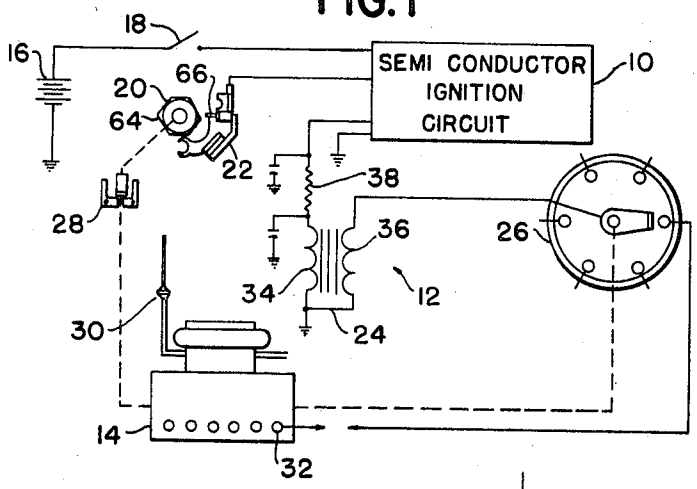
March 25, 1969 A. SCHNEIDER ET AL 3,434,462

SEMICONDUCTOR IGNITION

Filed June 21, 1965 Sheet 1 of 2

FIG. 1



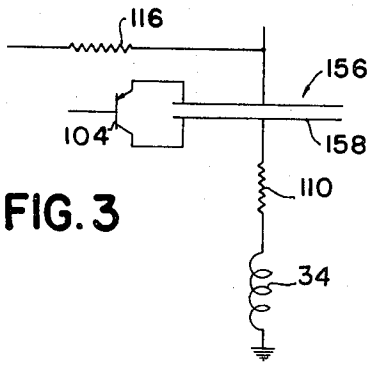


FIG. 3

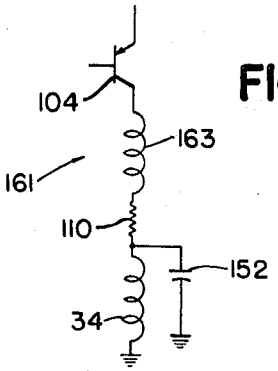


FIG. 5

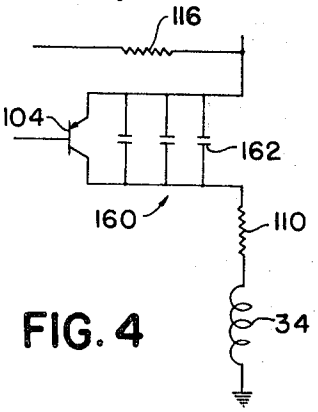


FIG. 4

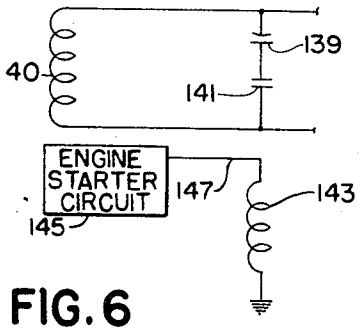


FIG. 6

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SEMICONDUCTOR IGNITION

Filed June 21, 1965 Sheet 2 of 2

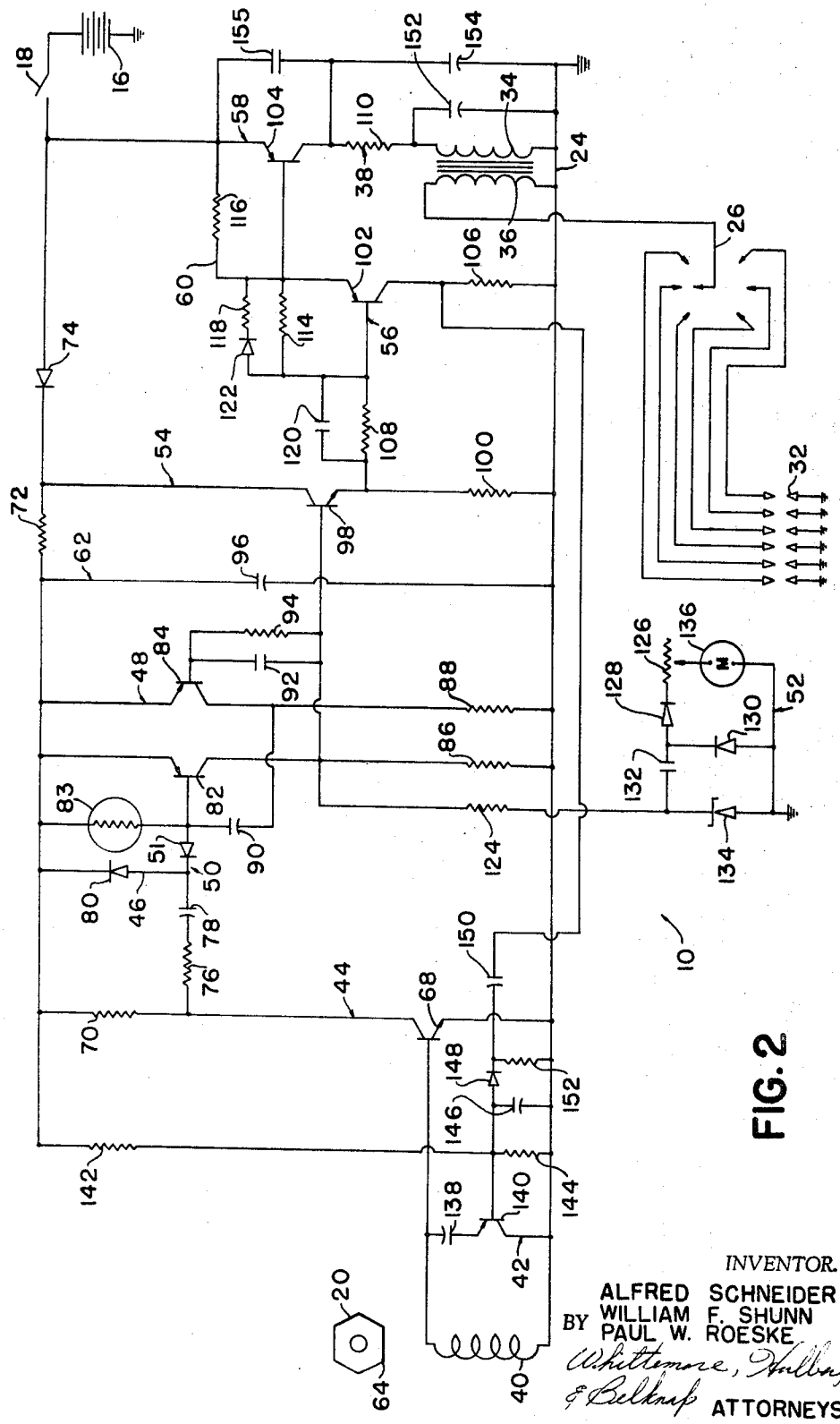


FIG. 2

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SEMICONDUCTOR IGNITION

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U.S. Cl. 123—148 15 Claims

ABSTRACT OF THE DISCLOSURE

A pulsed semiconductor ignition system for an internal combustion engine including a switching semiconductor and a radio frequency protection circuit for the switching semiconductor for permitting high energy sparks at lower current drain and cost with less heat. The semiconductor ignition circuit further includes an improved switching compensating circuit, an improved power supply filter circuit integral with the ignition system, spurious and multiple signal suppression circuits, and an integral tachometer circuit.

In the past semiconductor ignition systems, such as shown in commonly owned, herein incorporated, co-pending patent application Ser. No. 336,418, filed Jan. 3, 1964, now Patent No. 3,291,108, have provided protection for the switching semiconductor by means of a Zener diode connected across the emitter and collector of the switching semiconductor effective to limit the primary back voltage from the ignition coil to about one hundred volts. The Zener diode in the past has therefore limited the possible voltage of the spark whereby increased spark energy could only be obtained by higher current drain on the power supply which in the usual case is a limited storage battery. The expense and current drain inherent with Zener diode protection of the switching semiconductor has been considered necessary since without the Zener diode the switching semiconductor of past semiconductor ignition systems have failed apparently due to a high back voltage from the ignition coil produced by voltages in the ignition coil of sufficient magnitude to provide a spark having required energy at allowable current drain.

In experimental operation of semiconductor ignition systems without Zener diode protection for the switching semiconductor it was found that with the system disconnected from the spark plugs that the switching semiconductor could withstand considerably more back voltage than it was supposed to be able to and was able to with the spark plugs connected. Research into this phenomenon indicated that the lower break-down voltage of a switching semiconductor in an ignition circuit with the spark plugs connected is due to a very large radio frequency feed-back signal to the switching semiconductor from the ignition coil on firing of the ignition system. The radio-frequency feed-back signal may in practice reach one thousand volts and one hundred volts is typical.

It is therefore particularly desirable to provide radio frequency protection for the switching semiconductor. With such protection the relatively expensive Zener diode may be eliminated and voltage in the ignition coil increased to provide higher spark energy with less current drain and less heat which accompanied previously required high current drains.

Also, with pulse type semiconductor ignition systems as illustrated in the above referenced patent application, the circuit for generating a signal at a rate proportional to the speed of and synchronized with the operation of the engine has been found to be particularly sensitive to spurious signals, such as produced by cranking of the

engine starter, meshing of gears and even pounding on the engine during startup. The spurious signals are particularly detrimental to engine starting in that they produce firing of the ignition system with the pistons of an internal combustion engine, for example, in the wrong position, causing back-firing or bucking of the engine.

Further, in prior semiconductor ignition systems the initially produced pulse has sometimes been found to produce a train of pulses in the ignition circuit. This is particularly true in ignition systems wherein the synchronized initial pulse is differentiated for use in producing a switching signal for the switching semiconductor of the ignition system. Thus, a slow rising initial pulse synchronized with the engine operation may be differentiated three or four times before the pulse is dissipated. These multiple pulses are detrimental to operation of subsequent circuits in the ignition system or operating off of the ignition system on the basis of a sensed number of pulses such as some tachometers.

Also, in semiconductor ignition systems it is desirable to provide a tachometer to indicate engine speed. In the past such tachometers have been complicated and expensive to provide due to the poor regulation of power supplied to the ignition systems and the multiple pulses produced as indicated above. In addition the prior semiconductor ignition systems have been deficient in that the switching time of the switching semiconductor has been too long.

It is therefore one of the objects of the present invention to provide an improved semiconductor ignition system for internal combustion engines or the like.

Another object is to provide a pulsed semiconductor ignition system including a more economical circuit for providing more spark energy at less current drain than possible with prior similar semiconductor ignition systems.

Another object is to provide a semiconductor ignition system including improved switching semiconductor protection circuits.

Another object is to provide a semiconductor ignition system including a spurious signal suppression circuit.

Another object is to provide a semiconductor ignition system including a multiple signal suppression circuit.

Another object is to provide a semiconductor ignition system including an integral tachometer circuit.

Another object is to provide a semiconductor ignition system including an improved compensation circuit for fast switching of the switching semiconductor.

Another object is to provide a semiconductor ignition system including an improved power supply filter circuit.

Another object is to provide a protection circuit for a switching semiconductor.

Another object is to provide an improved compensating circuit for a switching semiconductor.

Another object is to provide an improved tachometer.

Another object is to provide a spurious signal suppression circuit.

Another object is to provide a multiple signal suppression circuit.

Another object is to provide a semiconductor ignition circuit which is simple in construction, economical to manufacture and efficient in use.

Other objects and features of the invention will become apparent as the description proceeds, especially when taken in conjunction with the accompanying drawings, illustrating a preferred embodiment of the invention, wherein:

FIGURE 1 is a partly block, partly schematic and partly diagrammatic diagram of an internal combustion engine and an ignition system including a semiconductor ignition circuit constructed in accordance with the invention in conjunction therewith.

FIGURE 2 is a schematic diagram of the semiconductor ignition circuit and a portion of the ignition system shown in FIGURE 1.

FIGURE 3 illustrates a modification of part of the portion of the ignition system illustrated in FIGURE 2.

FIGURE 4 illustrates another modification of part of the portion of the ignition system illustrated in FIGURE 2.

FIGURE 5 illustrates still another modification of part of the portion of the ignition system illustrated in FIGURE 2.

FIGURE 6 illustrates a modification of the spurious signal suppression part of the portion of the ignition system illustrated in FIGURE 2.

With particular reference to the figures of the drawings, one embodiment of the present invention will now be considered in detail.

The semiconductor ignition circuit **10** is illustrated in FIGURE 1 in a pulse type semiconductor ignition system **12**, in conjunction with an internal combustion engine **14**. The ignition system **12** besides the ignition circuit **10** includes a battery **16**, ignition switch **18**, distributor cam **20**, an electric pulse producing device **22**, ignition coil **24** and distributor **26**. The ignition system **12** further includes the centrifugal distributor cam advance mechanism **28**, engine vacuum advance apparatus **30** and the spark plugs **32** connected between the engine **14** and distributor **26**.

In operation of the ignition system **12**, with the ignition switch **18** closed, the battery **16** provides electrical energy for the operation of the semiconductor ignition circuit **10**. On rotation of the engine **14** and the distributor cam **20** mechanically connected thereto, the pulse producing device **22** provides a pulse of electric energy which is amplified and used to control the electric current flowing through the primary winding **34** of ignition coil **24**. Cutting off of the current through the primary winding **34** of ignition coil **24** produces a pulse of electric energy in the secondary winding **36** of ignition coil **24** at distributor **26**. Pulses of electric energy from the secondary winding **36** of ignition coil **24** are distributed by distributor **26** to the separate spark plugs **32** for firing fuel in the internal combustion engine **14** to produce rotation thereof.

Firing of the spark plugs **32** produces a considerable radio frequency signal which may be fed back through the ignition coil **24** to the semiconductor ignition circuit **10** to produce harmful effects on the components thereof. Therefore, in accordance with the invention a radio frequency filter circuit **38** is provided between the ignition coil **24** and the semiconductor ignition circuit **10** for isolating the semiconductor ignition circuit from the radio frequency signals produced on firing of the spark plugs **32**.

The structure and operation of batteries **16**, ignition switches **18**, ignition coils **24**, distributors **26**, spark plugs **32** and centrifugal and vacuum operated spark advance mechanisms for distributor cams in conjunction with internal combustion engines are well known and will not be considered in further detail herein. The structure and operation of the pulse producing device **22** is set forth in detail in the above referenced copending patent application and the commonly owned patent applications referred to therein in a semiconductor ignition system similar to the present semiconductor ignition system. The particular pulse producing device **22** will not therefore be considered in detail herein. The particular semiconductor ignition circuit **10** is however shown in detail in FIGURE 2.

The semiconductor ignition circuit **10** includes the coil **40** of the pulse producing device **22** in which pulses of electric energy synchronized with engine rotation are produced on rotation of the distributor cam **20**, a spurious signal suppression circuit **42** for suppressing high frequency extraneous electric signals that may be produced in the pulse producing device **22**, and a pulse amplifier circuit **44** for amplifying the signals produced in the coil **40** and passed by the spurious pulse suppression circuit **42**. The semiconductor ignition circuit **10** further includes a differentiating circuit **46** for differentiating the amplfied pulses from the pulse amplifier circuit **44** to provide a trigger signal for the multivibrator circuit **48** and a multiple signal suppression circuit **50** between the differentiating circuit **46** and multivibrator **48** for suppressing multiple signals produced in the differentiating circuit **46** corresponding to a single pulse of electric energy produced in the coil **40**.

A tachometer circuit **52** is connected to the multivibrator circuit **48** to provide an indication of engine rotational speed.

The ignition circuit **10** further includes an emitter follower circuit **54** connected to receive the output signal from the multivibrator circuit **48** and to control a driver amplifier circuit **56** which in turn drives a switching circuit **58**. The switching circuit **58** controls the current flow through the radio frequency filter circuit **38** and primary winding **34** of ignition coil **24**.

A compensating circuit **60** for aiding rapid switching of the switching semiconductor **104** in the switching circuit **58** is provided in conjunction with the cathode follower circuit **54**, driver amplifier circuit **56** and switching circuit **58**. The power supply filter circuit **62** for filtering the electrical signal applied to the ignition circuit **10** from battery **16** on closing of the ignition switch **18** completes the ignition circuit **10**.

More specifically a pulse of electric energy will be produced in the coil **40** each time a lobe or projection **64** on the distributor cam **20** passes the coil core member **66**. Since the distributor cam **20** is driven at a speed directly proportional to the speed of the engine **14**, the pulses produced in the coil **40** will be in timed relation to the speed of the engine **14** and provide a pulse of electric energy through the ignition circuit **10** at the distributor **26** to fire the spark plugs **30** in a predetermined sequence at desired times related to the rotational position of the engine **14**.

The pulses produced in coil **40** and passed by the spurious signal suppression circuit **42** which will be considered later in detail are amplified through the pulse amplifier circuit **44** including the semiconductor **68** and load resistor **70**. The emitter-collector circuit of the semiconductor **68** is connected in series with the load resistor **70** across the terminals of the battery **16** through the filter resistor **72** and diode **74** of the battery filter circuit **62**. The base circuit of the semiconductor **68** is connected across the coil **40**.

Thus, in operation, as a pulse is produced in the coil **40** and passed by the spurious signal suppression circuit **42**, the produced pulse biases the semiconductor **68** into operation to provide a relatively slow rising amplified pulse of electric energy across the load resistor **70**.

The pulse of electric energy amplified in the pulse amplifying circuit **44** is differentiated through the differentiating circuit **46** which includes the resistor **76**, capacitor **78** and diode **80**. Thus, as the signal changes between the load resistor **70** and semiconductor **68** on conduction of the semiconductor **68**, a charge is built up rapidly on capacitor **78** through the resistor **76** which has a relatively low value in comparison to the load resistor **70**. The charging path for the capacitor **78** is through the base circuit of the semiconductor **82** forming the left half of the multivibrator circuit **48** in FIGURE 2 and through the thermistor **83** in parallel with the base circuit of the semiconductor **82** and through the series connected diode **50**.

The differentiated signal on the capacitor **78** will trigger the monostable multivibrator **48** so that it will change operating state and the normally non-conducting semiconductor **82** will conduct for a predetermined time as set by the circuit constants of multivibrator **48**. Conduction of the normally non-conducting semiconductor **82** will cause the normally conducting semiconductor **84** of the multivibrator circuit **48** to stop conducting. The

capacitor 78 will then be discharged through the diode 80 to prepare the differentiating circuit 46 for subsequent differentiation of amplified pulses from coil 40 amplified through amplifier semiconductor 68.

The multivibrator circuit 48, as shown in FIGURE 2, includes the high gain normally non-conducting semiconductor 82 having an emitter-collector circuit in series across the battery 16 through the load resistor 86 and the normally conducting low gain semiconductor 84 having an emitter-collector circuit in series with the load resistor 88 across the battery 16. A feed-back capacitor 90 is provided between the collector of the semiconductor 84 and the base of the semiconductor 82, as shown in FIGURE 2, while a parallel combination capacitor 92 and resistor 94 are positioned between the collector of the semiconductor 82 and the base of the semiconductor 84.

In operation, on differentiating a pulse of electric energy in the differentiating circuit 46, bias will be applied to the semiconductor 82 of the multi-vibrator circuit 48 to produce an initial output from the semiconductor 82 at an exactly predetermined time with respect to the occurrence of an initial pulse in the coil 40. The duration of the conduction of the semiconductor 82 will depend on the time constant in the multivibrator feed-back circuit so that the output pulses provided by the multivibrator circuit 48 across the load resistor 86 will be exactly determined in width.

To stabilize this portion of the semiconductor ignition circuit 10, the electrical energy from the battery 16 is filtered through the filter circuit including capacitor 96 as well as the resistor 72 and diode 74 previously considered. The diode 74 is included in the power supply filter circuit to prevent discharge of filter capacitor 96 through battery 16.

Stabilization of the operation of the multivibrator circuit 48 at high temperature is further provided by the thermistor 83 positioned across the base circuit of the semiconductor 82, as shown in FIGURE 2. The thermistor 83 functions to lower the gain of the semiconductor 82 at high temperatures, thus preventing free running of the multivibrator circuit 48.

In operation of the pulse amplifier circuit 44, the differentiating circuit 46 and the multivibrator circuit 48 of the semiconductor ignition circuit 10, it has been found that the capacitor 78 of the differentiating circuit 46 will discharge through the capacitor 90 on conduction of the semiconductor 82 without the multiple signal suppression circuit 50 between capacitors 78 and 90. This discharge of the capacitor 78 would then permit a second charging thereof due to the still present relatively slowly rising amplified pulse in the pulse amplifier circuit 44 to produce another trigger pulse for the multivibrator circuit 48 without another pulse having been produced in the coil 40.

Due to the timing of the multivibrator and the time between the pulses produced in coil 40 synchronized with the rotation of the engine, it has therefore been possible in the past to provide an initial signal of exact predetermined width from multivibrator 48 corresponding to the desired rotational position of the engine. In addition to the desired signal, multiple signals from the multivibrator have therefore been produced of a number equal to the trigger pulses provided by the differentiating circuit. These multiple pulses are detrimental when subsequent circuit components function in accordance with the number of pulses received.

Thus, in accordance with the present invention, the multiple signal suppressing circuit 50 consisting of diode 51 positioned between the capacitor 78 and the capacitor 90 is provided in the semiconductor ignition circuit 10, as shown in FIGURE 2. Diode 51 permits bias current flow through the semiconductor 82 of the multivibrator 48 but prevents reverse current flow through the diode 51 which would permit the capacitor 78 to discharge through the capacitor 90.

The emitter follower circuit 54 includes the semiconductor 98 in series with the load resistor 100 across the battery 16. In operation of the semiconductor ignition circuit 10, the semiconductor 98 is normally non-conducting. On conduction of the semiconductor 82 in the multivibrator circuit 48, the semiconductor 98, the base of which is connected between the semiconductor 82 and the load resistor 86 thereof, is caused to conduct. Conduction of the semiconductor 98 will cause the driver amplifier circuit 56 and therefore the switching semiconductor circuit 58 to stop conducting.

The driver amplifier circuit 56 includes the semiconductor 102 having the emitter-collector thereof connected between the base of the switching semiconductor 104 and one side of the battery 16 through load resistor 106. The base of semiconductor 102 is connected to the emitter follower circuit 54 between the semiconductor 98 and the load resistor 100 through resistor 108 in the compensating circuit 60. An emitter base, leak resistor 114 is also provided.

In operation the normally conducting driver amplifier semiconductor 102 carries the base current for the switching semiconductor 104 in its emitter-collector circuit. On conduction of the emitter follower semiconductor 98 due to a pulse applied thereto from the semiconductor 82 of the multivibrator circuit 48, the driver amplifier circuit semiconductor 102 is caused to stop conducting whereby the base current through switching semiconductor 104 is cut off and the switching semiconductor 104 switched to a nonconducting state.

The switching semiconductor circuit 58 includes the switching semiconductor 104 having the emitter-collector circuit in series across the battery 16 with the resistor 110 of the radio frequency filter circuit 38 and the primary winding 34 of ignition coil 24. The base of the switching semiconductor 104 is connected in the emitter-collector circuit of the driver amplifier circuit semiconductor 102, as previously indicated, and is further connected to the compensating circuit 60, as shown in FIGURE 2. The usual emitter base leak resistor 116 is also provided.

In operation a relatively large quantity of current flows through the primary winding 34 of the ignition coil 24, resistor 110 and the emitter-collector circuit of switching semiconductor 104. When the switching semiconductor 104 is caused to cease conducting the current flowing in the primary winding 34 of ignition coil 24 is cut off sharply to induce an electrical signal in the secondary winding 36 of the ignition coil 24 which is distributed by the distributor 26 to spark plugs 30 to produce sparks in the cylinders of engine 14 and subsequent rotation of the engine 14.

The compensation circuit 60 is provided in conjunction with the cathode follower circuit 54, driver amplifier circuit 56 and switching circuit 58 to decrease the switching time of the switching semiconductor 104. The compensating circuit 60 includes the capacitor 120, diode 122 and resistor 118.

In operation, during conduction of the driver amplifier semiconductor 102 and the switching semiconductor 104, the capacitor 120 is charged in parallel with the resistor 108 in the base circuit of the semiconductor 102. The charge on the capacitor 120 at this time will be such as to tend to bias the conducting switching semiconductor 104 into a non-conducting condition. Thus, when the cathode follower circuit semiconductor 98 conducts to cause the driver amplifier and switching semiconductors 102 and 104 to stop conducting, the capacitor 120 will discharge through the diode 122, resistor 118 and the now conducting cathode follower semiconductor 98 to apply the charge thereon across the base circuit of the switching semiconductor 104 and tend to stop the conduction of the switching semiconductor 104 faster than it would otherwise

be stopped to shorten the switching time of the semiconductor **104**.

Prior compensating circuits wherein a capacitor has been provided across the resistor **114** as well as across the resistor **108** have been inefficient in that the capacitor placed across the resistance **114** tends to discharge into the capacitor **120** and retard the over-all compensation applied to the switching semiconductor **104**. The positioning of a diode **122** and current limiting resistor **118** across resistor **114** in place of the usual capacitor produces better compensation in that switching of the switching semiconductor **104** is accomplished quicker.

The tachometer circuit **52** includes resistor **124**, rheostat **126**, diodes **128** and **130**, capacitor **132** and Zener diode **134** along with meter **136** connected as illustrated best in FIGURE 2. Resistor **124** is connected at the upper end thereof between the semi-conductor **82** of multivibrator **48** and the load resistor **86** therefor to receive a signal when the semiconductor **82** is conducting. Meter **136** provides integration of signals fed thereto due to the natural integrating action of the components thereof.

In operation, as previously indicated, pulses the number of which are directly proportional to the speed of engine **14** are provided in the coil **40** of pulse producing device **22** each of which cause conduction of multivibrator semiconductor **22** for a predetermined time. Spurious pulses are suppressed by the pulse suppression circuit **42** while multiple pulses are suppressed by the multiple pulse suppression circuit **50**. Thus pulses of a predetermined width but of unknown amplitude are provided through resistor **124** in the tachometer circuit **52** at the ungrounded side of the Zener diode **134**.

The Zener diode **134** performs a clipping function to provide a constant amplitude for each of the pulses received from the multivibrator circuit **48**. The pulses passing the Zener diode **134** are then differentiated in the differentiating circuit including the capacitor **132** and diode **130** to produce positive and negative going impulses of predetermined size. The negative going pulses are then cut off by the diode **128** and the positive pulses of predetermined size are fed through the rheostat **126** to be integrated in the meter **136** where they provide an accurate indication of the speed of the engine **14**.

The spurious signal suppression circuit **42** includes a capacitor **138** in series with the emitter-collector circuit of semiconductor **140** across the coil **40**. The spurious signal suppression circuit **42** further includes the voltage divider resistors **142** and **144** positioned across the battery **16** and connected to the base of the semiconductor **140** to provide a predetermined initial bias on the semiconductor **140**, an integrating circuit including the capacitor **146** and diode **148** and the coupling circuit including capacitor **150** and resistor **152** for coupling a predetermined signal from the driver amplifier circuit **56** to the spurious signal suppression circuit **42**.

In operation, with the semiconductor **140** conducting, the pulses provided in the coil **40** due to rotation of the distributor cam which may be for example at a frequency or pulse repetition rate of between twenty and sixty cycles per second will be transferred to the pulse amplifier circuit **44** and will cause pulses from the multivibrator **48** to subsequently fire the spark plugs **30**. However, spurious signals, such as caused by cranking of the engine **14**, meshing of gears or even hammering on the motor **14** which have high frequency components that are picked up by the coil **40** are shunted through capacitor **138** and conducting semiconductor **140** to prevent the spurious signals from triggering the semiconductor ignition circuit **10**.

At higher speed operation of the engine **14**, such as rotation of the engine at one hundred revolutions per minute for example, the capacitor **138** tends to affect a retarding of the firing of the spark plugs **30** with respect to the position of rotation of the distributor cam **20**. This retarding of the spark produced by the ignition system **12** is undesirable.

Therefore, the pulsed signal at the driver amplifier semiconductor **102** across resistor **106** is fed back through the coupling capacitor **150** and resistor **152** of the spurious signal suppression circuit **42** and across the integrating circuit comprising the diode **148** and capacitor **146** to produce a bias sufficient to cut off the semiconductor **140**. The speed of rotation of the cam **20** at which the semiconductor **140** is caused to cease conducting may be varied if desired by substituting a potentiometer for the resistor **106** and coupling the capacitor **150** to the wiper arm of the potentiometer as will be understood by those in the art.

Providing spurious signal suppression is required only during engine starting which is often the case, the same signal suppression function can be provided at greatly reduced cost, particularly in original equipment by use of the modified circuit shown in FIGURE 6. As illustrated in FIGURE 6, the transistor **140**, capacitor **146**, diode **148** and resistors **144** and **152** are replaced by capacitor **139** in parallel with coil **40** with normally open relay contacts **141** closed. The relay contacts **141** are closed on energization of relay coil **143**. Relay coil **143** is energized only when the usual engine starting circuit **145** is energized to which it is connected by conductor **147**. The coil **143** may be connected to the starter motor armature, the starter solenoid, the starter relay, or the starter switch in the usual engine starting circuit **145**.

The semiconductor ignition system as thus far described in detail has usually included a Zener diode connected across the emitter-collector electrodes of the switching semiconductor **104**. The Zener diode is relatively expensive. However, with the Zener diode, it has been considered in the past that the back voltage from the ignition coil **24** would be high enough to damage the semiconductor **104** when the voltage in the ignition coil **24** is sufficient to produce a spark of required energy at the spark plugs **32**.

The Zener diodes normally limit the primary back voltage across the Zener diode to about one hundred volts. The energy in the spark at the spark plugs **32** can therefore only be increased by increasing the current through the semiconductor **104** which is detrimental in that the semiconductor **104** runs hotter and is therefore subject to early failure.

It is known that the usual switching semiconductors **104** can withstand voltages considerably higher than one hundred ten volts for short periods, such as is common in the occurrence of a back voltage from the ignition coil **24**. At the higher voltages it has been observed that the semiconductors **104** failed at much lower voltages with the spark plugs of the ignition system **12** connected to the ignition coil **24** than with the spark plugs disconnected.

An investigation of this phenomenon has led to the discovery that besides the usual considered back voltage from the ignition coil **24**, a radio frequency voltage of a magnitude which may even exceed the usual back voltage through the ignition coil **24** is fed from the spark plugs through the ignition coil to the switching semiconductor **104** to cause early failure of the switching semiconductor **104** without Zener diode protection thereacross. The radio frequency voltage presented at the switching semiconductor **104** on firing of spark plugs **32** may be as high as one thousand volts and is typically one hundred volts.

With the discovery of the high radio frequency voltage at the switching semiconductor **104** it is possible in accordance with the invention to delete the expensive Zener diode protection for the switching semiconductor **104** with the substitution of a radio frequency filter and protection circuit for the switching semiconductor **104**. The radio frequency circuit will permit higher primary back voltages of for example three hundred volts across the switching semiconductor **104** to materially increase the energy in the spark at the spark plugs **32** with less current through the switching semiconductor **104** and

therefore less heat produced and longer operating life of switching semiconductor **104**. In addition, the radio frequency filter and protection circuits cost in the order of three to ten cents to provide as against a cost of about one dollar for the usual Zener diode for the switching semiconductor.

In other words, discovery of a previously unsuspected radio frequency voltage at the switching semiconductor **104** and the substitution of a relatively cheap radio frequency filter for the usual relatively expensive Zener diode protection across the switching semiconductor permitted by the discovery of the radio frequency voltage permits higher energy sparks at the spark plugs with less current drain from the battery **16** and cooler operation for the switching semiconductor **104** to prolong the life thereof.

The radio frequency filter circuit **38**, best illustrated in FIGURE 2, includes the resistor **110** which provides ballast between the switching semiconductor **104** and the primary winding **34** of ignition coil **24**, capacitor **152** positioned across the primary winding **34** of the ignition coil **24** to shunt radio frequencies fed back to coil **24** to ground, capacitor **154** which functions as a surge capacitor to limit the initial build-up of back voltage across semiconductor **104** and the radio frequency bypass capacitor **155** connected across the switching semiconductor **104**, as shown in FIGURE 2.

Thus in operation of the radio frequency filter circuit **38**, on switching off of the semiconductor **104** a back voltage from ignition coil **24**, of for example three hundred volts, may be felt across the switching semiconductor **104** for a very short time which back voltage is lessened in rise time by the provision of the relatively large surge capacitor **154**. Substantially simultaneously with the back voltage applied to the semiconductor **104** a radio frequency voltage will be fed back from the spark plugs **32** through the coil **24** and will be shunted to ground through the capacitor **152**. Any part of the radio frequency signal which is not shunted to ground through the relatively small capacitor **152** will be bypassed around the switching semiconductor **104** by capacitor **155**. Thus, with the radio frequency protection circuit **38** the switching semiconductor **104** is substantially unaffected by the radio frequency signal produced on firing of the spark plugs **32**.

Other radio frequency filter circuits, such as illustrated in FIGURES 3, 4 and 5 may be used in place of the filter circuit **38**.

Thus, the filter circuit **156** illustrated in FIGURE 3 comprises the spark plates **158** placed across the emitter-collector electrodes of the switching semiconductor **104** in the semiconductor ignition circuit, as shown in FIGURE 3. The difficulty of connecting spark plates **158** makes their use less desirable than the filter circuit **38** illustrated in FIGURE 2. However, the radio frequency filtering efficiency of the spark plates **158** may be equal to that of the filter circuit **38**.

The filter circuit **160** illustrated in FIGURE 4 includes a plurality of low capacity low dissipation factor capacitors **162** placed across the emitter-collector electrodes of the switching semiconductor **104**. The efficiency of the filter circuit illustrated in FIGURE 4 may be equal to that of the filter circuit illustrated in FIGURE 2 with the cost slightly greater due to the number and type of condensers required and the number of connections therefor in the circuit **10**.

The filter circuit **161**, illustrated in FIGURE 5, includes a radio frequency choke coil **163** in series with the output circuit of the semiconductor **104** and positioned between the semiconductor **104** and resistor **110** as shown. The choke coil **163** may be used in place of or in conjunction with capacitors, such as capacitors **154** and **155**.

Thus, in over-all operation of the improved semiconductor ignition system **12** in conjunction with the engine **14** with the switch **18** closed, the engine **14** is cranked to rotate the distributor cam **20**. The pulse producing device **22** operably associated with the distributor cam **20** produces pulses at a rate proportional to the speed of the engine **14**. Spurious pulses generated in the coil **40** of the pulse producing device **22** are suppressed by the spurious pulse suppression circuit **42** due to the relatively high frequency components thereof.

Pulses synchronized with the rotation of the engine **14** are amplified through the pulse amplifying circuit **44** and are differentiated in the differentiating circuit **46** to provide a trigger pulse for the multivibrator circuit **48**. The multiple signal suppression circuit **50** prevents more than one trigger pulse for the multivibrator **48** due to one pulse amplified by the amplifier circuit **44**. The monostable multivibrator circuit **48** then produces a pulse of predetermined width for each trigger pulse received thereby. The pulses from the multivibrator circuit **48** which are still synchronized with the engine are passed to the tachometer circuit **52** to provide an indication of the speed of the engine **14** and are simultaneously passed to the emitter follower circuit **54** to cause conduction of the emitter follower semiconductor **98**. On conduction of semiconductor **98**, the driver amplifier circuit **56** stops conducting to switch off the switching semiconductor circuit **58**. The switching semiconductor **104** is caused to switch off rapidly by means of the compensating circuit **60** associated with the cathode follower circuit **54**, driver amplifier circuit **56** and switching semiconductor circuit **58**.

Switching off of the normally conducting switching semiconductor **104** produces a pulse of electric energy through the primary winding **34** of ignition coil **24**. A pulse of energy is thereby created in the secondary winding **112** of the ignition transformer **24** which is distributed by the distributor **26** to the spark plugs **30** for firing to produce sustained rotation of the engine **14** in the usual manner.

On firing of the spark plugs radio frequency energy is generated which is fed back through the ignition coil **24** to the switching semiconductor **104**. The radio frequency signal is passed to ground and/or around the switching semiconductor **104** through the radio frequency filter **38** positioned between the ignition coil **24** and switching semiconductor **104** and across the switching semiconductor **104**.

When the pulse repetition rate through the semiconductor ignition circuit **10** exceeds a predetermined value, the transient signal suppression circuit **42** which is not as desirable at high engine speeds is deenergized to prevent spark retardation by the circuit **42** which would otherwise occur at high speeds.

While one embodiment of the present invention and modifications thereof have been considered in detail, it will be understood that other embodiments and modifications are contemplated. It is the intention to include all embodiments and modifications as are defined by the appended claims within the scope of the invention.

What we claim as our invention is:

1. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed including a member rotatable at engine speed, a cam secured to said member for rotation therewith having a plurality of lobes thereon, a coil positioned adjacent the cam for developing electric pulses in accordance with the passing of the lobes by the coil, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses including an amplifying semiconductor having emitter, base and collector electrodes, said pick-up coil being connected between the base and emitter electrodes, said collector electrode being connected to one side of the battery through an amplifier resistor, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide

trigger pulses therefrom, comprising a resistor, capacitor and diode connected in series between the collector electrode of the amplifying semiconductor and the one side of the battery, a multivibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, including a pair of semiconductors having emitter, base and collector electrodes, the emitter electrodes of which are connected to the one side of the battery, the collector electrodes of which are connected through multivibrator resistors to the other side of the battery, the base electrode of the first of said multivibrator semiconductors being connected to the differentiating circuit between the capacitor and diode thereof, the base electrode of the other of the multivibrator semiconductors being connected to the collector electrode of the one multivibrator semiconductor through a resistor and capacitor in parallel, a thermistor connected between the emitter and base electrodes of the one multivibrator semiconductor, a capacitor being connected between the base electrode of the one multivibrator semiconductor and the collector electrode of the other multivibrator semiconductor, an emitter follower circuit connected to the multivibrator circuit operable to conduct only on reception of a pulse from the multivibrator circuit, including an emitter follower semiconductor having emitter, collector and base electrodes, the emitter electrode being connected through an emitter follower resistor to the other side of the battery, the collector electrode being connected to the one side of the battery and the base electrode being connected to the collector electrode of the one multivibrator semiconductor, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, including a driver amplifier semiconductor having emitter, collector and base electrodes, the emitter electrode of which is connected to the one side of the battery through a first driver resistor, the collector electrode of which is connected to the other side of the battery through a second driver resistor, and the base electrode of which is connected to the emitter electrode of the emitter follower semiconductor through a third driver resistor and a fourth driver resistor connected between the emitter and base of the driver semiconductor, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition coil on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit, including a switching semiconductor having emitter, collector and base electrodes, the emitter electrode being connected to the one side of the battery, the collector electrode of the switching semiconductor being connected through the primary winding of the ignition coil to the other side of the battery, and the base electrode of the switching semiconductor being connected to the emitter electrode of the driver amplifier, and a radio frequency protection circuit operably associated with the switching semiconductor for preventing break-down of the switching semiconductor due to a radio frequency feed-back from the ignition system, including a radio frequency bypass capacitor connected between the emitter and base electrodes of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency bypass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

2. Structure as set forth in claim **1** and further including a spurious signal suppression circuit connected between the pulse producing means and the pulse amplifying circuit for suppressing signals having high frequency components and means for suppressing the spurious signal suppression circuit at high engine speeds, comprising a spurious signal suppression semiconductor having emitter, collector and base electrodes, a capacitor connected between the base of the amplifier semiconductor and the emitter electrode of the spurious signal suppression semiconductor, the collector of the spurious signal suppression semiconductor being connected directly to the other side of the battery, a pair of spurious signal suppression resistors connected between the opposite sides of the battery, the base electrode of the spurious signal semiconductor being connected to the junction between the two spurious signal suppression resistors, a diode and capacitor connected in series between the base electrode of the spurious signal suppression semiconductor and the collector electrode of the driver amplifier, a third spurious signal suppression resistor connected between the diode and capacitor in series at one end and the other side of the battery at the other end, and a capacitor connected between the base electrode of the spurious signal suppression semiconductor and the other side of the battery.

3. Structure as set forth in claim **1** and further including a multiple signal suppression circuit comprising a diode connected between the junction of the capacitor and diode in the differentiating circuit and the base electrode of the one multivibrator semiconductor for limiting the output of the differentiating circuit to a single trigger pulse for the multivibrator for each pulse received by the differentiating circuit from the pulse amplifying circuit.

4. Structure as set forth in claim **1** and further including a compensating circuit connected to the emitter follower circuit, driver amplifier circuit and switching circuit for providing a voltage tending to cut off the switching semiconductor during switching of the switching semiconductor to decrease the switching time thereof, comprising a resistor and diode in series with each other and connected between the emitter and base electrodes of the driver amplifier, and a capacitor connected between the emitter electrode of the emitter follower semiconductor and the base electrode of the driver amplifier semiconductor.

5. Structure as set forth in claim **1** and further including a filter circuit for filtering electric energy applied to the ignition circuit integral with the ignition circuit, including a diode, resistor and capacitor connected in series across the battery.

6. Structure as set forth in claim **1** and further including a tachometer circuit connected to the multivibrator for providing an indication of the speed of the engine associated with the ignition circuit, comprising a tachometer, resistor and Zener diode connected in series between the collector of the one multivibrator semiconductor and the other side of the battery, a capacitor, diode, variable resistance and indicating meter connected in series across the Zener diode and a diode connected between the capacitor and diode in series on one side and the other side of the battery on the other side.

7. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger pulses therefrom, a multi-vibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, an emitter follower circuit connected to the multi-vibrator circuit operable to conduct only on reception of a pulse from the multivibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition coil on and off connected to the driver amplifier circuit for switch-

ing on and off in accordance with the state of conduction of the driver amplifier circuit and a radio frequency protection circuit operably associated with the switching semiconductor for preventing breakdown of the switching semiconductor due to a radio frequency feedback from the ignition system, including a radio frequency by-pass capacitor connected between the emitter and base electrodes of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

8. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed including a member rotatable at engine speed, a cam secured to said member for rotation therewith having a plurality of lobes thereon, a coil which is adjacent the cam for developing electric pulses in accordance with the passing of the lobes by the coil, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses including an amplifying semiconductor having emitter, base and collector electrodes, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger pulses therefrom, a multi-vibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, an emitter follower circuit connected to the multi-vibrator circuit operable to conduct only on reception of a pulse from the multi-vibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition coil on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit and radio frequency protection circuit operably associated with the switching semiconductor for preventing breakdown of the switching semiconductor due to a radio frequency feedback from the ignition system, including a radio frequency by-pass capacitor connected between the emitter and base electrodes of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected to the opposite ends of the filter resistor and the other side of the battery.

9. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses including an amplifying semiconductor having emitter, base and collector electrode, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger pulses therefrom, comprising a resistor, capacitor and diode connected in series between the collector electrode of the amplifying semiconductor and the one side of the battery, a multi-vibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, an emitter follower circuit connected to the multi-vibrator circuit operable to conduct only on reception of a pulse from the multi-vibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition coil on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit, and a radio frequency protection circuit operably associated with the switching semiconductor for preventing breakdown of the switching semiconductor due to a radio frequency feedback from the ignition system, including a radio frequency by-pass capacitor connected between the emitter and base electrodes of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

10. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger pulses therefrom, a multi-vibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, including a pair of semiconductors having emitter base and collector electrode, the emitter electrodes of which are connected to one side of the battery, the collector electrodes of which are connected through multi-vibrator resistors to the other side of the battery, the base electrode of the first of said multi-vibrator semiconductor being connected to the differentiating circuit, the base electrode of the other of the multi-vibrator semiconductors being connected to the collector electrode of the one multi-vibrator semiconductor through a resistor and capacitor in parallel, a thermistor connected between the emitter and base electrodes of the one multi-vibrator semiconductor, a capacitor being connected between the base electrode of the one multi-vibrator semiconductor and the collector electrode of the other multi-vibrator semiconductor, an emitter follower circuit connected to the multi-vibrator circuit operable to conduct only on reception of a pulse from the multi-vibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit and a radio frequency protection circuit operably associated with the switching semiconductor for preventing breakdown of the switching semiconductor due to a radio frequency feedback from the ignition system, including a radio frequency by-pass capacitor connected between the emitter and base electrodes of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

11. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger

pulses therefrom, a multi-vibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, an emitter follower circuit connected to the multi-vibrator circuit operable to conduct only on reception of a pulse from the multi-vibrator circuit, including an emitter follower semiconductor having emitter, collector and base electrodes, the emitter electrode being connected through an emitter follower resistor to the other side of the battery, the collector electrode being connected to the one side of the battery and the base electrode being connected to the multi-vibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, including a driver amplifier semiconductor having emitter, collector and base electrodes, the emitter electrode of which is connected to the one side of the battery through a first driver resistor, the collector electrode of which is connected to the other side of the battery through a second driver resistor, and the base electrode of which is connected to the emitter electrode of the emitter follower semiconductor through a third driver resistor and a fourth driver resistor connected between the emitter and base of the driver semiconductor, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition coil on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit, and a radio frequency protection circuit operably associated with the switching semiconductor for preventing breakdown of the switching semiconductor due to a radio frequency feedback from the ignition system including a radio frequency by-pass capacitor connected between the emitter and base electrode of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

12. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger pulses therefrom, a multivibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, an emitter follower circuit connected to the multivibrator circuit operable to conduct only on reception of a pulse from the multivibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, a switching circuit connected between the battery and ignition coil for switching current between the battery and ignition on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit, including a switching semiconductor having emitter, collector and base electrodes, the emitter electrode being connected to the one side of the battery, the collector electrode of the switching semiconductor being connected through the primary winding of the ignition coil to the other side of the battery, and the base electrode of the switching semiconductor being connected to the driver amplifier circuit, and a radio frequency protection circuit operably associated with the switching semiconductor for preventing breakdown of the switching semiconductor due to a radio frequency feedback from the ignition system, including a radio frequency by-pass capacitor connected between the emitter and base electrodes of the switching semiconductor, a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

13. A semiconductor ignition circuit for use in an ignition system including a battery and an ignition coil having a primary winding in conjunction with an internal combustion engine or the like, comprising means for producing pulses at a rate proportional to engine speed, a pulse amplifying circuit connected to the pulse producing means for amplifying the developed pulses, a differentiating circuit connected to the pulse amplifying circuit for differentiating the amplified pulses to provide trigger pulses therefrom, a multi-vibrator circuit connected to the differentiating circuit for receiving the trigger pulses and producing a pulse of predetermined width each time a trigger pulse is received thereby, an emitter follower circuit connected to the multi-vibrator circuit operable to conduct only on reception of a pulse from the multi-vibrator circuit, a normally conducting driver amplifier circuit connected to the emitter follower for cut-off on conduction of the emitter follower circuit, a switching circuit connected between the battery and ignition coil including a switching semiconductor for switching current between the battery and ignition coil on and off connected to the driver amplifier circuit for switching on and off in accordance with the state of conduction of the driver amplifier circuit and a radio frequency protection circuit operably associated with the switching circuit for preventing break-down of the switching semiconductor due to a radio frequency feedback from the coil of the ignition system.

14. Structure as set forth in claim **13** wherein the radio frequency protection circuit includes a radio frequency by-pass capacitor connected between the emitter and base electrodes of the switching semiconductor.

15. Structure as set forth in claim **13** wherein the radio frequency protection circuit includes a filter resistor connected between the collector electrode of the switching semiconductor and the primary winding of the ignition coil and a pair of parallel radio frequency by-pass capacitors connected between the opposite ends of the filter resistor and the other side of the battery.

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