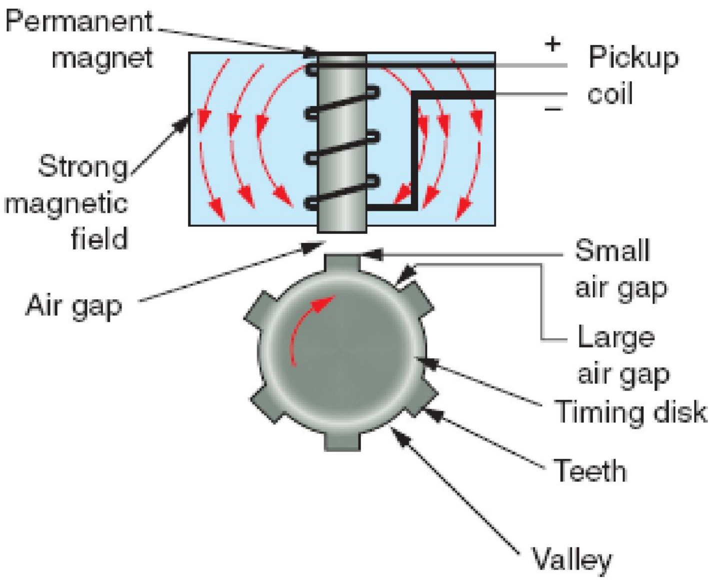
Electronic Trigger Devices

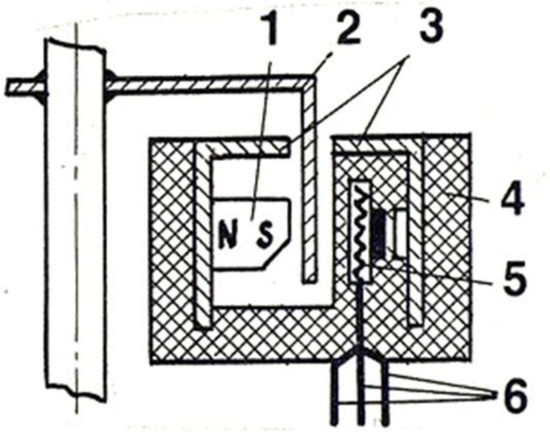
When an electronic ignition system is used in a power equipment engine, a sensor is used to monitor the position of the crankshaft and control the flow of current to the primary side of the ignition coil.

These sensors primarily include:

- magnetic-pulse generators and
- Hall-effect sensors.

An electronic switch completely eliminates the need for breaker points and a condenser.





Magnetic-Pulse Generator

A magnetic pulse generator is located generally on the engine's crankshaft or camshaft and consists of two parts:

- a timing disc (also known as a reluctor) and
- a pickup coil (Figure 15).

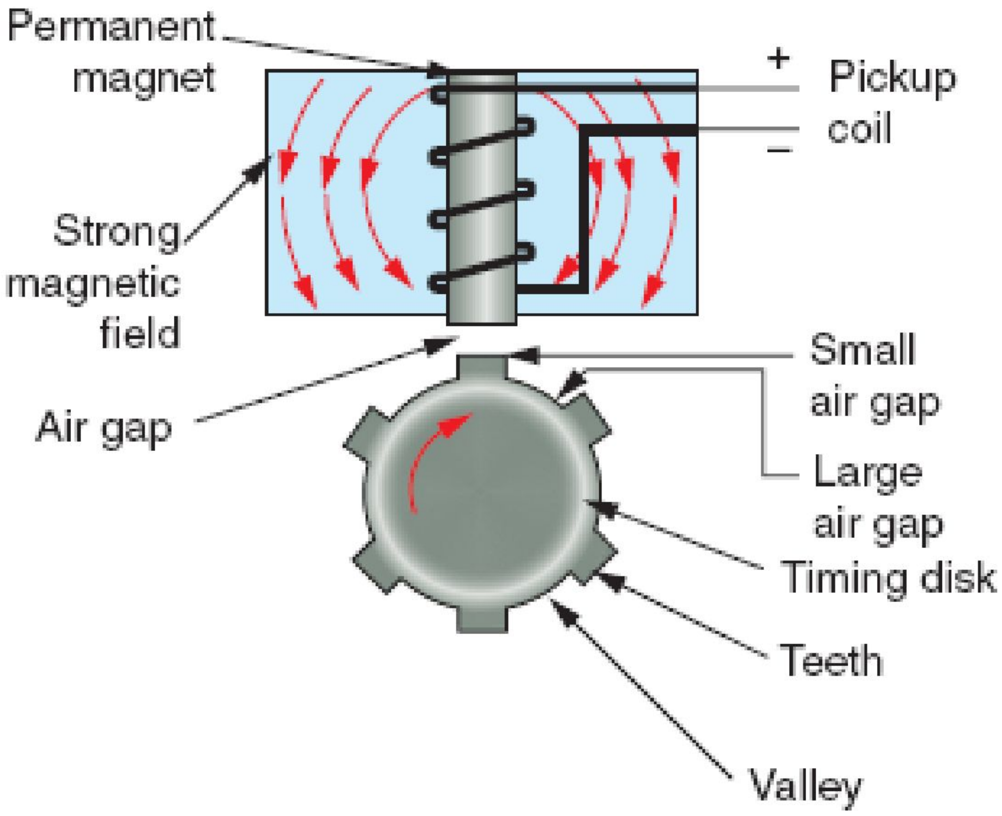


Figure 15 A magnetic-pulse generator is located near the engine's crankshaft or camshaft in most cases.

The pickup coil consists of a length of wire wrapped around a permanent magnet. The magnetic-pulse generator operates on the basic electromagnetic principle that voltage can be induced only when a conductor *moves* through a magnetic field. When the crankshaft or camshaft is turned, the timing disc moves through the magnetic field.

As the timing disc teeth approach the pickup coil, a voltage is induced, and this is used to control the voltage to the primary side of the ignition coil, just as the opening and closing of the contact points in the breaker-points-and-condenser switching system. A specific, manufacturer-determined air gap is required to ensure that a signal of appropriate strength is being produced.

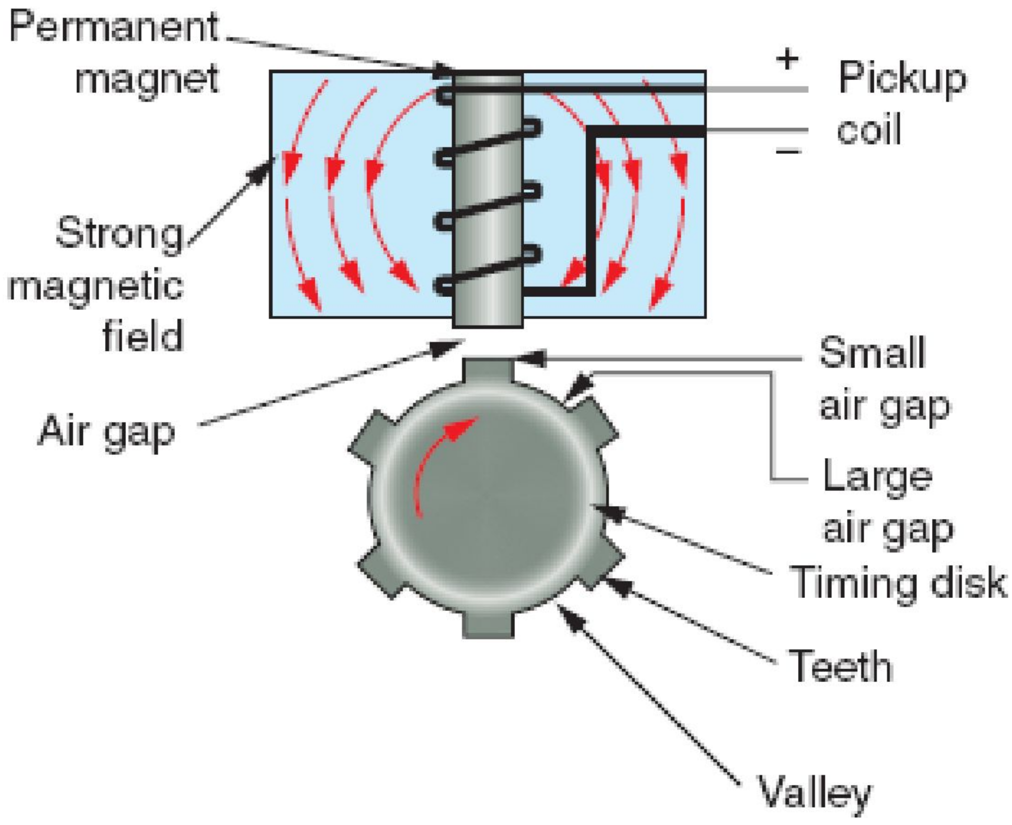


Figure 15 A magnetic-pulse generator is located near the engine’s crankshaft or camshaft in most cases.

Hall-Effect Sensor

The Hall-effect sensor or switch is the most commonly used engine position sensor used in a power equipment engine that uses an electronic ignition system. There are several reasons for this. Unlike the magnetic pulse generator, the Hall-effect sensor produces an accurate voltage signal across the entire rpm range of the engine.

Furthermore, a Hall-effect switch produces a square-wave pattern that is more compatible with the digital signals required by onboard computers.

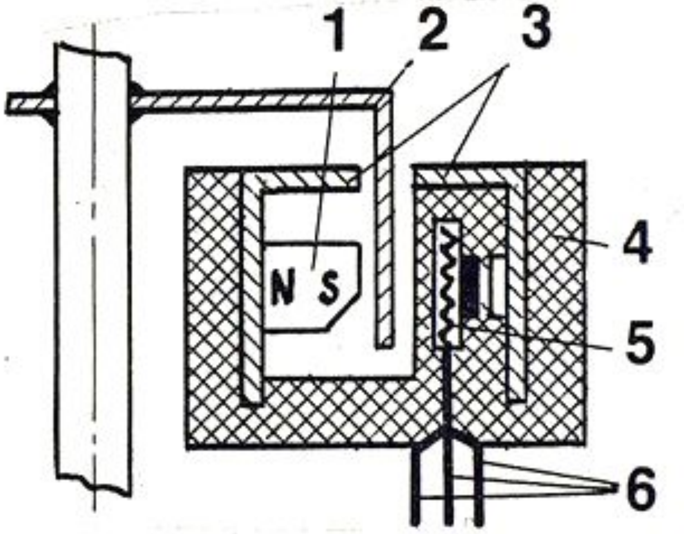


Figure 15a The Hall-effect sensor

Hall-Effect Sensor

Functionally, a Hall-effect switch performs the same tasks as a magnetic-pulse generator. But the Hall-effect switch's method of generating voltage is quite unique. It's based, as you may guess, on the Hall-effect principle. This states that if a current is allowed to flow through a thin conducting material and that material is exposed to a magnetic field, voltage is produced in the conductor. In essence, a Hall-effect switch is either on or off. It also uses a timing disc that is used to switch the power on and off as it passes by the sensor.

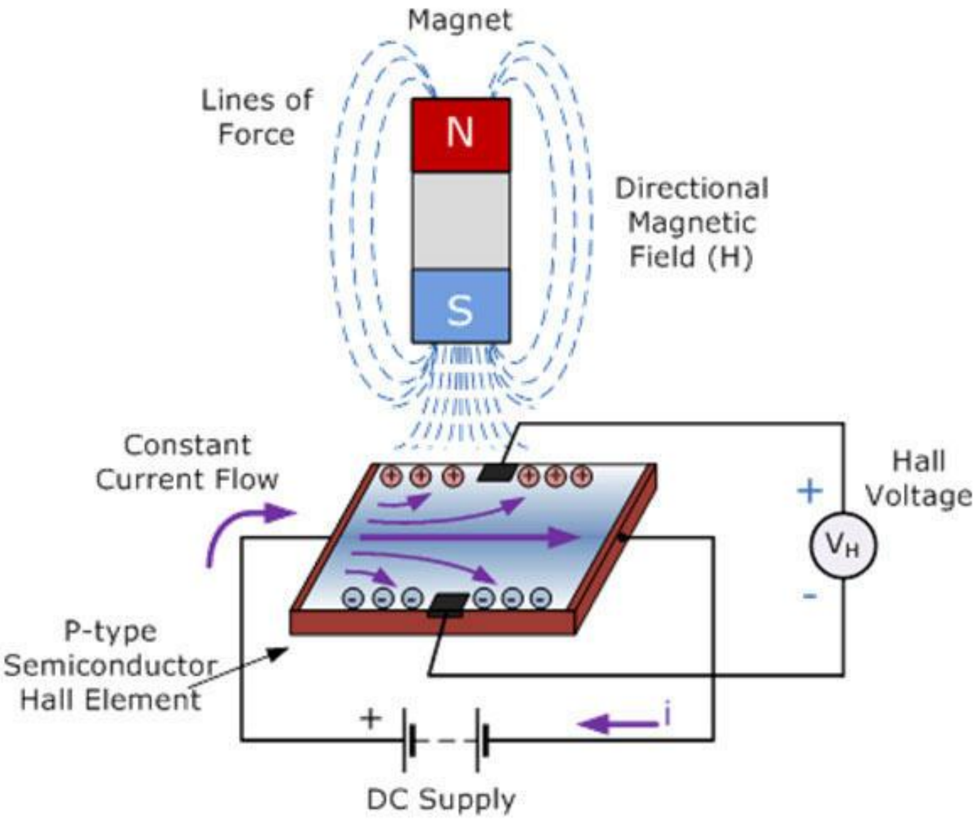


Figure 15b The Hall-effect principle

Stop Switch

Once an engine is started, it will keep running until it runs out of fuel or is put under a heavy-enough load to cause it to stall. The stop switch provides a convenient means to stop the engine.

Different types of stop switches are found in different types of ignition systems. In some power equipment engines, the stop switch interrupts the flow of electricity to the spark plug by giving the electrical current an easier path to ground. This type of switch consists of a button that grounds the ignition system (Figure 4).

In other engines, the stop switch is designed to prevent the flow of electricity through the primary winding of the ignition coil. This type of stop switch is connected in series with the primary side of the ignition coil. When you turn the switch to the Off position, the ignition circuit is made to open and the engine stops.

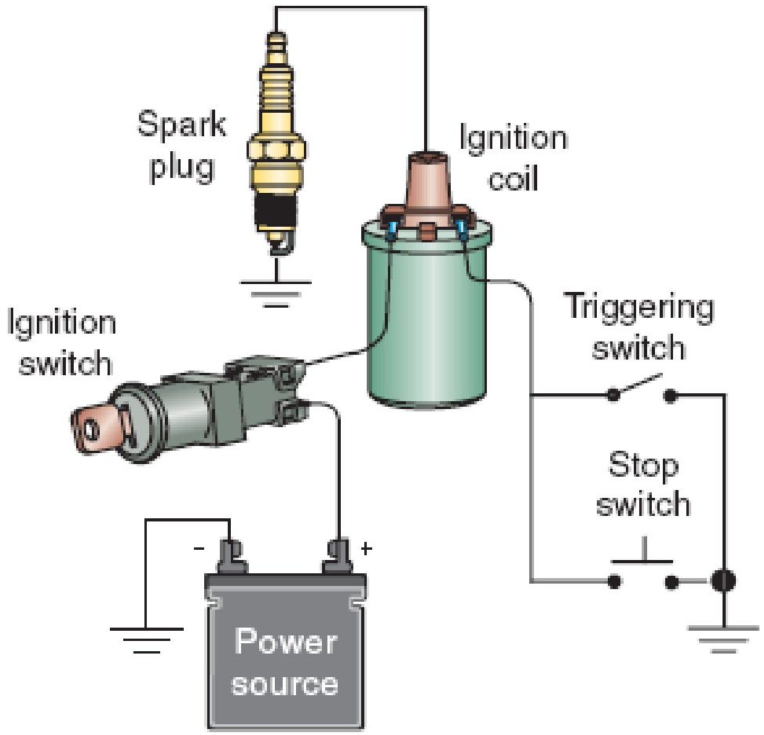


Figure 4 The basic components of an ignition system.

TYPES OF IGNITION SYSTEMS

Now that you understand how a basic ignition system in a power equipment engine operates, let’s take a closer look at the construction of some types of ignition systems. The two general types are the:

I. Breaker point ignition system

II. Electronic ignition system

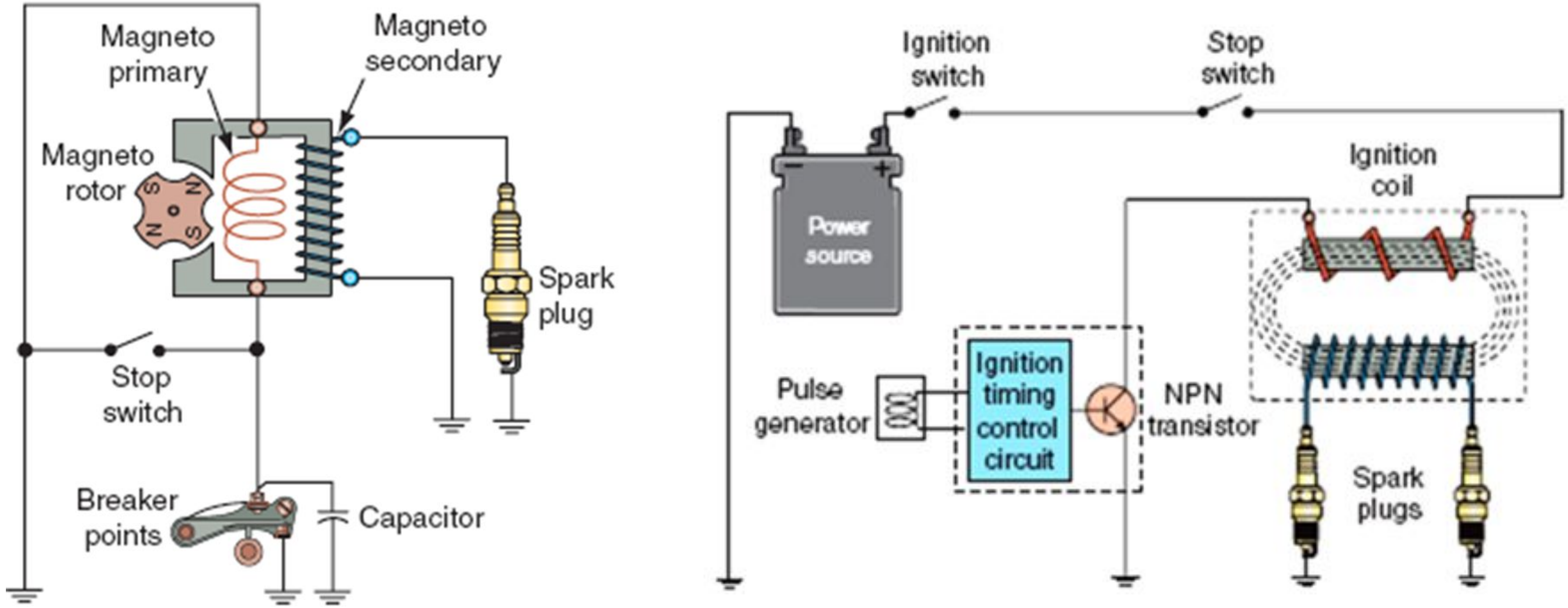


Figure 15c A breaker point ignition and electronic ignition systems

I. Breaker point ignition system

There are two types of breaker point systems.

(1) The magneto breaker point ignition system is usually found in older machines, where a voltage is needed only to power the spark plug—not a starter system or lights.

(2) The battery-and-points ignition system is found in most of the older power equipment engines that have electric starter systems and lights.

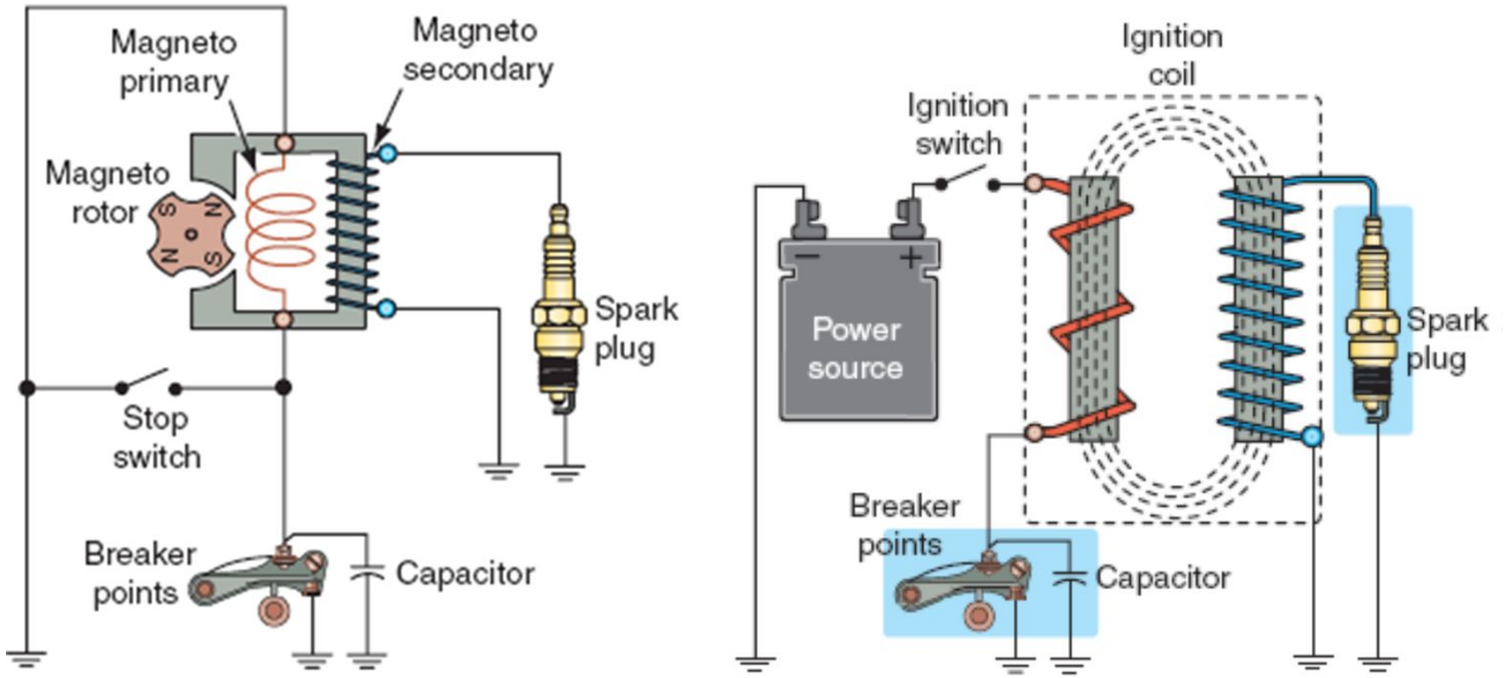


Figure 15d A high-tension magneto system and battery-and-points ignition system

(1)Magneto Ignition Systems

In magneto ignition systems in older power equipment engines without any lights or a battery, the AC source may have the sole function of operating the ignition system. In other models that include lighting systems, one AC generator coil may be used for ignition, and another for lighting. All magneto ignition systems operate without a battery, or are independent of the battery if one is used for the operation of other electrical functions.

The magneto ignition system uses permanent magnets installed on the engine's flywheel/rotor. Magnetos are classified as being one of three types:

- High tension
- Low tension
- Energy transfer

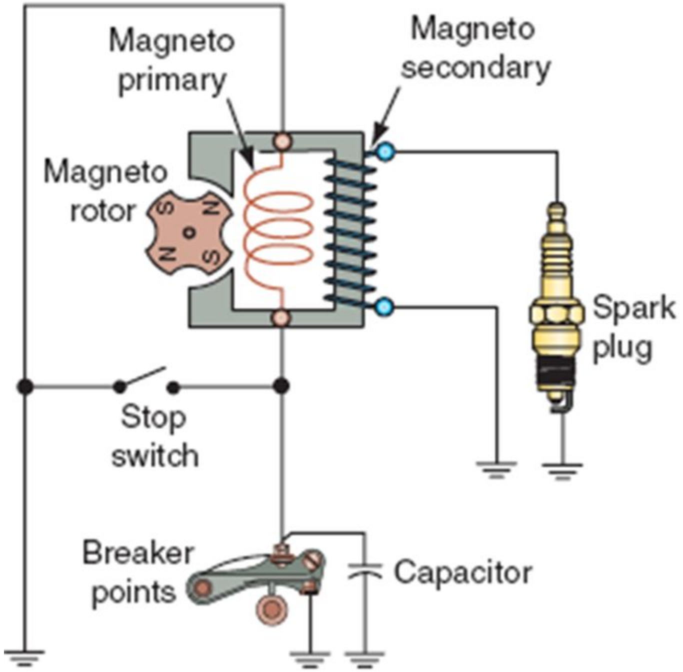


Figure 16 A high-tension magneto system

High-Tension Magneto Ignition System

High-tension magneto ignition systems (Figure 16) haven't been in use in power equipment engines for quite a few years, but they were once the most popular ignition system, found in small engines.

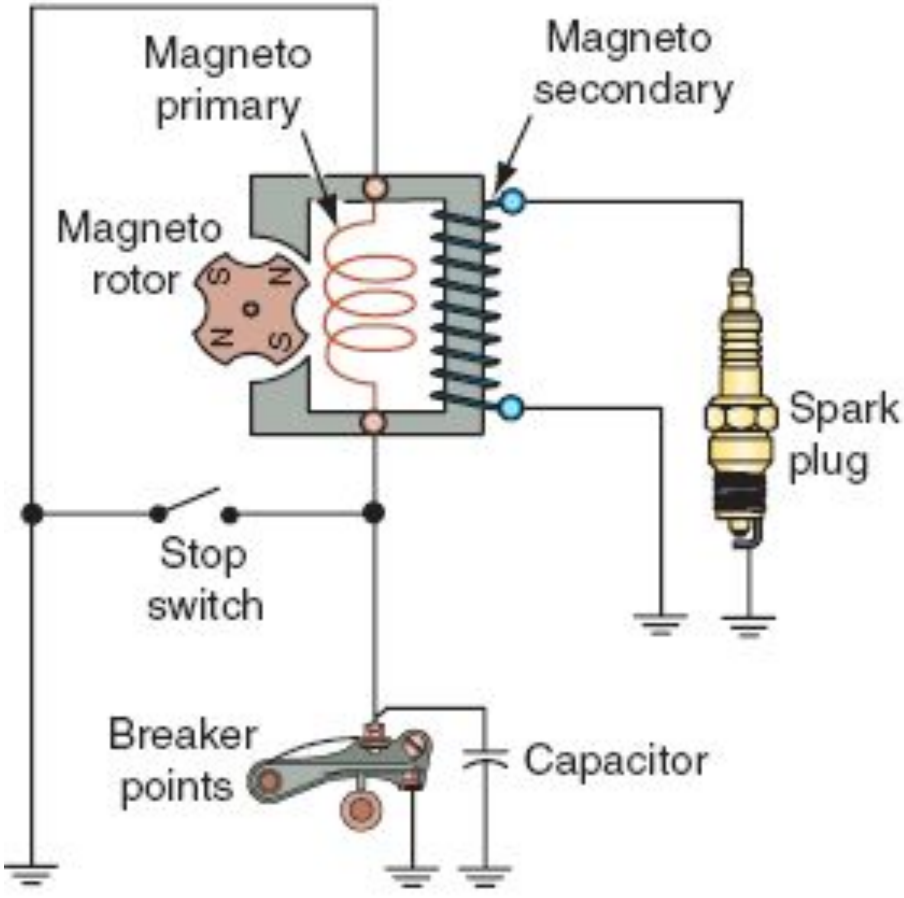


Figure 16 A high-tension magneto system.

With this ignition system, the ignition coil (magneto primary and secondary windings) is mounted in a stationary position near the flywheel/rotor. When the flywheel/rotor turns, the magnets induce a voltage in the primary winding of the ignition coil.

The position of the magnets on the flywheel/rotor is important. To generate the voltage at the exact time needed, the magnets in the flywheel/rotor must be properly aligned. This means that the flywheel/rotor must be located exactly in the position required on the crankshaft.

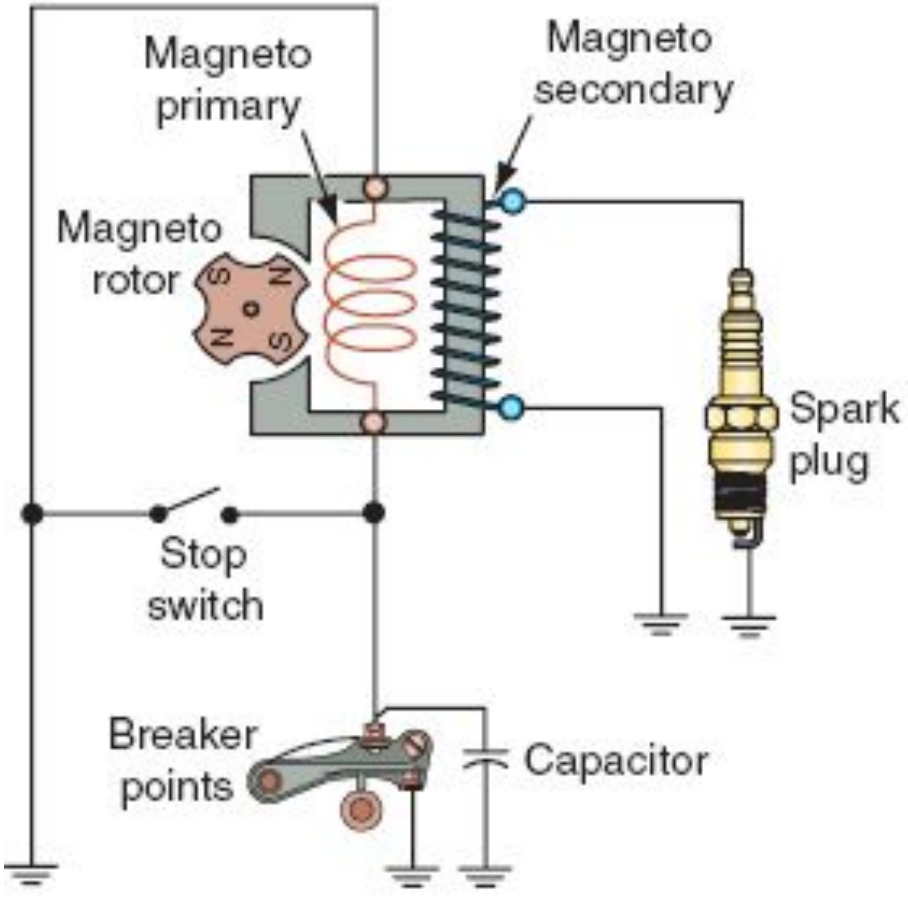


Figure 16 A high-tension magneto system.

The gap between the edge of the flywheel/rotor and the iron core of the ignition coil is an important specification in a high-tension magneto ignition system. The engine manufacturer's specification for this gap is of the order of thousandths of an inch or hundredths of a millimeter. This is one of the specifications that must be checked when you're servicing a high-tension magneto ignition system.

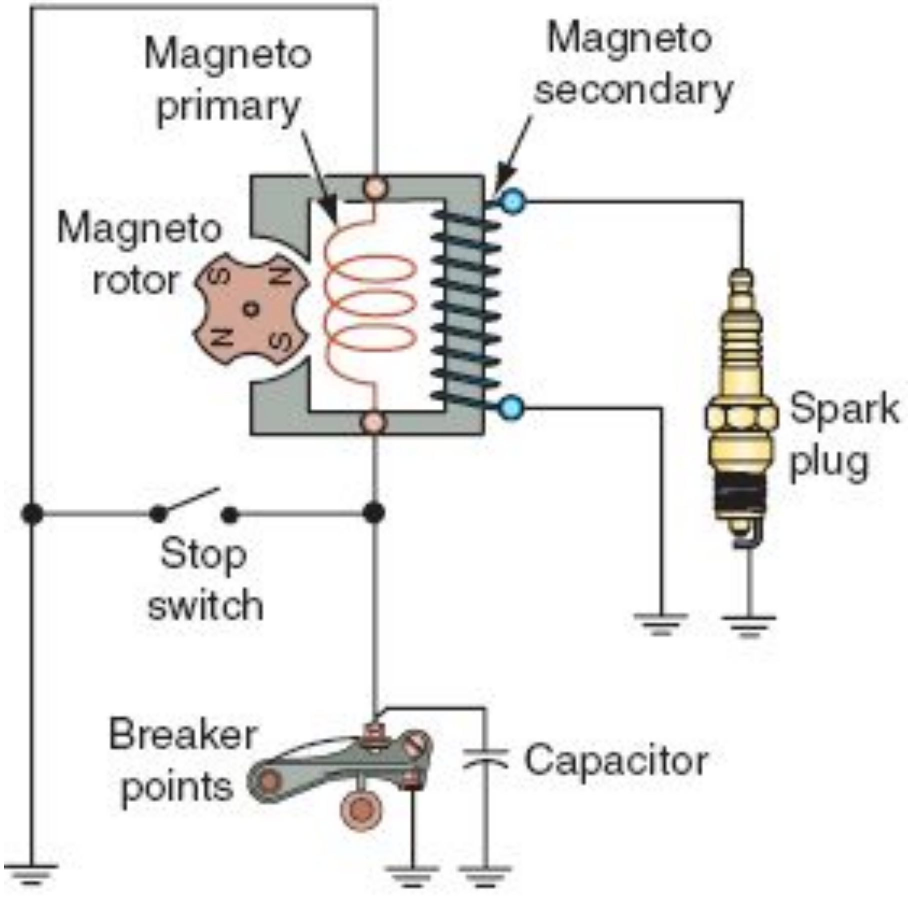


Figure 16 A high-tension magneto system.

Now, let's take a closer look at the operation of a high-tension magneto system. Figure 17 illustrates a simplified drawing of a high-tension magneto system in operation. You can see the breaker points at the center of the flywheel/rotor. In actual practice, the breaker points are located underneath the flywheel/rotor.

Remember that the ignition coil is basically a transformer and contains a primary winding and a secondary winding. In a typical hightension magneto ignition coil, the primary winding comprises about 150 turns of fairly heavy copper wire, and the secondary winding comprises about 20,000 turns of very fine copper wire. This difference in the windings is what causes the voltage to be multiplied as it's induced by the primary to the secondary.

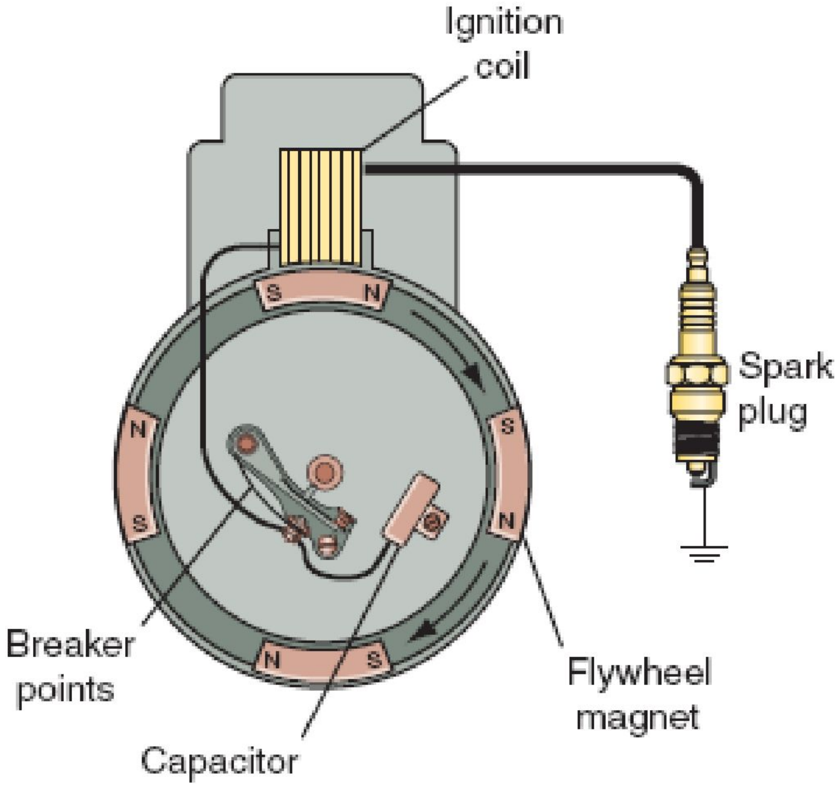


Figure 17 A high-tension magneto ignition system.

As the flywheel/rotor turns, the permanent magnets mounted near the edge of the flywheel/ rotor move past the ignition coil. This movement magnetizes the soft iron core (coil armature) and induces a current in the primary winding of the ignition coil. The magnetic field produced by the primary winding induces a voltage in the secondary winding. However, the buildup and collapse of the magnetic field by this action isn't fast enough to induce the voltage strong enough to fire the spark plug.

This is when the condenser comes in handy. The primary winding, as can be seen in Figure 17, is connected to the breaker points. When the breaker points are closed, a complete circuit is formed, and a current flows through the primary winding to produce a magnetic field.

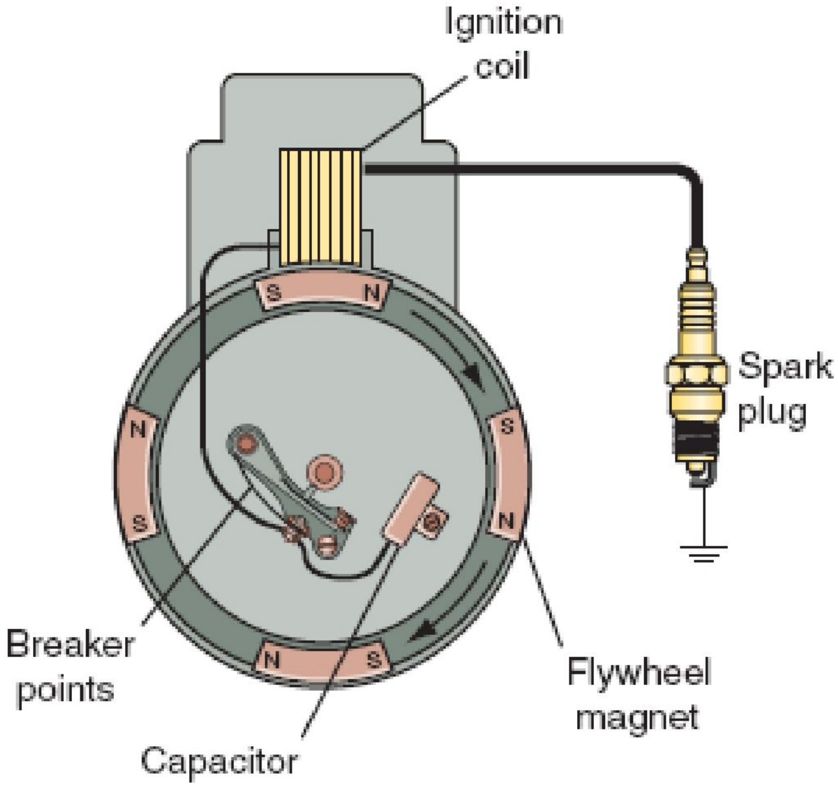


Figure 17 A high-tension magneto ignition system.

The eccentric egg-shaped cam that is located on the crankshaft is timed to open the breaker points just as the magnetic field in the primary begins to collapse. This interrupts the current flow in the primary circuit, causing the magnetic field around the primary winding to rapidly collapse. At the same time, the condenser (which also protects the breaker points from burning) releases its charge back through the primary winding to hasten the collapse of the magnetic field. This action helps to increase the voltage induced in the secondary winding to the required high strength.

The high voltage induced in the secondary winding causes a current to flow through the spark plug wire and arc across the spark plug gap. After the high voltage in the secondary winding is released as a spark, the flywheel/rotor continues to turn until the magnet positions itself by the ignition coil again, and the process repeats itself.

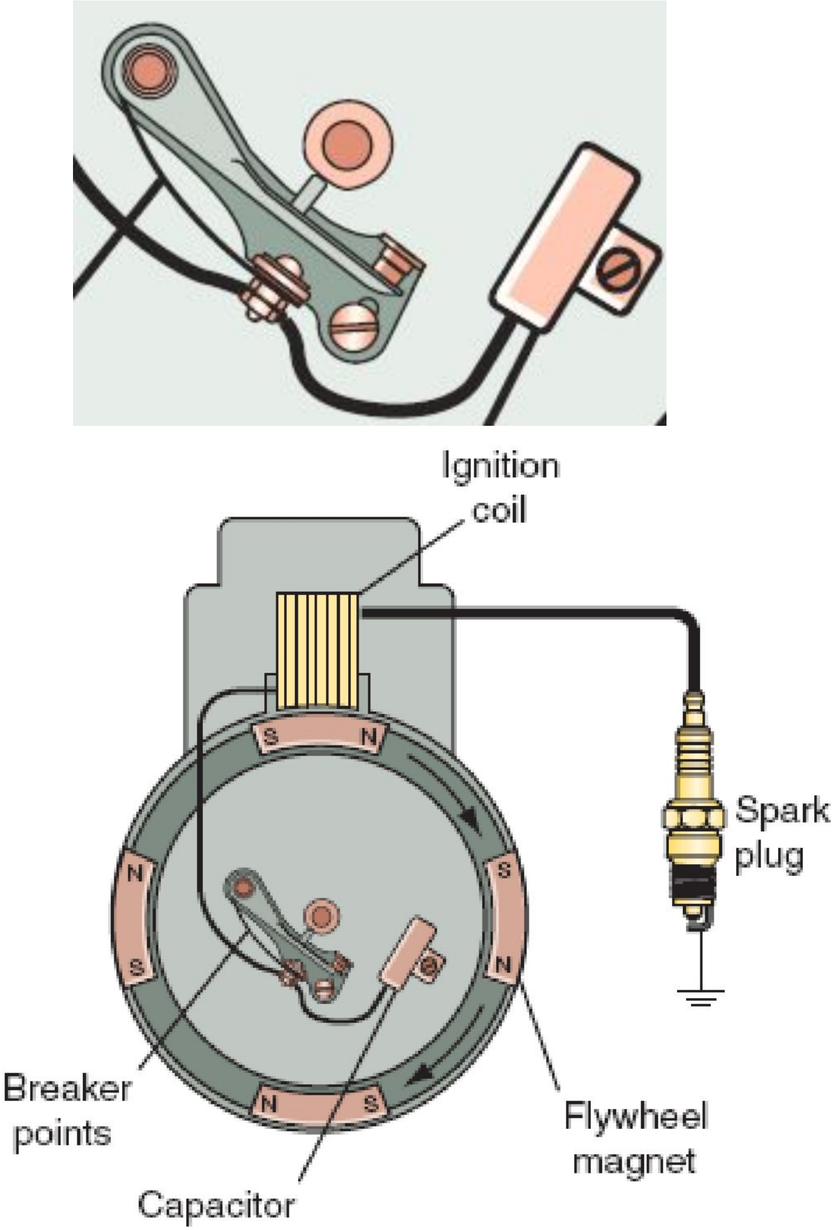


Figure 17 A high-tension magneto ignition system.

Low-Tension Magneto Ignition System

Not found often in power equipment engines, the low-tension magneto system is similar in operation to the high-tension magneto system.

The main difference is that the low-tension system uses a separate ignition coil. The breaker points in both the high-and low-tension magneto ignition systems are connected in series with the primary circuit. When the breaker points are closed in the low-tension magneto system, the primary circuit is completed (Figure 18). As the magneto rotor turns, AC (alternating current) is generated in the magneto windings and flows through the ignition coil primary winding. The primary winding in the ignition coil produces a magnetic field in the ignition coil.

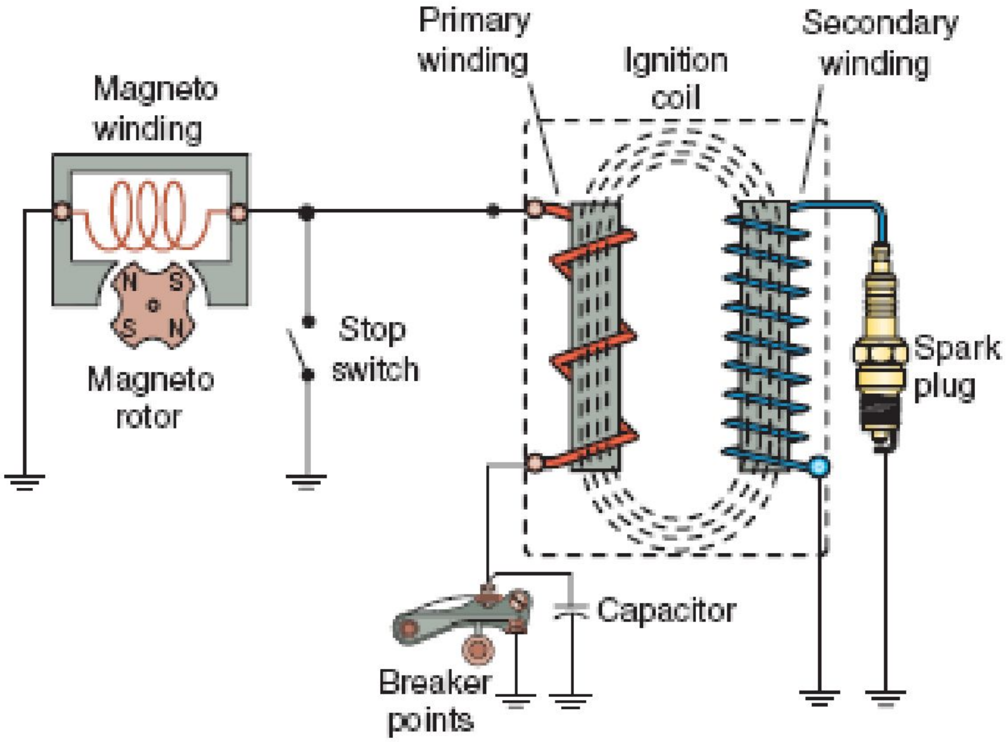


Figure 18 A low-tension magneto ignition system.

Energy-Transfer Ignition System

The energy-transfer ignition system (Figure 19) is another type of magneto ignition system found in power equipment engines.

The primary difference between the energy-transfer system and the magneto systems is that the breaker points are connected in parallel with the primary circuit instead of in series. By having the points wired in parallel, the primary winding in the ignition coil induces voltage into the secondary windings by using a rapid buildup of a magnetic field instead of a rapid collapse of the field.

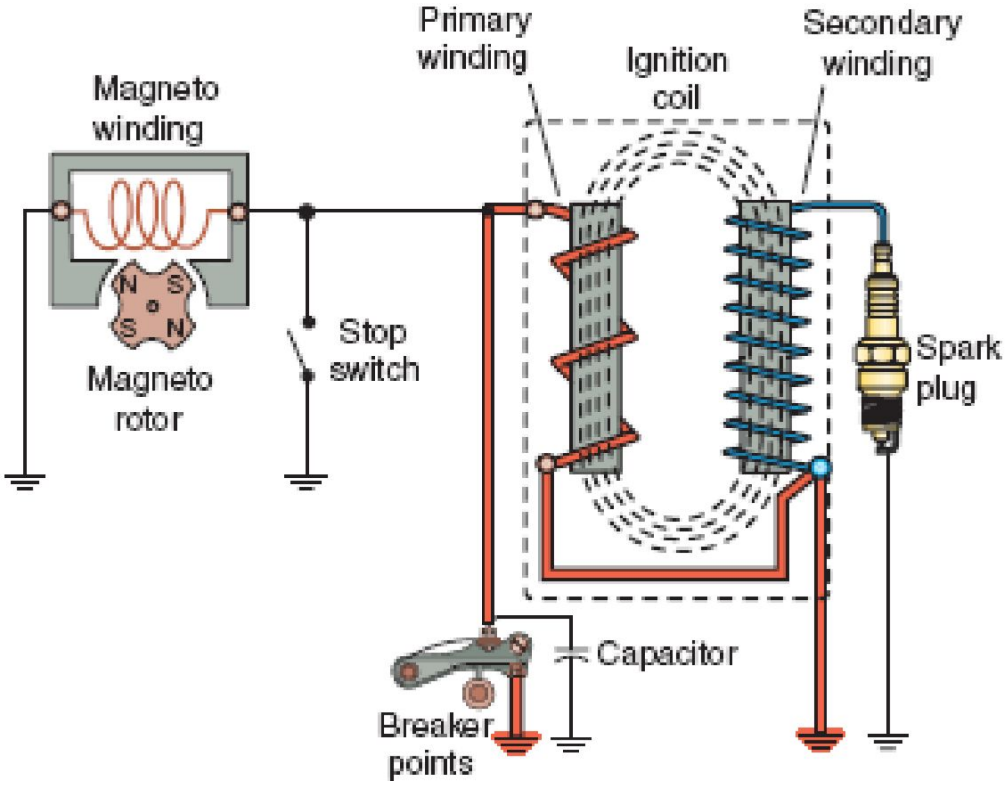


Figure 19 An energy-transfer ignition system.

(2) Battery-and-Points Ignition Systems

Now, let's look at a battery-and-points ignition system. Remember that battery ignition systems were used in older street-type power equipment engines.

In a battery-and-points ignition system, a battery is used to provide power to the ignition coil instead of a magneto; however, the remainder of the system is similar to the magneto systems we've discussed. The battery-and-points system (Figure 20) uses the same type of breaker points, condenser, and spark plug as magneto-type ignition systems.

The battery used in this type of system is the lead acid storage battery. Besides providing electricity to power the ignition coil, the battery may also be used to power lights, electric starter systems, and other accessories.

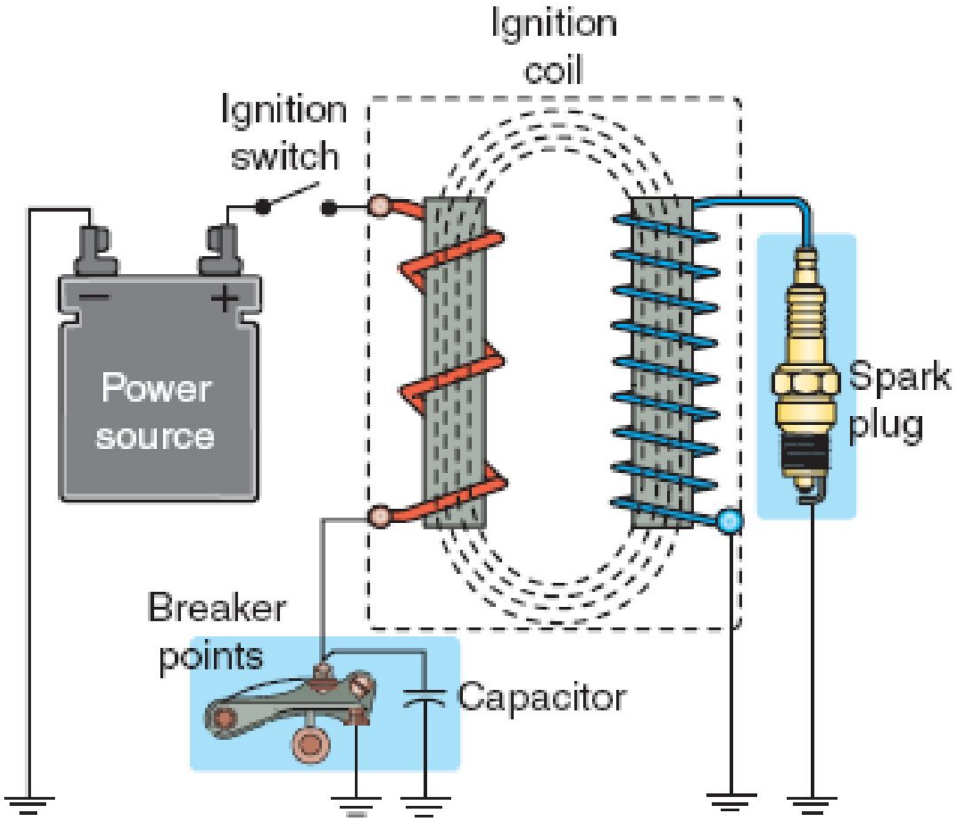


Figure 20 The battery-and-points system

The breaker points, the secondary winding, and the spark plug operate in exactly the same manner as in the high- and low-tension magneto systems. The contact points are opened by the breaker-point cam at the specified time.

As the points open, the primary magnetic field rapidly collapses, causing a high voltage to be induced into the secondary windings. The only difference between this ignition system and the magneto ignition system is that DC (direct current from the battery) is used to energize the primary winding of the ignition coil in the former, instead of the AC (alternating current).

When the ignition switch is turned off, the switch contacts open, and the flow of power from the battery to the primary winding of the ignition coil is stopped. As a result, the engine stops running.

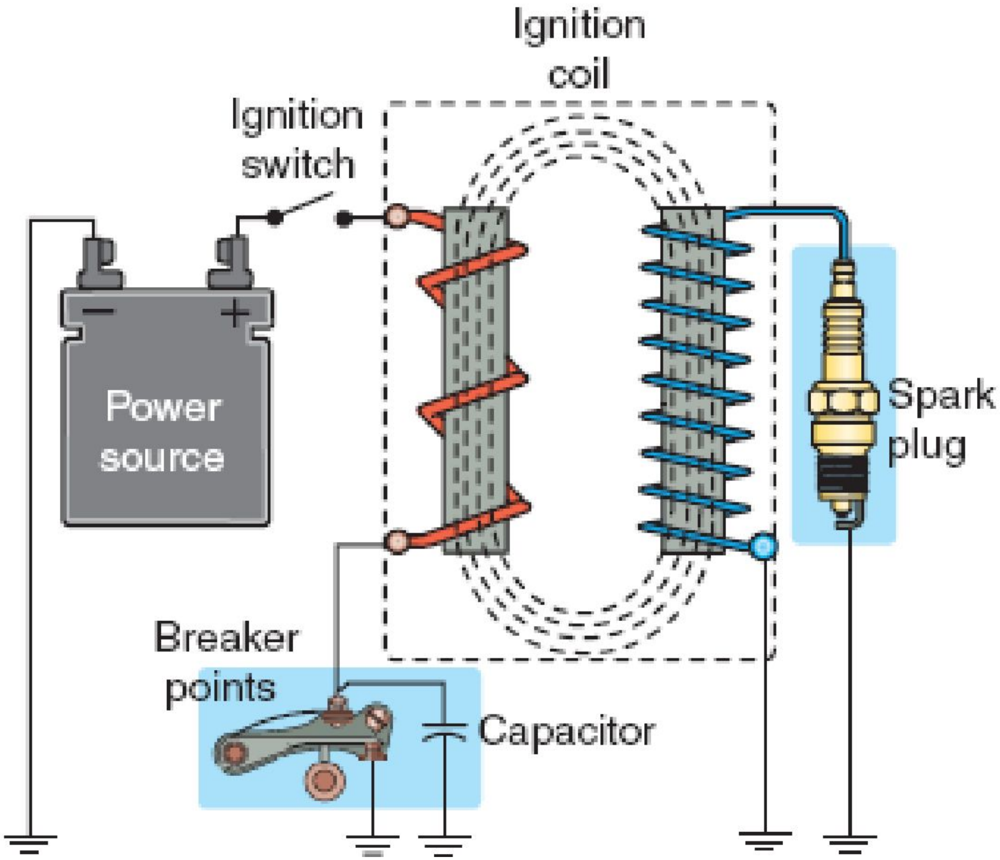


Figure 20 The battery-and-points system

II. Electronic Pointless Ignition Systems

Breaker-points-and-condenser ignition systems have been in use for many years, but you may see these types of ignition systems only in older power equipment engines. Newer power equipment engines come with electronic ignition systems. The reason for this is that mechanical breaker points eventually wear out and fail.

The result is poor engine performance at first and ultimately, total ignition failure. Electronic ignition systems are durable because they use permanent magnets, electronic sensors, diodes, transistors in place of mechanical switching components.

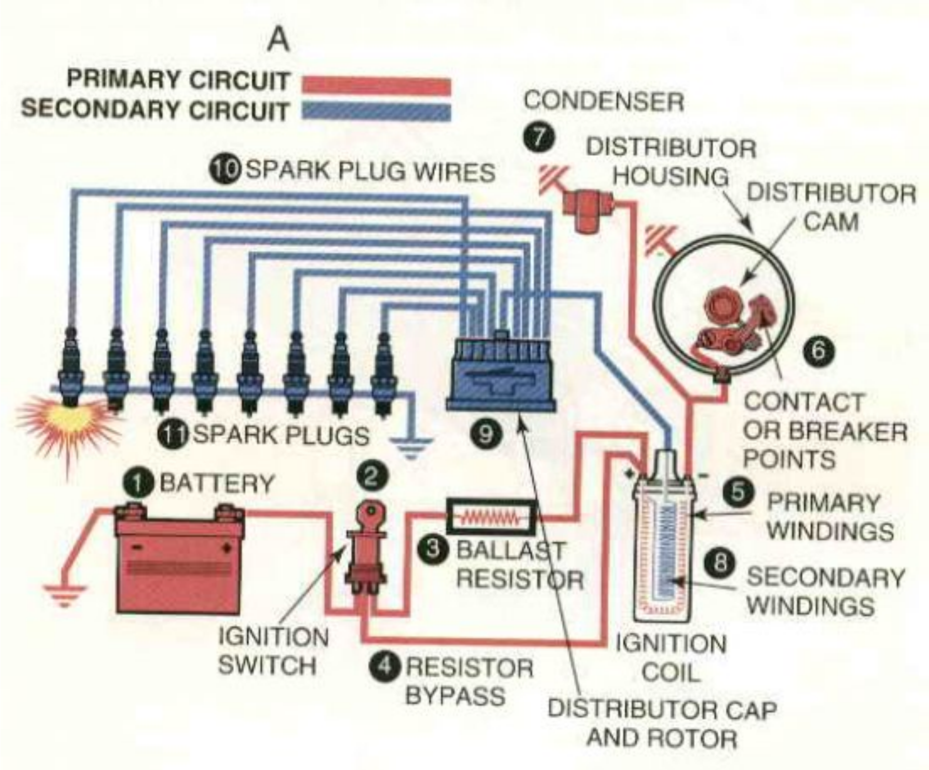


Figure 20a The breaker-points-and-condenser ignition systems

Except for the breaker points and condenser, electronic ignition systems use the same basic components that we've discussed. In place of the breaker points and condenser, the electronic ignition system uses an electronic ignition control module (ICM or ECM).

This module is a sealed, non-repairable unit that's generally mounted on a bracket on the chassis or can also be part of the ignition coil. The unit is frequently black in color, which has led to the term *black box* often being used for this module.

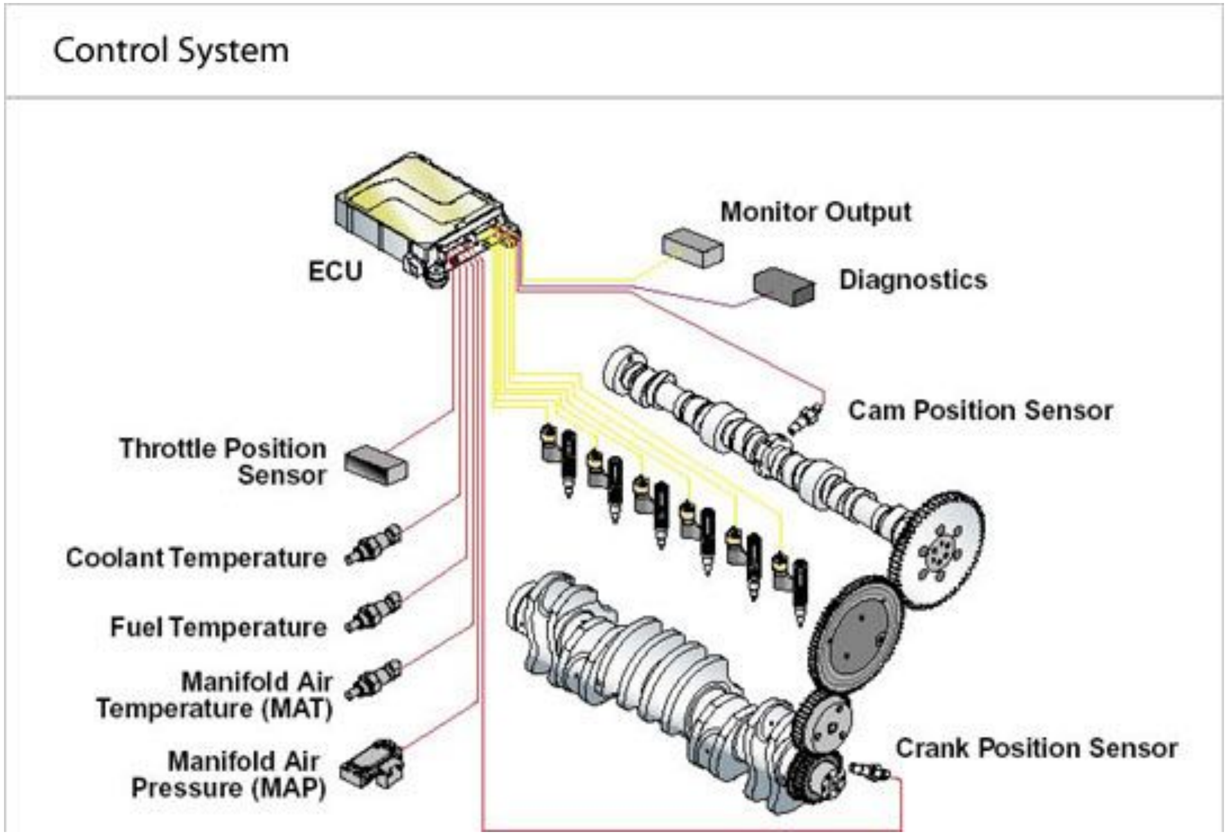


Figure 20b Electronic ignition systems

Electronic Pointless Ignition Systems

Other than the rotor and its magnets, electronic ignition systems have no moving parts; so the performance of the system doesn’t decline through operation. ICMs are resistant to moisture, oil, and dirt. Although resistant to outside conditions, water can get into modules and cause interruptions or failure to the ignition system.

However, in general, they’re reliable, don’t require adjustments, and have long life spans. An electronic ignition system provides easy starting and smooth, consistent power during the operation of the power equipment engine.

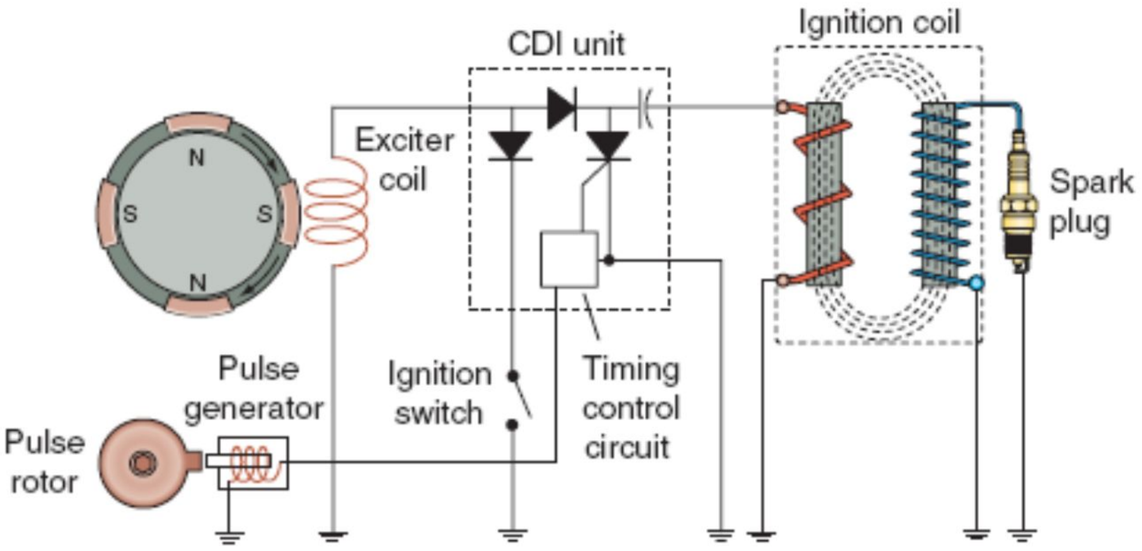


Figure 21 A typical capacitor discharge ignition (CDI) system.

Although there are many variations, there are three basic types of electronic ignition configurations that we'll discuss:

1. Capacitor discharge ignition;

2. Transistorized ignition;

3. Digitally controlled transistorized ignition.

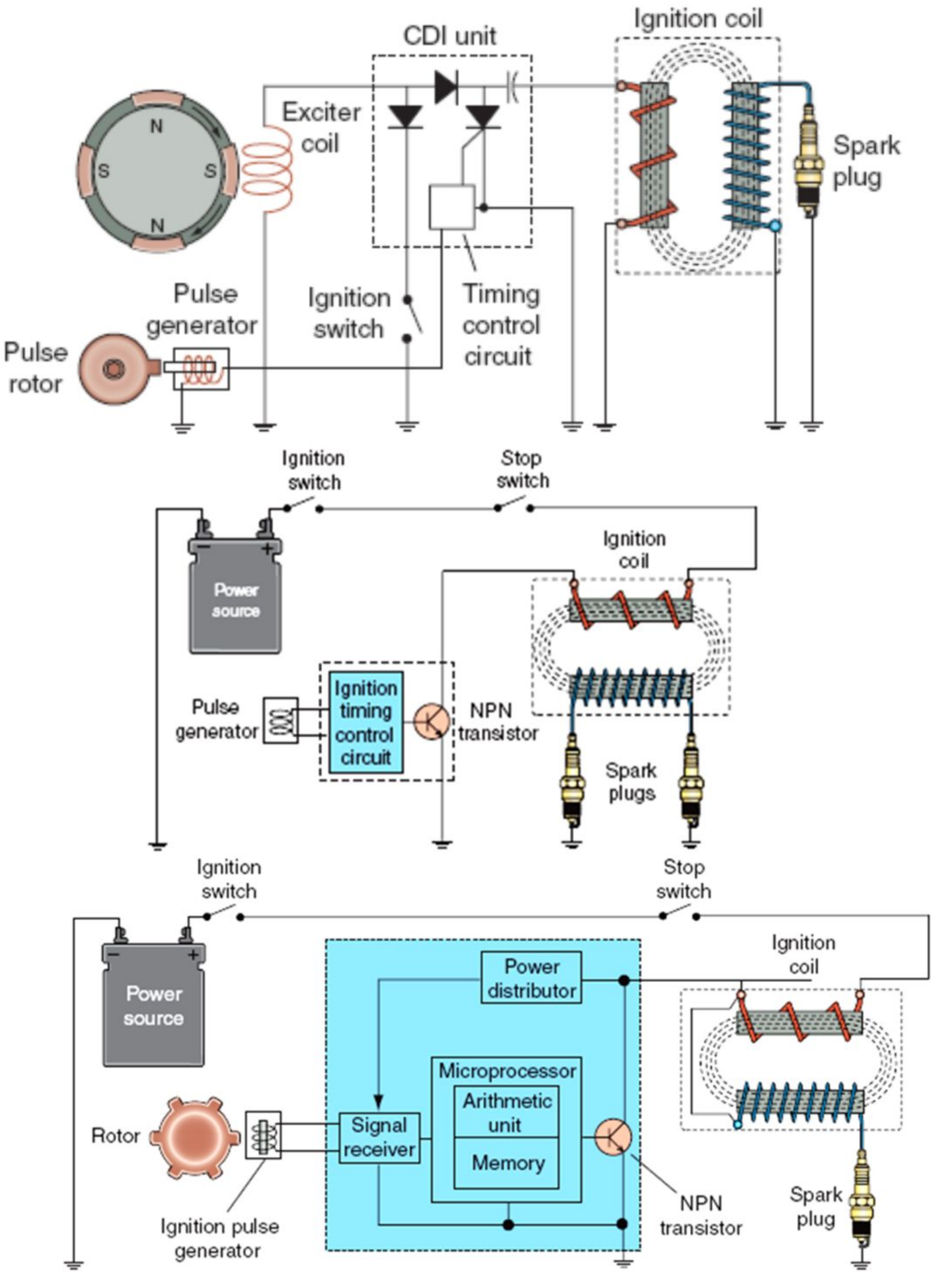


Figure 21a The three basic types of electronic ignition configurations.

1. Capacitor Discharge Ignition Systems

The electronic ignition system most often used in small power equipment engines is the CDI system.

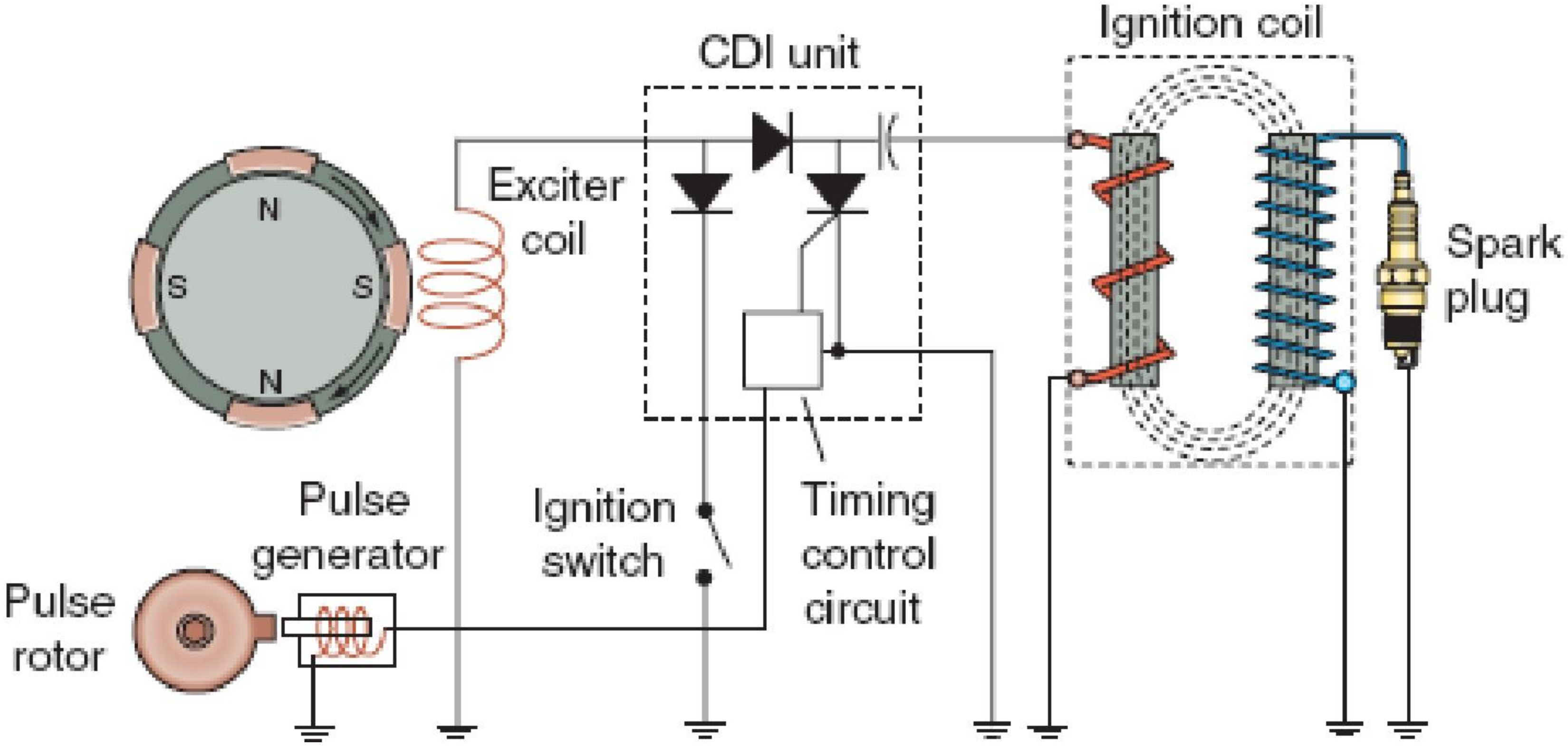


Figure 21 A typical capacitor discharge ignition (CDI) system.

The basic components of a **capacitor discharge ignition** (CDI) system may be configured in several ways. Although various CDI systems may have different arrangements of wiring and parts, they all operate in much the same way.

Figure 21 shows how the components of a CDI system are arranged in a typical power equipment engine.

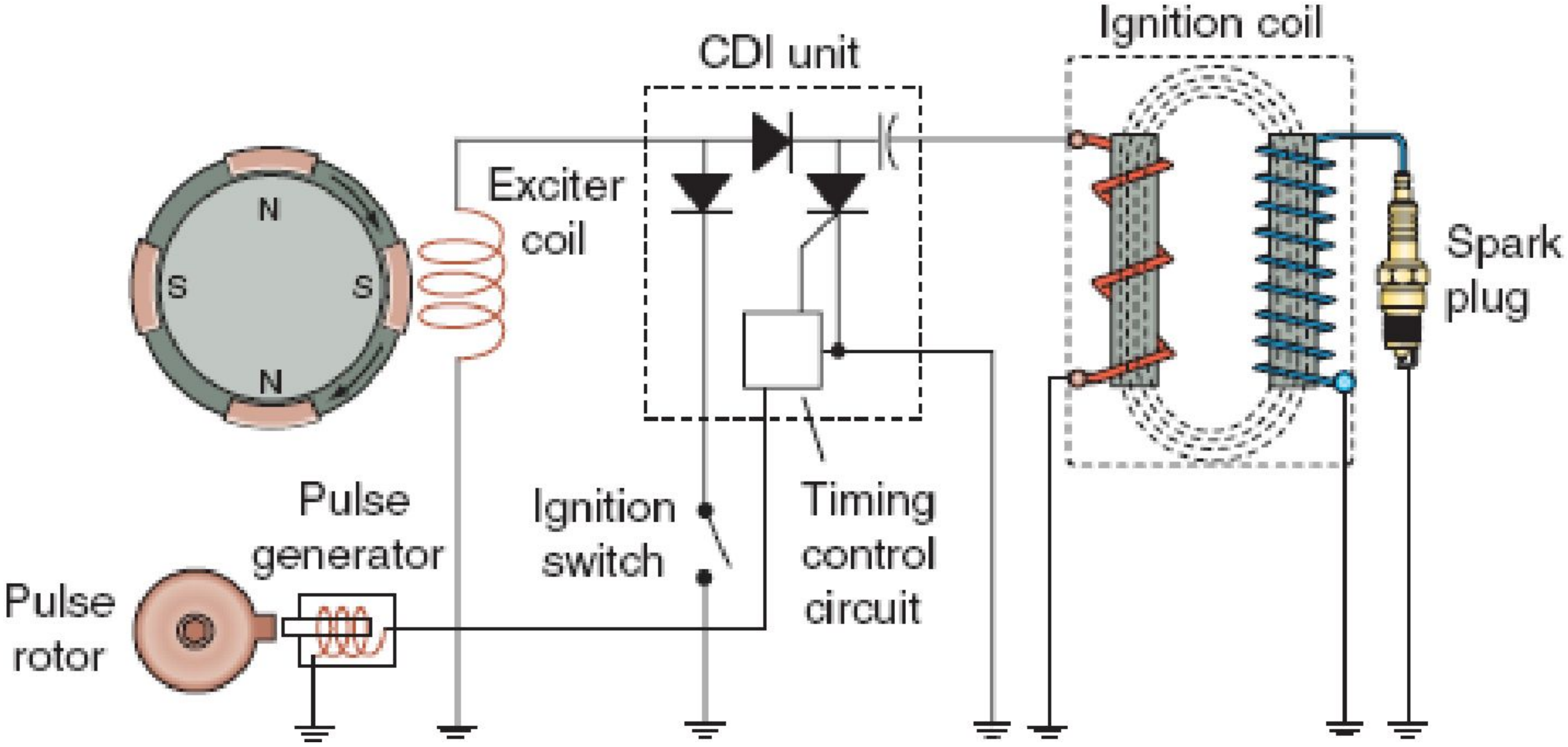


Figure 21 A typical capacitor discharge ignition (CDI) system.

Note that the CDI system contains two coils (windings) that are triggered by magnets in the flywheel/rotor or AC generator. The larger coil is called the charging or exciter coil, and the smaller coil is called the trigger coil. The trigger coil controls the timing of the ignition spark and essentially replaces the breaker points.

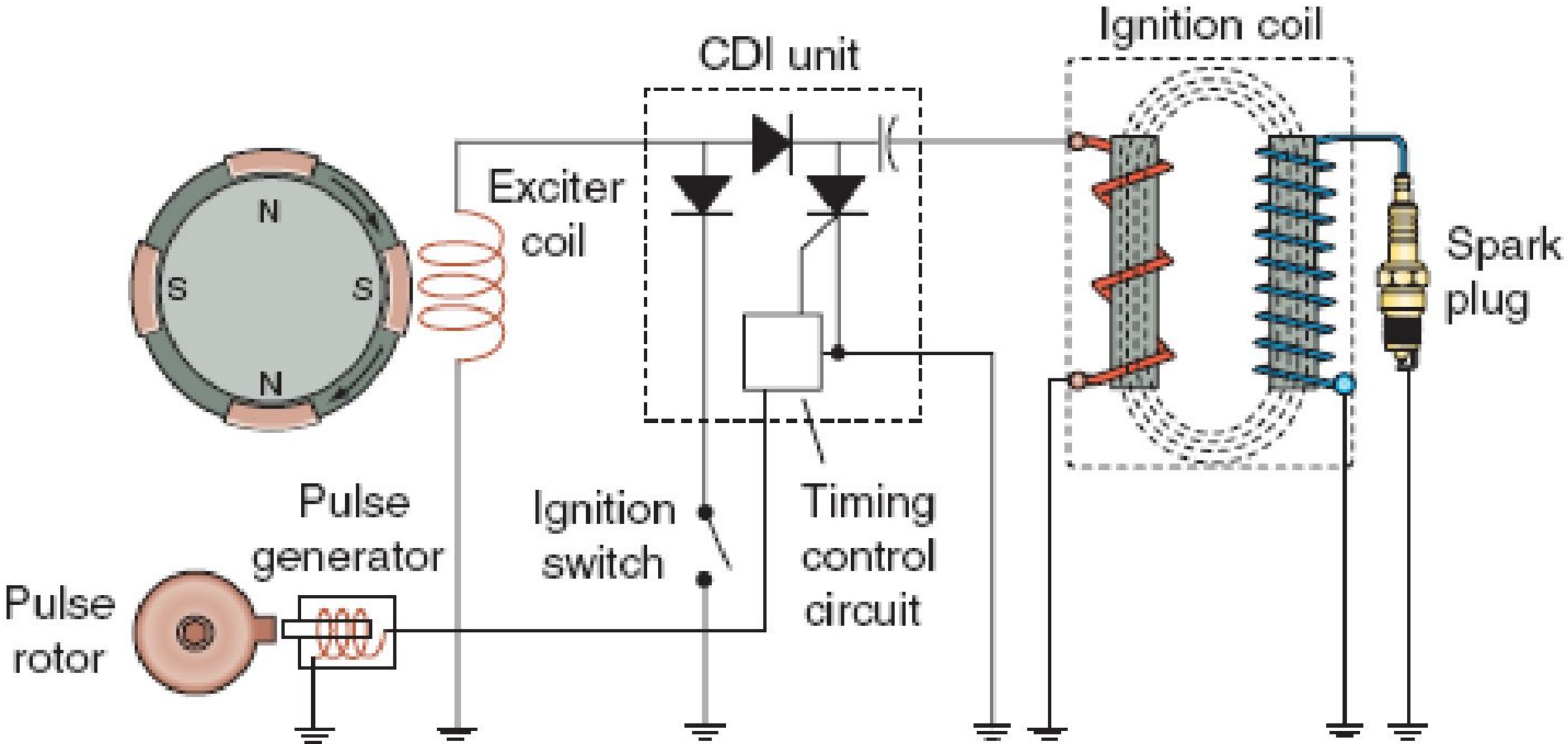


Figure 21 A typical capacitor discharge ignition (CDI) system.

As the flywheel/rotor rotates past the exciter coil, the AC produced by the exciter winding is rectified (changed to DC) by the diode in the CDI unit. The capacitor in the CDI unit stores this energy until it's needed to fire the spark plug (Figure 22).

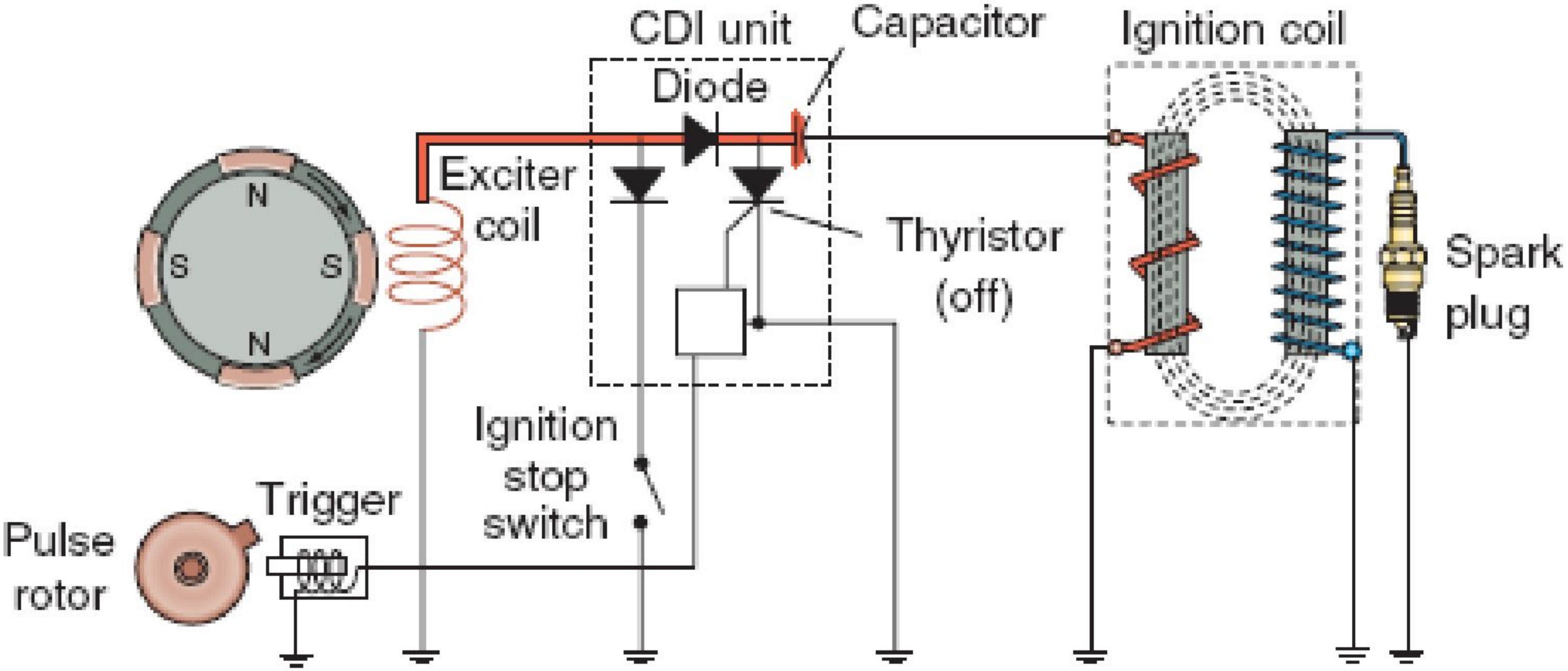


Figure 22 The capacitor in the CDI unit stores the diode-rectified DC until it's needed to fire the spark plug.

As the flywheel/rotor magnet rotates past the trigger coil, a low-voltage signal is in the trigger coil, which activates the electronic switch in the CDI unit (Figure 23).

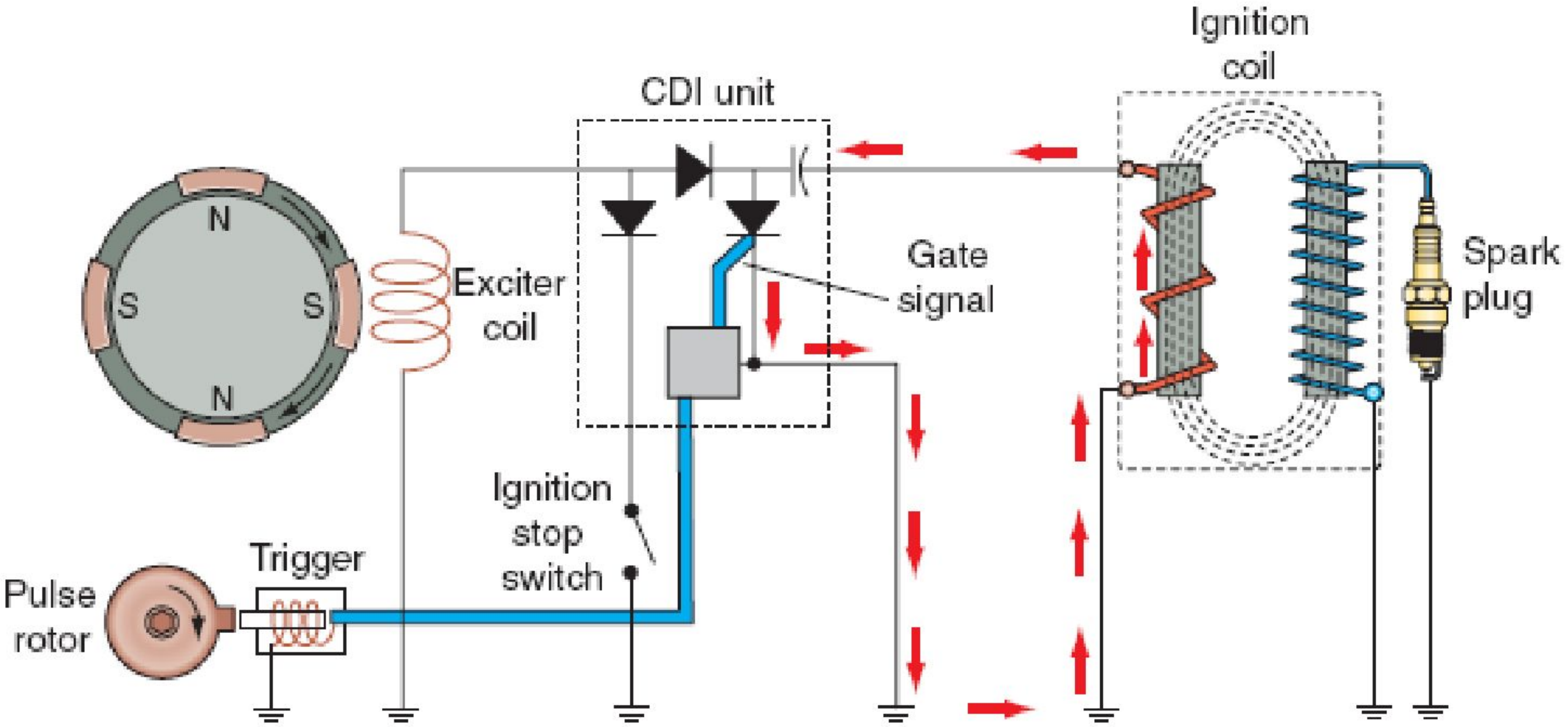


Figure 23 A low-voltage signal induced in the trigger coil

The electronic switch acts as the power source to the primary side of the circuit. This completes the primary circuit, to allow the energy stored by the capacitor to pass through the primary winding of the ignition coil. The transformer action of the ignition coil causes a high voltage to be induced in the secondary of the ignition coil, which fires the spark plug (Figure 24).

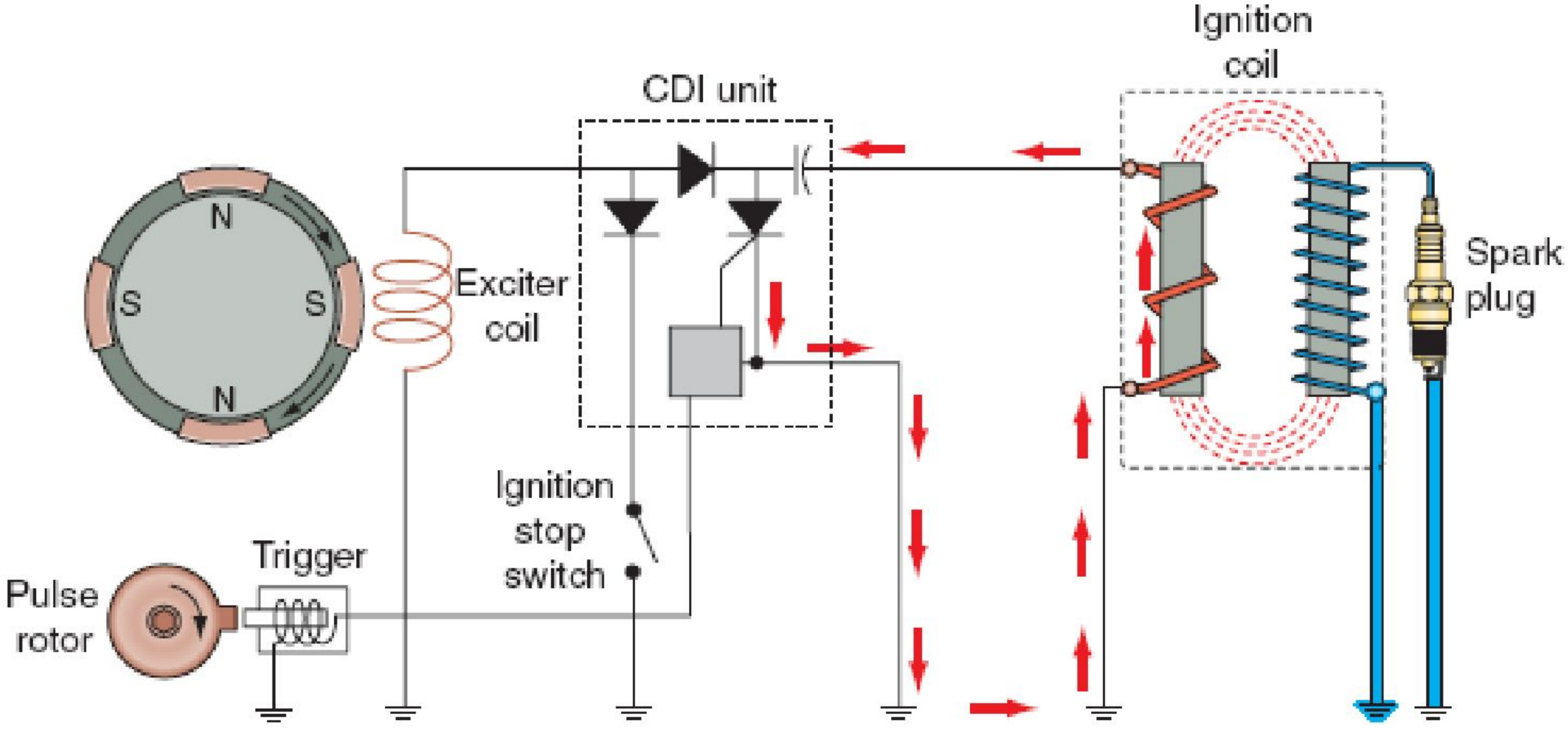


Figure 24 The transformer action of the ignition coil causes a high voltage to be induced in the secondary of the ignition coil, which fires the spark plug.

Another type of CDI ignition system found in some power equipment engines is one that uses DC from a battery as its source of voltage, with a voltage booster placed in the CDI unit, instead of the AC generator and an exciter coil (Figure 25). The voltage booster amplifies the battery voltage to over 200 volts. This type of CDI system uses the same components we've just discussed and operates in the same fashion.

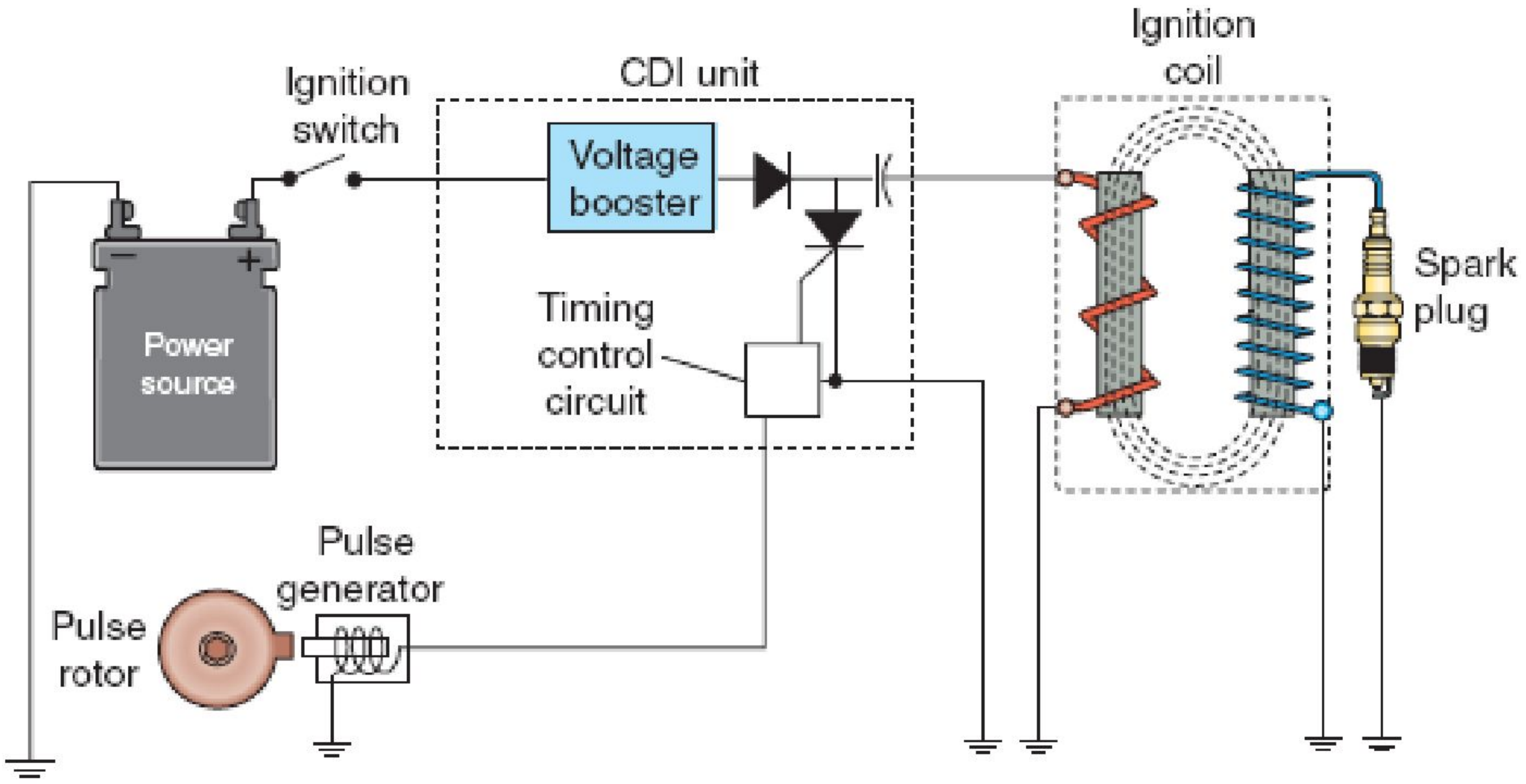


Figure 25 A simplified DC CDI system.

2.Transistorized Ignition Systems

Not popular but still used in some power equipment engines, the transistorized ignition system (Figure 26) operates by controlling the flow of electricity to the primary coil of the ignition. With this type of ignition system, transistors are contained within the ICM and are used to supply electricity to the primary coil.

When the voltage level in the primary reaches a certain level, a second transistor turns off the first transistor. This causes the magnetic field around the primary coil to collapse, which creates the high voltage across the secondary coil. The high voltage is then discharged across the spark plug.

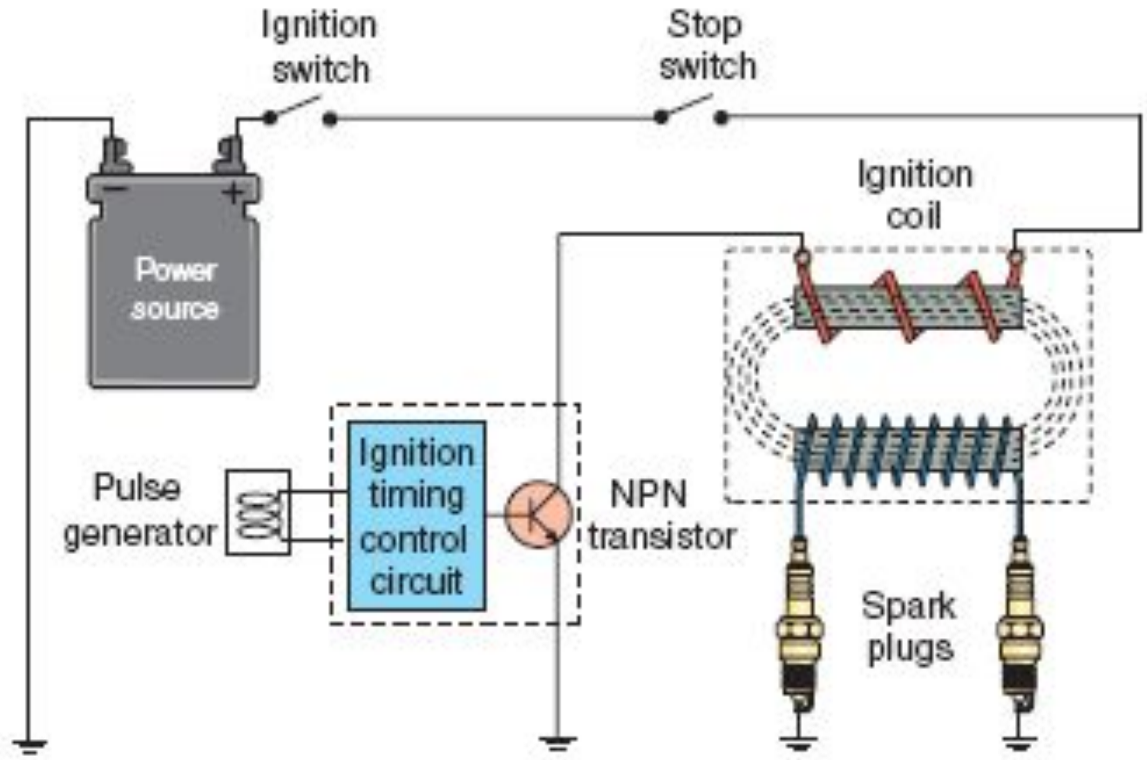


Figure 26 A transistorized ignition system.

3. Digitally Controlled Transistorized Ignition Systems

The digitally controlled transistorized ignition system is a type of **Transistorized Pointless Ignition** (TPI) that's found in most power equipment engine applications today (Figure 27).

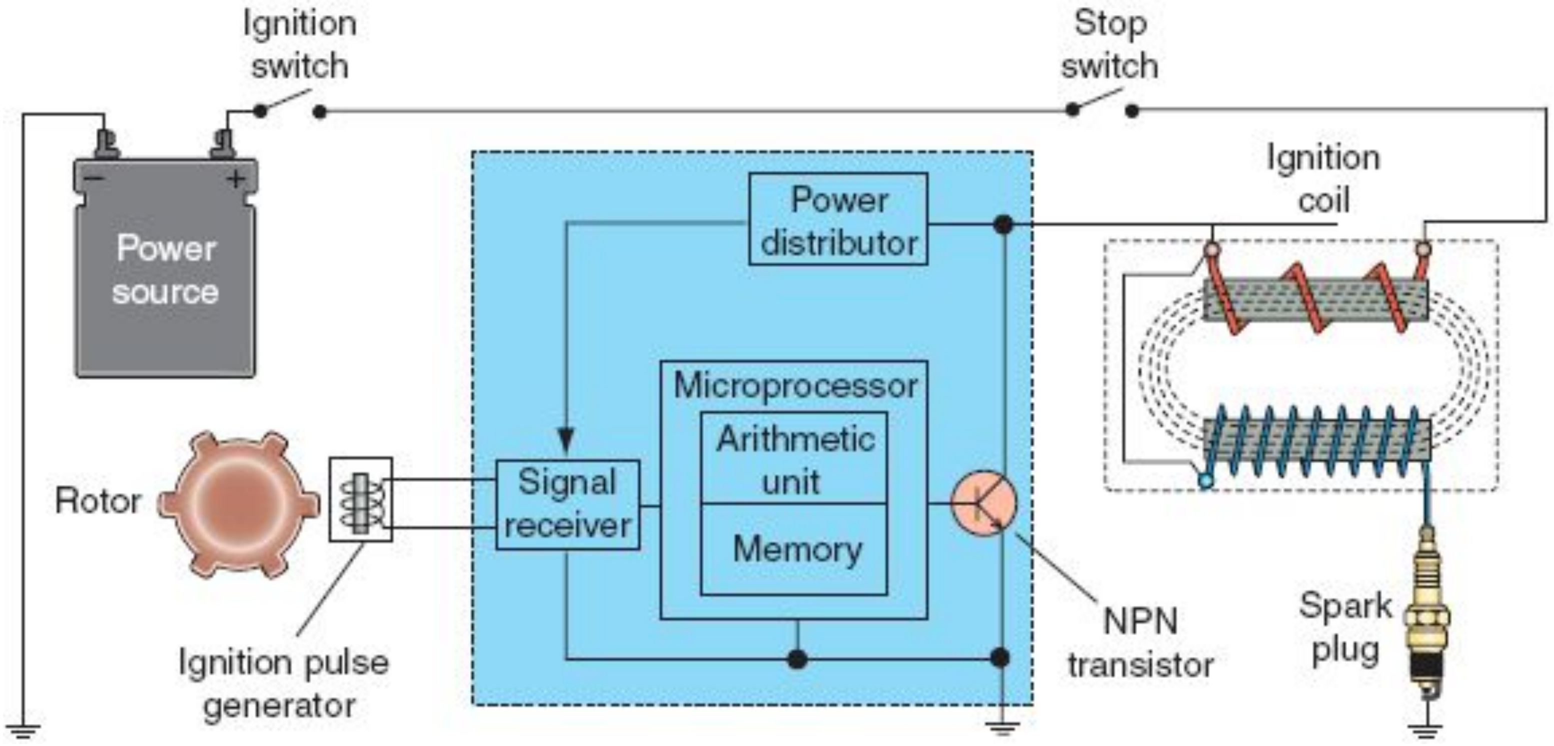


Figure 27 A digitally controlled transistorized ignition system.

The electronic components of a digitally controlled ignition system are contained in one unit that can be mounted directly to the power equipment engine. In this type of system, a transistor and a microcomputer are used to perform the trigger switching function.

The digitally controlled transistorized ignition system digitally controls ignition timing using a microcomputer inside the ICM.

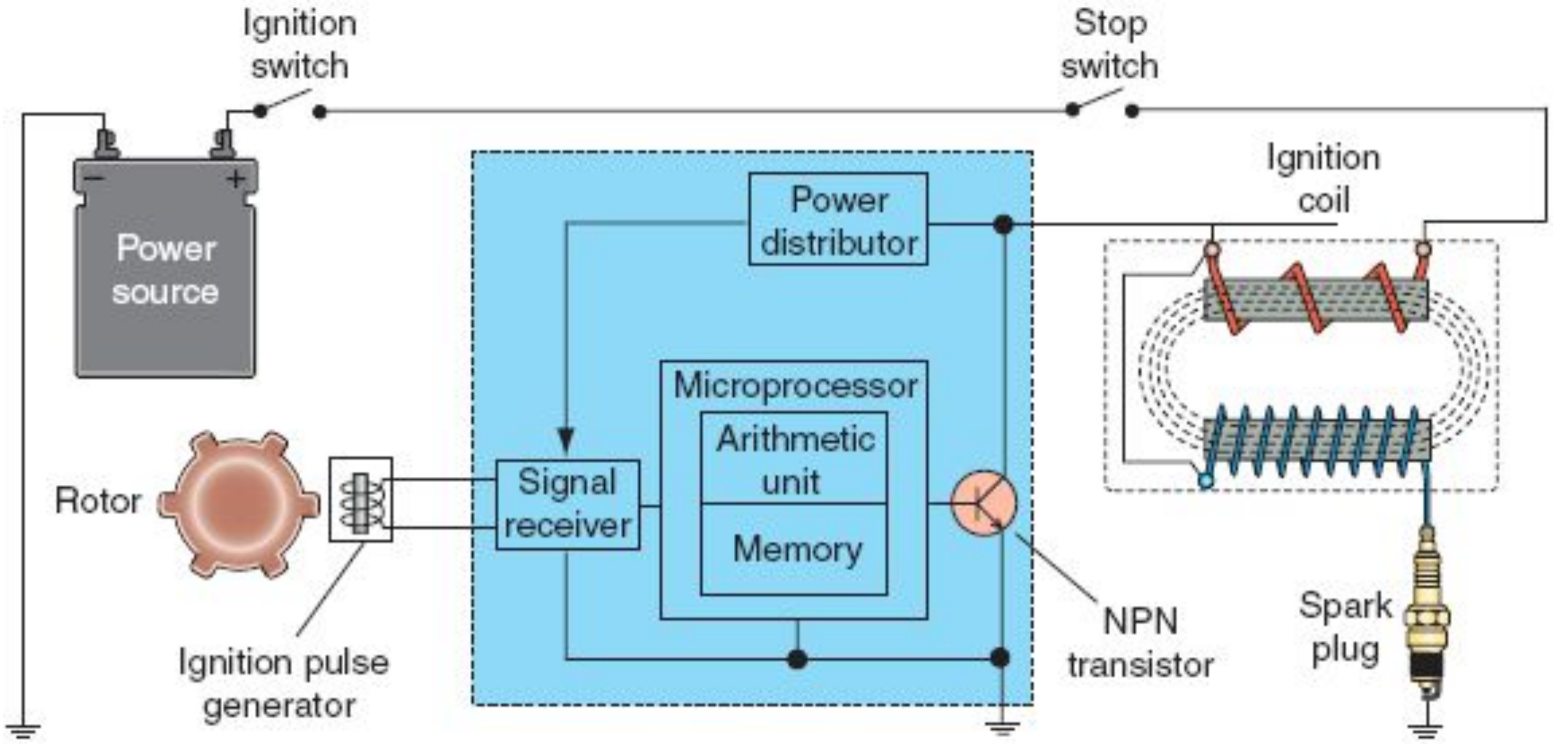


Figure 27 A digitally controlled transistorized ignition system.

The microcomputer calculates the ideal ignition timing at all engine speeds. The microcomputer also has a fail-safe mechanism, which cuts off power to the ignition coil in case the ignition timing becomes abnormal. These ignition systems can also have built-in rev-limiters.

The generator rotor has projections, known as reluctors, that rotate past the ignition pulse generator, producing electronic pulses. The pulses are sent to the ICM.

The engine rpm and crankshaft position of the cylinder are detected by the relative positions of the projections that are located on the rotor.

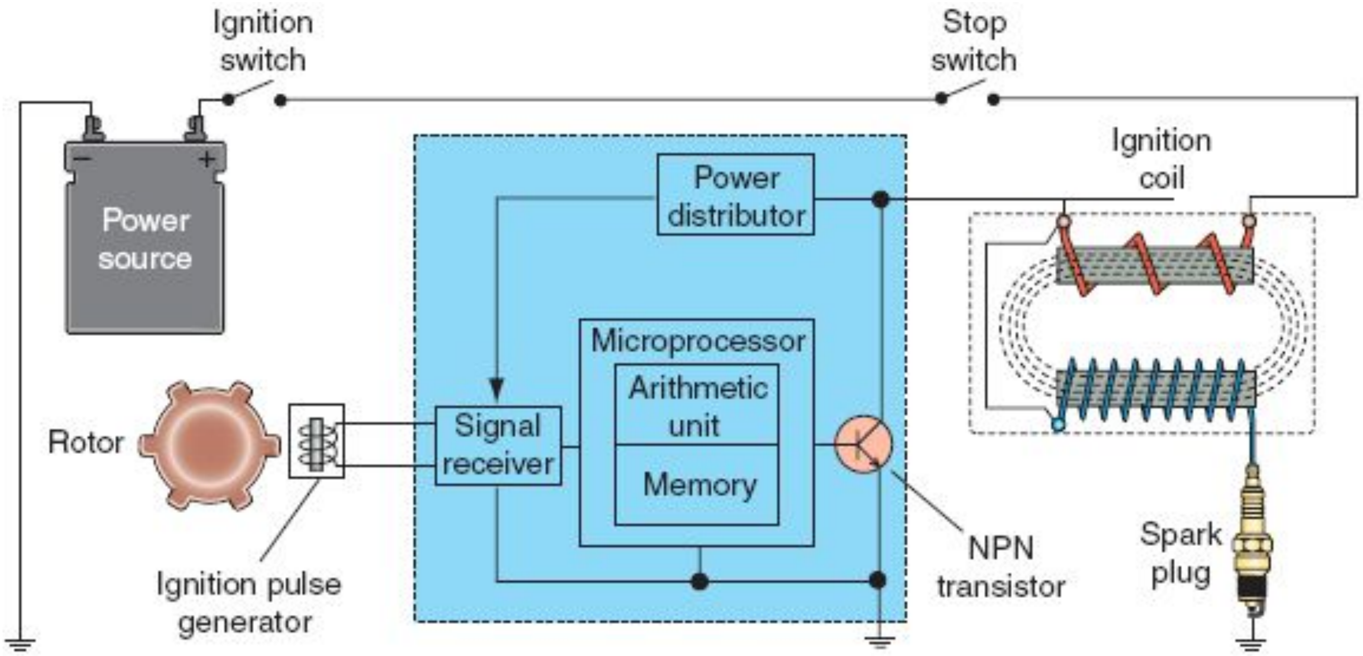


Figure 27 A digitally controlled transistorized ignition system.

The ICM consists of a power distributor, a signal receiver, and a microcomputer. The power distributor distributes battery voltage to the ICM when the ignition switch is turned to the On position and the engine stop switch is in the Run position.

The signal receiver uses the electronic pulse from the ignition pulse generator and converts the pulse signal to a digital signal. The digital signal is sent to the microcomputer, which has a memory unit and an arithmetic unit. The memory unit stores predetermined characteristics of the timing for different engine speeds and crankshaft positions.

It then determines when to turn the transistor on and off to achieve the correct spark plug firing time.

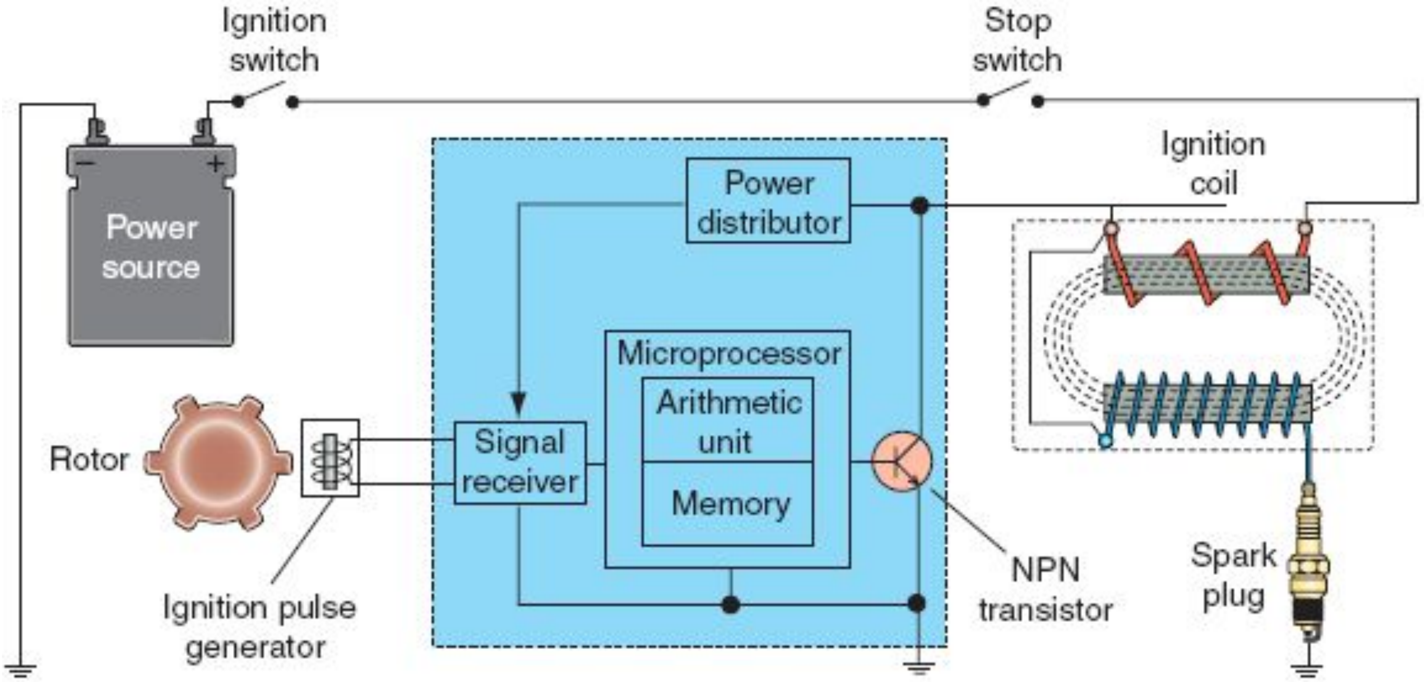


Figure 27 A digitally controlled transistorized ignition system.

When the transistor is turned on, the primary winding of the ignition coil is fully energized. The microcomputer turns the transistor off when it’s time to fire the spark plug. This collapses the magnetic field and induces a high voltage in the ignition coil secondary winding to fire the spark plug.

Visually, both the standard TPI (Transistorized Pointless Ignition) system and the digital TPI system look similar. The primary visual difference between these two popular ignition systems is the ignition pulse generator rotor. When used on a standard TPI, the pulse generator rotor has only one reluctor to signal the pulse generator. On the digital TPI system, there are several reluctors to “inform” the microcomputer of the engine’s rpm and crankshaft position.

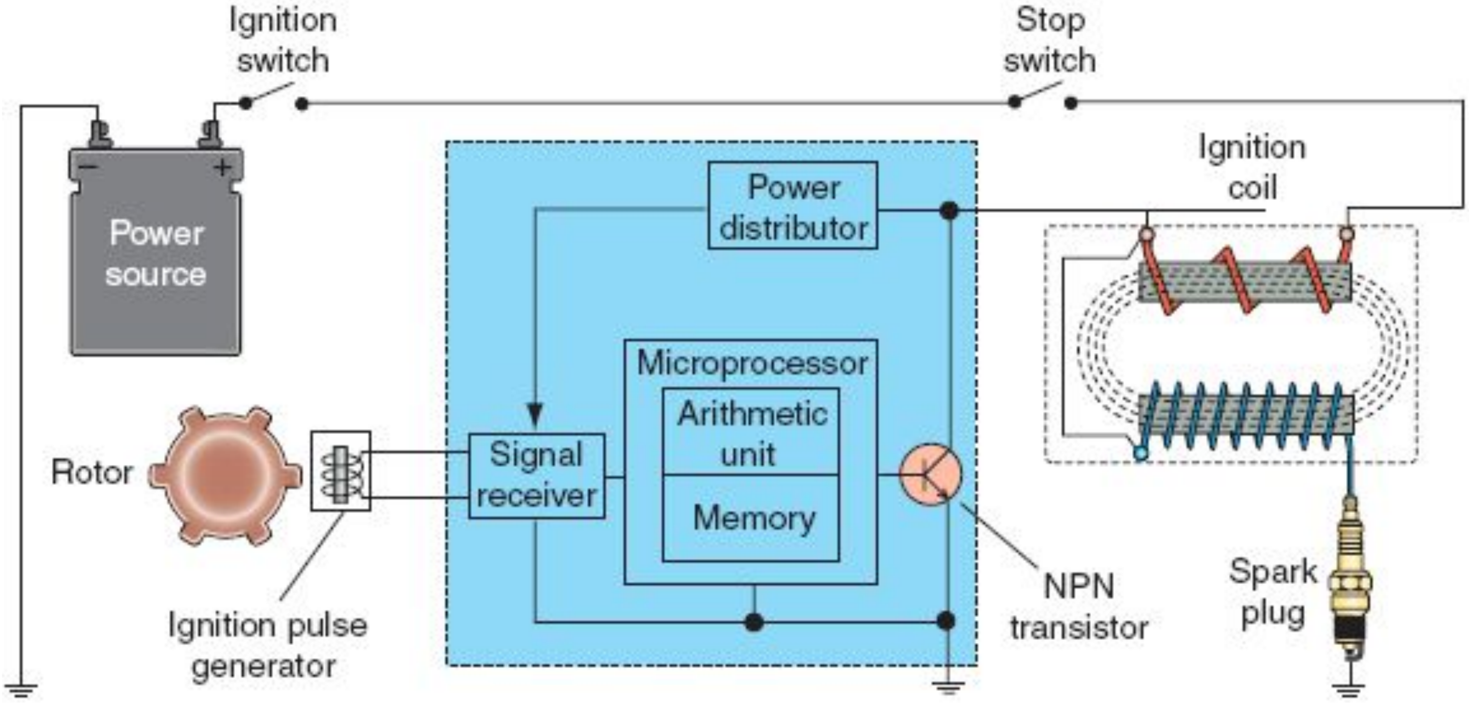


Figure 27 A digitally controlled transistorized ignition system.

Summary

1. The ignition system has three main functions:

- first, it must generate an electrical spark that has enough heat to ignite the air-fuel mixture in the combustion chamber;
- second, it must maintain that spark long enough to allow for the combustion of all the air and fuel in the cylinder;
- lastly, it must deliver a spark to the cylinder so combustion can begin at the right time during each compression stroke of the piston.

2. The main components of an ignition system are the power source, ignition switch, ignition coil, spark plug, triggering switch, and stop switch.

3. All ignition systems use a primary coil and a secondary coil. The current in the primary coil induces a relatively large voltage in the secondary, to create a high output voltage to the spark plug.

Summary

4. There are two general types of ignition systems:
  - breaker point and
  - electronic ignition.
5. There are four types of breaker point systems:
  - high-tension magneto,
  - low-tension magneto,
  - energy transfer, and
  - battery point.
6. There are three basic types of electronic ignition systems:
  - capacitive discharge,
  - transistorized, and
  - digitally controlled transistorized systems.