United States Patent [19]

Polo

[11] **3,923,029**

[45] **Dec. 2, 1975**

[54] **ELECTRONIC IGNITION SYSTEM**

[76] Inventor: **Benito Polo,** 9446 Borson St., Downey, Calif. 90241

[22] Filed: **Apr. 17, 1974**

[21] Appl. No.: **461,773**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 361,652, May 18, 1973, which is a continuation of Ser. No. 167,900, Aug. 2, 1971.

[52] **U.S. Cl.** ..... **123/148 E;** 123/117 R

[51] **Int. Cl.²** **F02P 5/04**

[58] **Field of Search** ..... 123/117 R, 148 E, 148 DC

[56] **References Cited**

UNITED STATES PATENTS

3,202,146	8/1965	Short	123/148 E
3,587,552	6/1971	Varaut	123/148 E
3,592,178	7/1971	Schiff	123/148 E
3,660,689	5/1972	Oishi	123/148 E
3,756,212	9/1973	Schirmer	123/148 E
3,800,757	4/1974	Finch	123/148 E
3,811,420	5/1974	Vogel	123/148 E

Primary Examiner—Wendell E. Burns
Assistant Examiner—Ronald B. Cox
Attorney, Agent, or Firm—Nilsson, Robbins, Bissell, Dalgarn & Berliner

[57] **ABSTRACT**

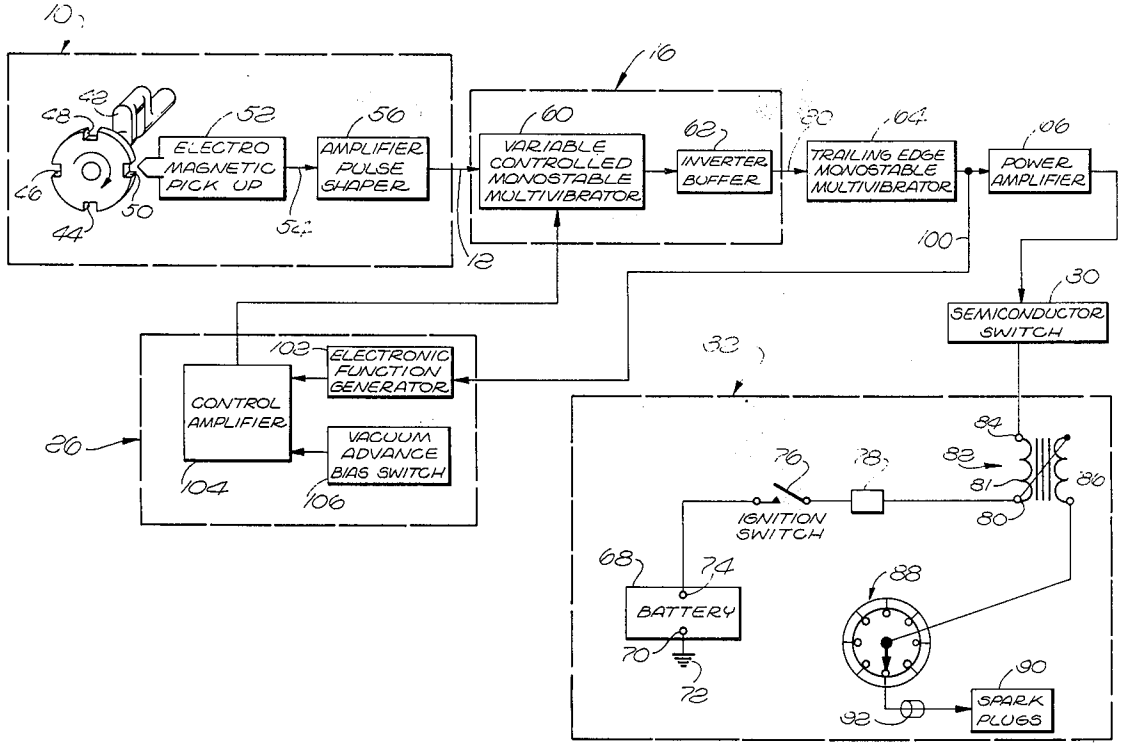
An electronic ignition system designed to replace the breaker points, cam, centrifugal and vacuum mechanisms, thus providing a fully electronic ignition system.

Output pulses synchronized with engine speed are provided by an electromagnetic pickup connected with an amplifier and pulse shaper. These pulses trigger a monostable multivibrator which produces a variable-duration output pulse. The output pulse from this monostable multivibrator is coupled so that the termination thereof effects application of electrical energy to the sparkplugs of an internal combustion engine.

The duration of the pulse from the monostable multivibrator is controlled through the utilization of an electronic spark-advance means which includes an electronic function generator. The function generator produces a waveform of predetermined shape which commences upon initiation of the spark (the termination of the signal from the controlled AND gate). The output of the function generator is applied to the timing circuit in the monostable multivibrator thereby to control the duration of the signal therefrom in a manner to provide the desired spark advance as engine speed increases.

Also provided is a switch means for introducing additional spark advance in response to increase in vacuum in the manifold of an internal combustion engine.

8 Claims, 7 Drawing Figures



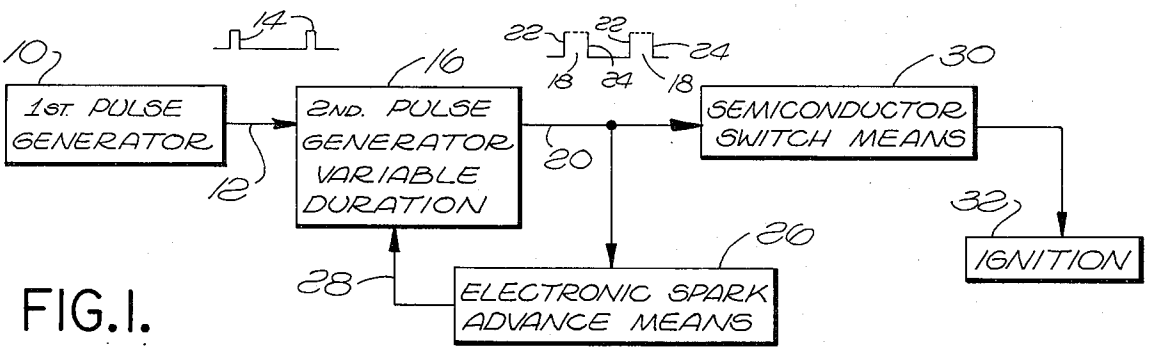

10
1ST. PULSE GENERATOR
12
14
16
2ND. PULSE GENERATOR VARIABLE DURATION
18
22
24
20
30
SEMICONDUCTOR SWITCH MEANS
32
IGNITION
26
ELECTRONIC SPARK ADVANCE MEANS
28

FIG.1.

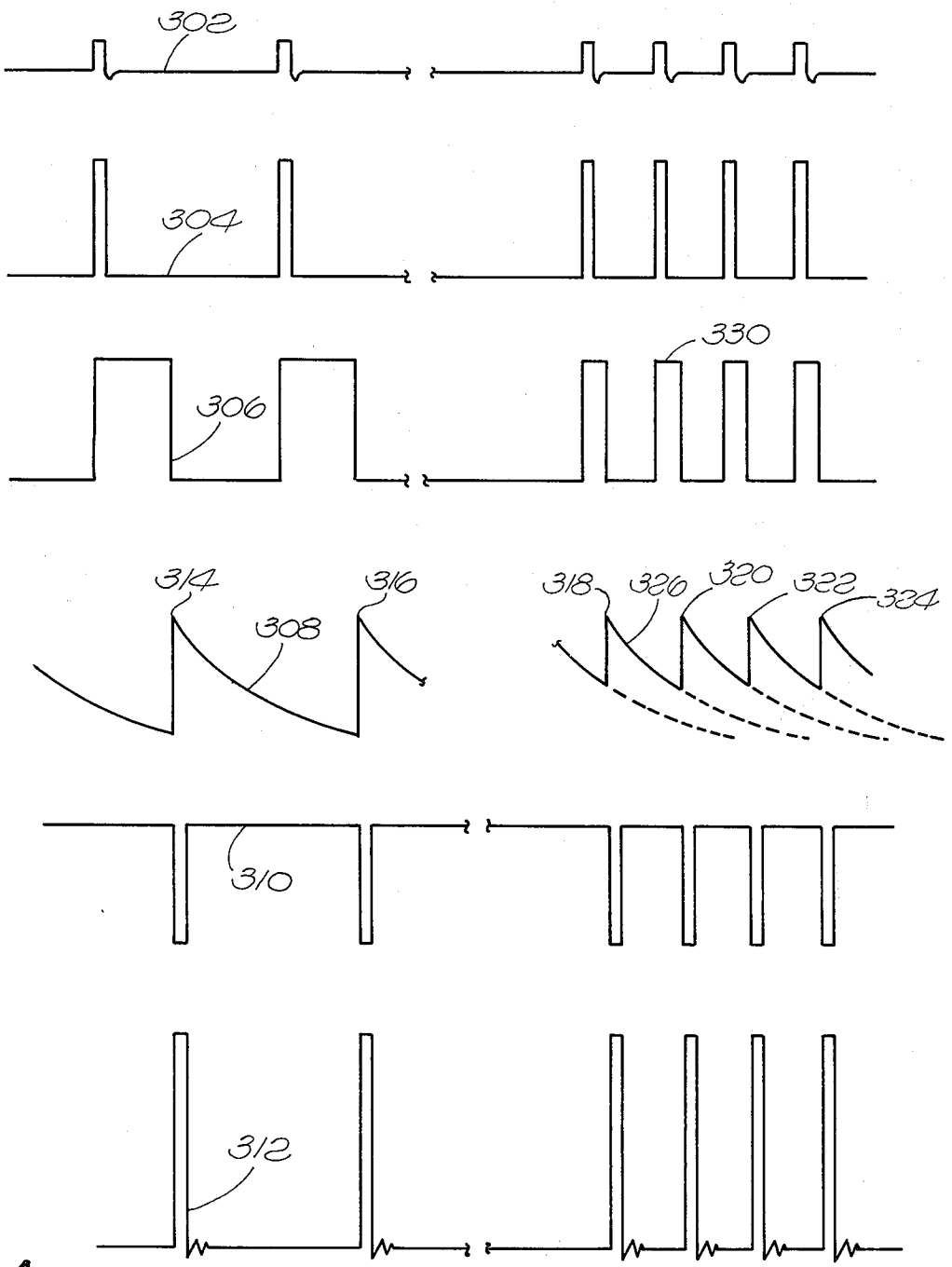

302
304
306
330
314
308
316
318
320
322
324
310
312

FIG.4.

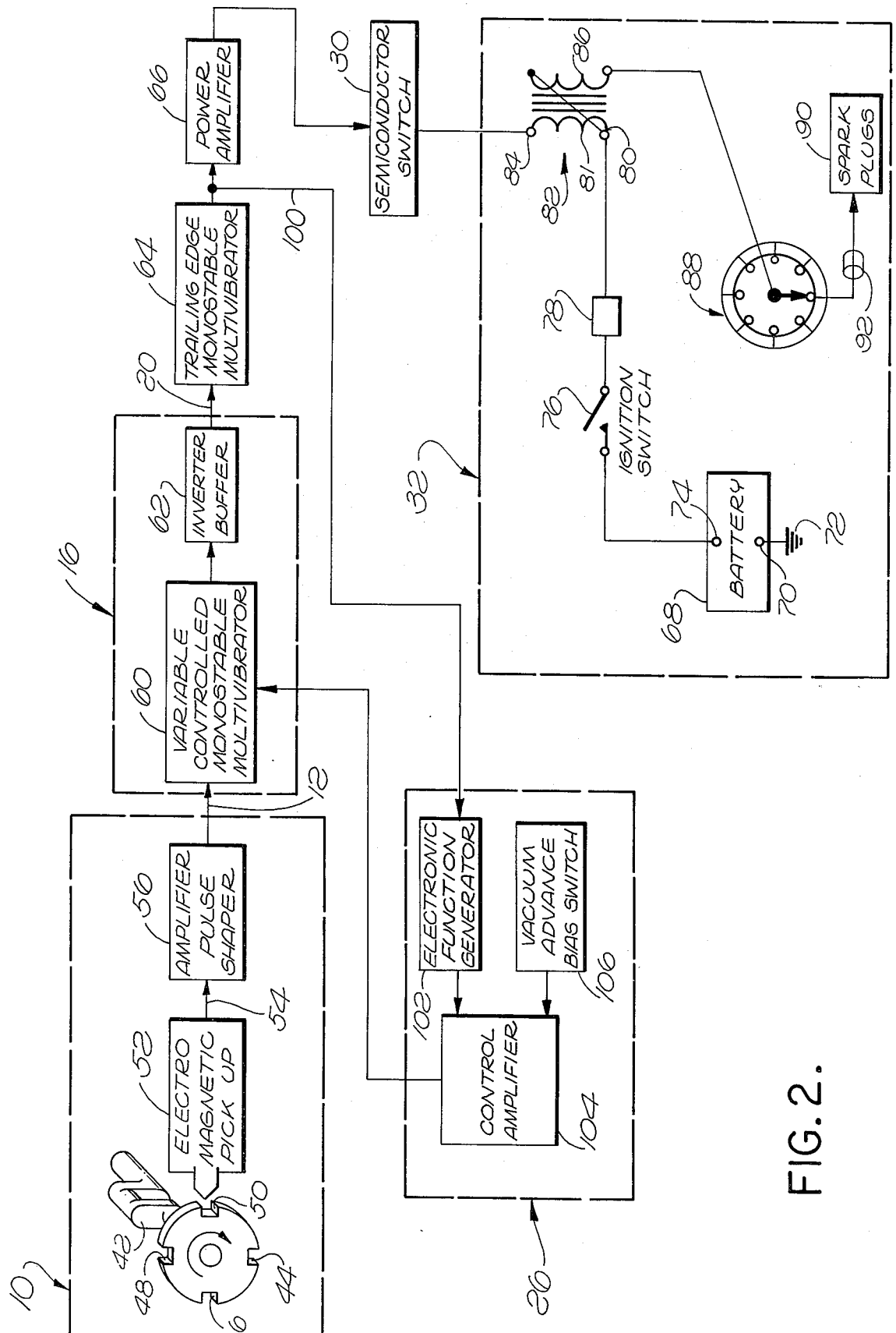

POWER AMPLIFIER
66
SEMICONDUCTOR SWITCH
30
TRAILING EDGE MONOSTABLE MULTIVIBRATOR
64
INVERTER BUFFER
62
VARIABLE CONTROLLED MONOSTABLE MULTIVIBRATOR
60
AMPLIFIER PULSE SHAPER
56
ELECTRO MAGNETIC PICK UP
52
ELECTRONIC FUNCTION GENERATOR
102
VACUUM ADVANCE BIAS SWITCH
106
CONTROL AMPLIFIER
104
SPARK PLUGS
90
IGNITION SWITCH
76
BATTERY
74
68
70
72
78
88
92
80
81
82
84
86
100
54
50
42
44
46
48
10
12
16
20
26
32

FIG. 2.

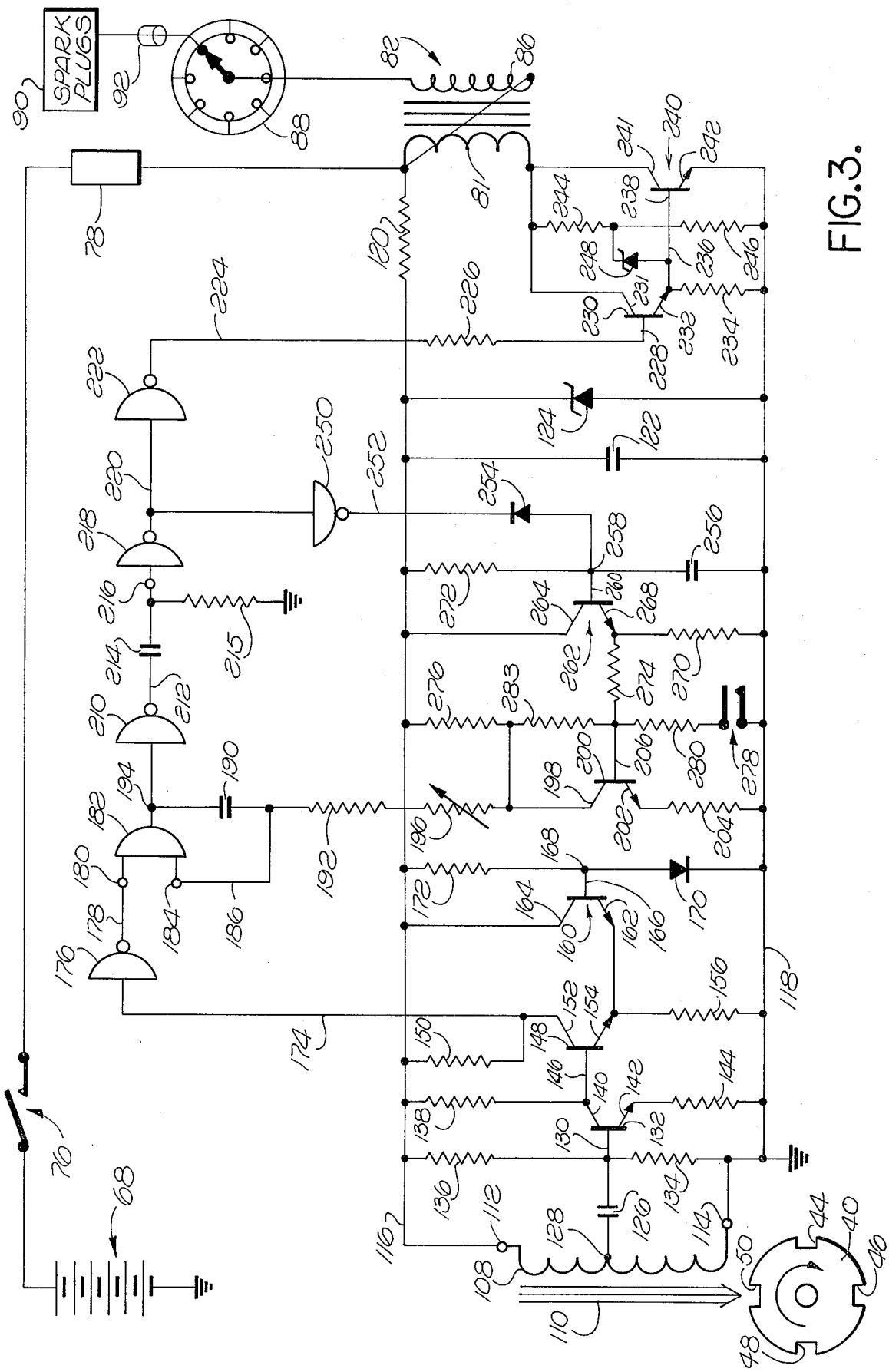

SPARK PLUGS
90
92
88
82
86
81
78
120
241
240
242
244
238
248
231
236
246
230
232
234
228
226
224
222
124
122
250
252
220
254
218
258
256
216
272
204
260
268
215
214
262
270
283
274
212
210
280
278
200
206
198
202
194
190
196
192
168
182
180
172
164
170
178
160
162
166
176
184
186
174
150
148
152
154
156
118
146
140
142
144
138
130
132
136
134
112
128
120
114
116
108
110
50
44
40
46
48
70
68

FIG.3.

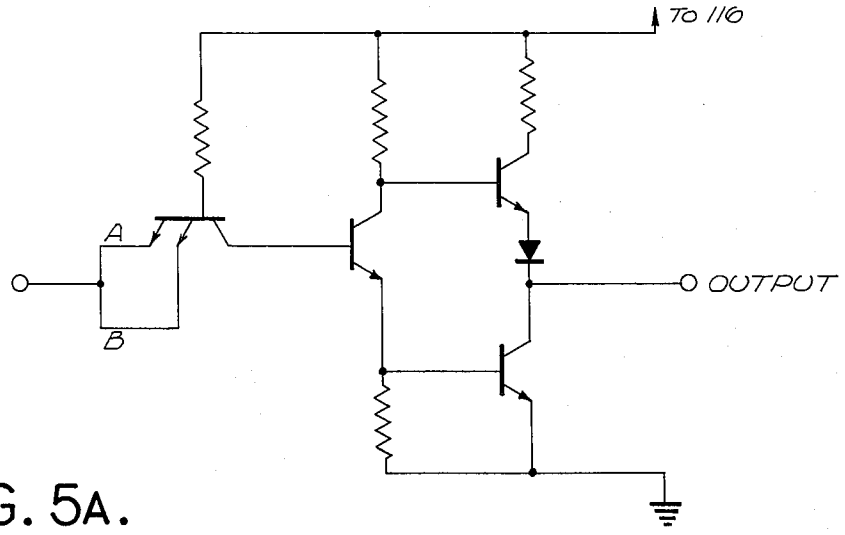


FIG. 5A.

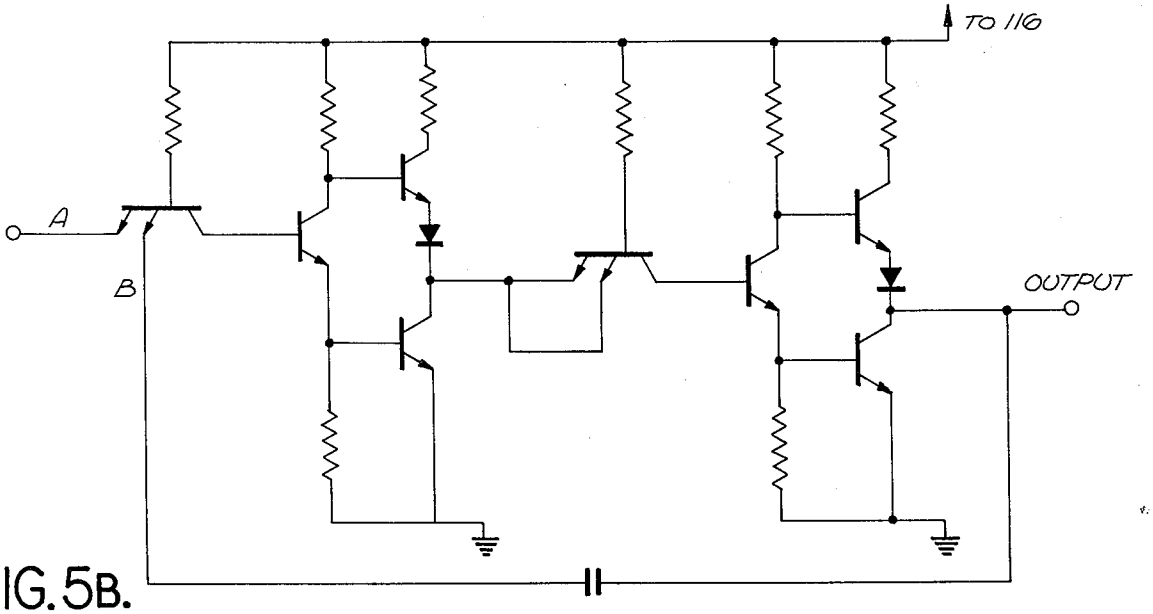


FIG. 5B.

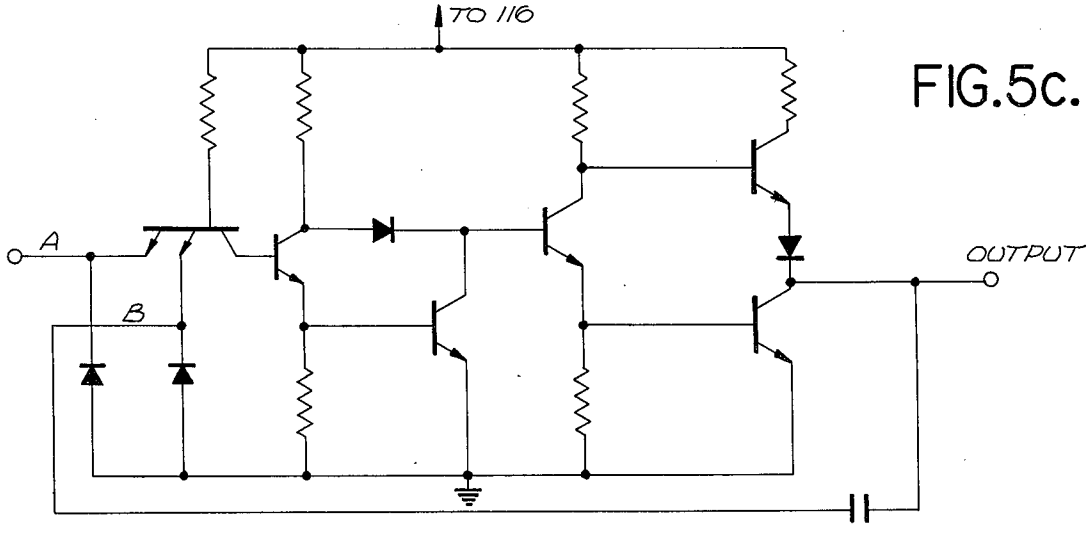


FIG. 5c.

ELECTRONIC IGNITION SYSTEM

REFERENCE TO OTHER APPLICATIONS

This application is a continuation-in-part of my copending application Ser. No. 361,652, filed on May 18, 1973, which is a continuation of my application Ser. No. 167,900, filed on Aug. 2, 1971.

BACKGROUND OF THE INVENTION

It has long been known that to provide maximum burning of the air-fuel mixture in the cylinder of an internal combustion engine, there must be provided an appropriate spark of sufficient magnitude and duration. The time required for complete combustion of the mixture is approximately one millisecond. It has also been known that to provide properly timed combustion thereby to properly transmit the power generated as a result of this combustion to the crankshaft, the initiation of the spark must be advanced as engine speed increases.

With prior art ignition systems utilizing traditional breaker points and condensers in conjunction with the battery and coil, various difficulties were encountered resulting in compromises as to coil design thereby to provide sufficient voltage at high engine speeds without imparting damage to the remainder of the ignition system. Even so, at a relatively high engine spped, it was found that the air-fuel mixture introduced into the cylinder was only partially or improperly burned in many instances. As a result, undesirable pollutants were introduced into the atmosphere. Furthermore, it was found that the various mechanical components comprising a bulk of the ignition system were constantly in need of adjustment or replacement as a result of wear.

Furthermore, as above referred to, the spark timing advance mechanisms utilized to accomplish the advance of the spark at high engine speeds were also mechanical and took the form of camshaft springs and weights commonly referred to as a centrifugal spark timing advance mechanism and a pneumatic actuator commonly known as the vacuum spark timing advance mechanism. Again, these mechanisms introduced inaccuracies as well as difficulties in adjustment and maintenance.

In an attempt to solve some of the foregoing problems, various electronic ignition systems have been developed. Representative of such systems are those described in U.S. Pat. Nos. 3,202,146; 3,363,615; 3,368,539; 3,357,416; 3,434,462 and 3,587,552, all of which were cited in the above-referred-to applications. Although these electronic ignition systems solved some of the problems inherent in the mechanical systems heretofore used, difficulties remained. For example, in these systems, the traditional mechanical spark advance timing mechanisms utilizing the centrifugal and vacuum devices are retained in the system or have been replaced by other mechanical apparatus, thus injecting much of the prior art problems previously existing. In those instances where the mechanical apparatus has been eliminated, reliance is placed upon the ability of an electronic oscillator to detect the passage of a metal part which changes the Q of the resonant circuit to thereby detect the speed of the engine and provide an ignition advance signal.

These prior art systems leave much to be desired insofar as efficiently and completely burning all of the fuel injected into the cylinder during the entire operating cycle of the internal combustion engine at all speeds. As a result, air pollution continues through the exhaust of the improperly combusted fuels into the atmosphere.

SUMMARY OF THE INVENTION

An electronic ignition system wherein an electromagnetic synchronization device provides an output signal representative of engine speed. Such output signals are applied to a pulse generator to initiate the pulse having a variable duration, the duration being determined by the desired spark advance depending upon engine speed. The pulse is coupled to a semiconductor switch so that upon termination of the pulse, a spark is generated at a sparkplug to initiate combustion of the air-fuel mixture in the cylinder. Simultaneously with the termination of the signal from the pulse generator, an electronic function generator is triggered and is caused to provide an output which in turn is coupled to the pulse generator thereby to effect termination of the output pulse therefrom in a manner representative of the desired spark advance.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating generally an electronic ignition system in accordance with the present invention;

FIG. **2** is a partly diagrammatic illustration of an electronic ignition system in accordance with the present invention;

FIG. **3** is a schematic circuit diagram of an electronic ignition system in accordance with the present invention;

FIG. **4** is a diagram illustrating waveforms taken at various points throughout the circuit of FIG. **3**; and

FIGS. **5, 5A, 5B** and **5C** are schematic diagrams illustrating specific circuits utilized in the preferred embodiment of the present invention.

DESCRIPTION OF THE DETAILED EMBODIMENT

As is illustrated in FIG. **1**, an electronic ignition system in accordance with the present invention includes a first pulse generator **10** which is adapted to provide a series of output pulses having a predetermined and fixed amplitude and duration. The frequency of the pulses generated by the pulse generator **10** is representative of the engine speed of the internal combustion engine which is utilizing the electronic ignition system in accordance with the present invention. Thus, appearing on the lead **12** is a plurality of pulses **14** having a predetermined amplitude and duration and frequency (or repetition rate) representative of engine speed. The pulses **14** are applied as an input signal to a second pulse generator **16.** The second pulse generator provides a plurality of output signals **18** appearing on the lead **20.** Each of the output signals **18** has a leading edge **22** substantially coincident with the leading edge of the pulses **14.** However, the trailing edge **24** of the pulses **18** is caused to occur at variable times. Thus, the output signal from the second pulse generator **16** constitutes a plurality of pulses of predetermined amplitude but variable duration. The occurence of the trailing edge **24** of the pulses **18** is determined by the electronic spark advance means **26.** The electronic spark advance means **26** in response to the occurence of the trailing edge **24** of the pulses **18** produces an output signal which varies in a predetermined manner as a function of time. This output signal is applied by the lead **28**

to the second pulse generator **16.** Through the combination of the repetition rate of the pulses **14** and the particular function with respect to time of the signal applied from the electronic spark advance means **26** over the lead **28,** the trailing edge **24** of the pulses **18** will be caused to occur in such a manner as to accommodate the required spark advance to effect efficient and complete combustion of the air-fuel mixture in the cylinders.

Simultaneously upon the occurence of the trailing edge **24** of the pulses **18,** a semiconductor switch means **30** is caused to effect the sequence of events in the ignition **32** causing application of a spark to the combustion chamber in the cylinder.

Referring now more particularly to FIG. **2,** the electronic ignition in accordance with the present invention is illustrated in some further detail. As is therein shown, the first pulse generator **10** includes an iron disc **40** which is connected to the crankshaft **42** of the internal combustion engine and thus is rotated thereby. The disc **40** is notched as illustrated at **44, 46, 48** and **50.** These notches are equiangularly disposed about the periphery of the disc **40** and represent the number of sparkplugs which will fire during each revolution of the disc. Thus, as is illustrated in FIG. **2,** four sparkplugs will fire during each revolution of the disc **40** and such represents an eight-cylinder internal combustion engine. In the event the apparatus is applied to a six-cylinder internal combustion engine, there would be three such notches disposed **120°** apart. Although the disc is shown as being notched, other configurations may be utilized as desired. That is, the notches may be replaced by protruding lobes, or a non-ferrous disc may be utilized with magnetic materials inserted at spaced positions thereabout. In any event, the notches, protrusions, or ferrous inserts cooperate with an electromagnetic pickup means **52** designed to sense the magnetic discontinuities in the disc and provide on the lead **54** an output signal which is applied to an amplifier and pulse shaper **56.** The amplifier and pulse shaper **56** then produces the series of pulses **14** on the lead **12** as above described.

The second pulse generator **16** is a variable controlled AND gate **60** and inverter buffer **62.** The output signal appearing on the lead **20** is the pulses **18** as above described.

Also provided is a monostable multivibrator **64** which senses the trailing edge **24** of the pulses **18** and responsive thereto provides an output signal of predetermined duration and amplitude which in turn is applied to the power amplifier **66.** The power amplifier **66** provides an output signal to control the semiconductor switch **30** which in turn controls the generation of the spark as is well known.

The battery **68** is shown with one terminal **70** connected to a point of common reference such as ground **72** while the other terminal **74** is connected through the ignition switch **76** and ballast resistor **78** to one terminal **80** of the ignition coil **82.** The other terminal **84** of the ignition coil **82** is connected to the semiconductor switch **30.** The secondary coil **86** of the ignition coil **82** is connected through the distributor **88** and to the sparkplugs **90** by way of the various leads **92,** which is well known in the art. Thus, after the ignition switch is closed, the battery current is continuously applied through the primary winding **81** of the ignition coil and through the semiconductor switch **30** which is normally closed thus causing the usual buildup of magnetic flux in the ignition coil **82.** The signal from the multivibrator **64** causes the semiconductor switch **30** to open thus generating a high voltage signal in the secondary coil **86** of the ignition coil **82** which generates the spark in the sparkplugs as is well known.

The output signal from the trailing edge monostable multivibrator **64** is also applied by way of the lead **100** as a trigger signal to the function generator **102.** The function generator is utilized to provide an output signal which is a predetermined function with respect to time. The function which is chosen is that which is desired for the particular spark advance profile as is required for the particular internal combustion engine and the mode of operation thereof under consideration. The output of the function generator **102** is applied to a control amplifier **104,** the output of which in turn is applied to the variable controlled AND gate **60.** The output of the control amplifier is the function generator signal properly amplified for application to the AND gate **60,** thereby to determine the occurence of the trailing edge of the output signal therefrom. As above described, such in turn determines the occurence of the spark. Thus, by proper combination of the output signal from the function generator and the pulses from the first pulse amplifier **10,** the desired spark advance can be obtained.

If desired, and to control those situations where the internal combustion engine is not under load, a vacuum advance bias switch as illustrated at **106** may be utilized. Such an apparatus senses the vacuum present in the intake manifold of the internal combustion engine and automatically injects a predetermined amount of bias at the control amplifier **104.** Such bias effectively shifts the electronic function generated by the function generator **102** a predetermined amount to thus appropriately advance the spark.

Referring now more particularly to FIG. **3,** there is illustrated in further detail an electronic ignition system constructed in accordance with the present invention. As is therein shown, the electromagnetic pickup **52** includes a coil **108** which is wound upon a core of ferromagnetic material **110** which is positioned adjacent the disc **40** which is rotated by the engine crankshaft. The coil **108** has one terminal **112** connected to bus **116** and the other terminal **114** connected to bus **118.** A source of potential provided by the resistor **120,** the capacitor **122** and the zener diode **124,** is connected such that the positive terminal thereof is connected to the bus **116** and the negative terminal thereof is connected to the bus **118,** the bus **118** also being connected to ground potential as is illustrated. In the power supply the zener diode **124** provides regulation while the capacitor **122** provides filtering and the resistor **120** is a dropping resistor thus providing a potential of approximately five volts on the bus **116.** A capacitor **126** is connected from the terminal **128** on the coil **108** to the base **130** of the transistor **132.** Also connected to the base **130** is a resistor **134,** the other side of which is connected to ground as illustrated. An additional resistor **136** is connected from the bus **116** to the base **130** of the transistor **132.** A load resistor **138** is connected from the bus **116** to the collector **140** of the transistor **132** while the emitter **142** is connected through a resistor **144** to ground. The base **146** of a transistor **148** is connected to the collector **140** of the transistor **132.** A load resistor **150** is connected from bus **116** to the collector **152** of the transistor **148** while the emitter **154** thereof is connected through the resistor **156** to ground

as shown. An additional transistor **160** has its emitter **162** also connected to ground through the resistor **156,** while the collector **164** thereof is connected to the bus **116.** The base **166** of the transistor **160** is connected to a common point **168** between the reference diode **170** and the resistor **172,** the series combination of which is connected between the bus **116** and **118.**

As the disc **40** rotates and the notches **44** through **50** pass the pickup device, thereby changing the magnetic flux appearing therein, pulses are generated which are coupled through the capacitor **126** and resistor **134** to the base of the transistor **132.** The transistor **132** is normally non-conducting and upon application of the signal generated by the magnetic pickup device thereto, becomes conducting. The transistors **148** and **160** comprise a differential amplifier with the transistor **148** normally conducting and the transistor **160** normally non-conducting. When the transistor **132** becomes conducting, the voltage appearing at the collector electrode **140** thereof drops causing the transistor **148** to become non-conducting and the transistor **160** to become conducting. This condition will be maintained until the voltage appearing at the base **146** of the transistor **148** overcomes the bias appearing across the resistor **156** at which time the transistor **148** will again become conducting thereby cutting off the transistor **160.** This change in the state of conduction of the transistor **148** produces at its collector electrode a positive-going pulse of five volts and **100** microseconds duration. The combination of elements thus far described comprises the first pulse generator **10** which includes the electromagnetic pickup and the amplifier and pulse shaper **52** and **56** as shown in FIG. **2.**

The collector **152** of the transistor **148** is also connected by the lead **174** as an input to the inverting NAND gate **176.** The function of the NAND gate **176** is merely that of isolation and inversion and any device capable of performing these functions may be utilized in place of the NAND gate **176.** It has however been determined that this function is appropriately performed by the structure employed as a NAND gate and such is therefore chosen as being preferred in the present invention.

The output from the gate **176** is applied by way of the lead **178** to an input terminal **180** of an AND gate **182.** The other terminal **184** of the AND gate **182** is connected by way of the lead **186** to a common point **188** between the capacitor **190** and the resistor **192.** The other side of the capacitor **190** is connected to the output terminal **194** of the AND gate **182.** A variable resistor **196** is connected from the resistor **192** to the collector **198** of the transistor **200,** the emitter **202** of which is connected through the resistor **204** to ground. The function of the resistor **200** will be described more in detail hereinbelow.

The AND gate **182** functions to produce an output signal of constant amplitude but variable duration. Under quiescent operating conditions, that is when no signal appears at the lead **178,** the terminal **180** of the AND gate **182** is high and in this particular circuit application is at 5 volts. Under these circumstances if the terminal **184** exceeds a threshold voltage which in this particular circuit application is approximately 1.7 volts, then the output terminal **194** is also high and in this particular application is at five volts. Upon application of the positive-going pulse to the lead **174** as above described, the output of the NAND gate **176** goes negative and drops from +5 volts to zero. Thus, zero volts is applied to terminal **180** of the AND gate **182.** When such occurs, the AND gate output is caused to change states from high to low and thus drops from +5 volts to zero volts. When such occurs, the change in state is coupled to the input terminal **184** of the AND gate **182.** Capacitor **190** immediately commences charging toward +5 volts through the resistors **192, 196** and **276** and to the bus **116.** When the charge across the capacitor **190** exceeds the 1.7 volt threshold voltage, the output signal at the terminal **194** of the AND gate **182** will then again go to its high or +5 volt state. Such assumes of course that the voltage appearing at the terminal **180** has again gone to the high or +5 volt state, which will have occurred at the termination of the input signal appearing on lead **174** connected to the NAND gate **176.** This time duration as above pointed out is approximately 100 microseconds.

When the engine speed is relatively slow, that is approximately 0–600 revolutions per minute, the spark should occur substantially at top-dead center of the piston stroke and thus no spark advance is required. Under these circumstances, the time constant for charging the capacitor **190** is such that the duration of the negative-going pulse at the output terminal **194** of the AND gate **182** imparts no spark advance. The variable resistor **196** provides appropriate adjustment to effect this time constant at the desired point.

The negative-going signal thus generated by the AND gate **182** is applied as an input signal to the inverting NAND gate **210.** NAND gate **210** functions precisely the same as NAND gate **176** and thus provides a positive-going signal on the lead **212** having a duration as determined by the controlled AND gate **182.** This signal is differentiated by the capacitor **214** and resistor **215** with a differentiated signal appearing at the input terminal **216** of the NAND gate **218.** The NAND gate **218** functions as a monostable multivibrator responsive only to negative-going signals. Thus, by differentiation of the output pulse from gate **210,** only the negative-going spike caused by the trailing edge of the output pulse effects any response in the NAND gate **218.** Thus, when the negative-going signal appears at the terminal **216** of the NAND gate **218** and drops below the threshold of 1.7 volts, the output appearing on the lead **220** of the NAND gate **218** is a positive-going signal. The input differentiating network of the AND gate **218** is designed such that the output signal has a duration of 100 microseconds. It should be noted that the leading edge of this output signal coincides with the trailing edge of the output signal from the AND gate **182.** This output signal is coupled through the inverting NAND gate **222** and appears as a negative-going signal 100 microseconds in duration on the lead **224.** This signal is coupled by way of the resistor **226** to the base **228** of the transistor **230.** The emitter **232** of the transistor is connected through the emitter resistor **234** to ground as illustrated and also by way of the lead **236** to the base **238** of the transistor **240,** the emitter **242** of which is connected to ground as illustrated. The collectors **231** and **241** of the transistors **230** and **240** are each connected through the primary winding **81** of the ignition coil **82** and through the ballast resistor **78** and the ignition switch **76** to the battery **68.** The resistors **244** are connected in series between the collectors of the two transistors and ground, and a diode **248** is connected between the common point of the two resistors and the lead **236.** The combination of the two resistors **244** and **246** and the diode **248** functions to protect the

transistors **230** and **240** from inductive kick voltage of high magnitude, for example, in excess of **200** volts. During quiescent conduction, that is when no signals are applied from the magnetic pickup through the circuit thus far described, the transistors **230** and **240** are in their **244** and **246** conducting states since the emitter-base diodes of each are forward biased as is well known to those skilled in the art. Under this circumstance those skilled in the art will recognize that the battery **68** potential is applied continuously through the primary winding **81** of the ignition coil **82** and through the conducting transistor **240** to ground. Thus, the magnetic flux is built up in the ignition coil. Upon application of the negative-going **100** microsecond signal by way of the lead **224** to the base of the transistor **230,** the transistors **230** and **240** are caused to go to their non-conducting state. As a result, current flow through the primary winding ceases and the magnetic field collapses. As a result thereof, the secondary coil has induced therein a high voltage potential which is applied as above described to the sparkplugs **90.** Upon termination of the negative-going pulse to the transistor base **228** of the transistor **230,** the transistors **230** and **240** again return to their conducting states and once again the current flows through the primary winding **81** thus building the flux appearing therein to a maximum.

Turning now to the spark-advance circuit of the present invention, the output signal from the trailing edge monostable multivibrator comprising the NAND gate **218** is applied through an inverting NAND gate **250** where it is inverted and at the lead **252** is a negative-going **100** microsecond duration pulse. This pulse is applied to the cathode of the diode **254** the anode of which is connected through the capacitor **256** to ground. A common point **258** between the diode and the capacitor is connected to the base **260** of a transistor **262** which is connected in an emitter-follower configuration. The collector **264** thereof is connected to the bus **116** while the emitter **268** thereof is connected through the resistor **270** to ground. A resistor **272** is connected from the common point **258** to the bus **116.**

It will be noted that the diode **254** is reversed biased by the output signal appearing on the lead **252** being high. Under these circumstances the transistor **262** is conducting. When the negative-going signal appears on the lead **252** at the output of the inverting NAND gate **250,** the diode **254** is forward biased thus immediately shorting any charge which appears on the capacitor **256.** Upon the expiration of the **100** microsecond pulse, the diode **254** is once again reversed biased and the capacitor **256** is connected in series with the resistor **272** between ground and the five volts appearing on the bus **116.** As a result, the capacitor **256** will charge from its zero voltage condition toward five volts in the traditional charging cycle of a capacitor with a time constant determined by the resistor **272** and the capacitor **256.** The charge appearing across the capacitor **256** is connected as the input signal to the base **260** of the transistor **262.** since the transistor is in an emitter-follower stage, this output signal then appears across the resistor **270.** The output signal is coupled by way of the resistor **274** to the base **206** of the transistor **200.** The transistor **200** functions as an amplifier which inverts the signal appearing across the resistor **270** while at the same time amplifying the same. The output signal appears across the load resistor **276** connected between the collector **198** and the bus **116.** Thus the signal appearing across the resistor **276** is applied to the resistors **192** and **196** which are connected to the capacitor **190** thereby effectively decreasing the time constant required for the capacitor **190** to charge by an amount proportional to the signal appearing across the resistor **276.** It will now be recognized that if the firing time for the sparkplugs occurs at any time during the change period of the capacitor **256,** that is before it reaches its full charge, then this voltage is applied to the charge path of the capacitor 190 thereby decreasing its time constant for charging allowing it to reach the threshold of 1.7 volts faster than before. As a result, the trailing edge of the output signal from the controlled AND gate **182** occurs sooner. However, if the spark firing time occurs after the capacitor **256** has achieved substantially its entire charge, then the output signal developed by the transistor **200** will have no effect on the charge time of the capacitor **190** and thus the spark will not be advanced but rather will occur in the zero advance or retarded condition as will have been previously established by the adjustment of the resistor **196.**

It will also be recognized by those skilled in the art that if the firing time occurs early in the charge cycle of the capacitor **256,** then a substantial signal is applied by way of the transistor **200** to the charge circuit of the capacitor **190.** Such substantially decreases the resistance appearing in the charge path and decreases the R-C time constant thus allowing the capacitor to more rapidly charge to a value above the threshold established for the controlled AND gate thereby terminating the output pulse therefrom much sooner. In this fashion the spark is advanced substantially and in direct relationship to the speed of the engine.

It will be noted that a switch **278** is connected between ground and a variable resistor **280** the other side of which is connected to the base **206** of the transistor **200.** An additional resistor **282** is also connected between the base **206** and the collector **198** of the transistor **200.** The switch **278** is connected to sense the vacuum appearing at the intake manifold of the engine. Upon the occurrence of a predetermined amount of vacuum at that point, for example, in the preferred embodiment approximately ten pounds per square inch, the switch **278** will close inserting the resistor **280** into the circuit and inserting it in parallel with the resistors **270** and **274,** thus lowering the bias on the base of the transistor **200.** As a result, the output signal at the collector of the transistor **200** increases thereby inserting an even greater amount of voltage in the charge path of the capacitor **190** causing it to reach the threshold voltage even sooner. As a result, upon actuation of the switch **278** the spark is advanced by a larger amount through the technique of effectively placing the function generated across the capacitor **256** on a pedestal of voltage.

Referring now to FIG. **4,** various wave forms are illustrated taken at various points throughout the circuit of FIG. **3.** In FIG. **4,** voltage is plotted on the ordinate and time along the abscissa. The curve **302** is taken across the resistor **134** and represents the signal generated by the electromagnetic pickup device. The curve **304** is taken from the collector **152** of the transistor **148** to ground and represents the input signal to the inverting NAND gate **176.** The curve **306** is taken at the output of the inverting NAND gate **210.** The curve **308** is taken from the collector **198** of the transistor **200** to ground and represents the voltage which is a wave function with respect to time that is applied to effectively reduce the time constant in the charge path of

the capacitor **190.** The curve **310** is the output signal of the inverting NAND gate **222** which is utilized to cut off the semiconductor switch consisting of transistor **240,** and the curve **312** is the voltage applied to the sparkplugs **90.**

In the left half of FIG. **4** the curves illustrated are taken during the time period when an internal combustion engine is operating at idle speed, that is in the range of approximately 600 revolutions per minute. Under these circumstances the electronic function generator produces a repetitive curve **308** and the spark occurs substantially at the conclusion thereof with the resultant of substantially no spark advance. It will be recognized that the curve **308** in the example given is substantially a logarithmic function and is generated by the charging of the capacitor **256** with that function inverted through the amplifier including the transistor **200.** It will be recalled that each time the spark is initiated the charge across capacitor **256** is shorted out, and the capacitor again commences to charge toward its maximum of 5 volts. Thus, the function **308** always commences at the same point. Thus, the points illustrated at **314** and **316** illustrate the commencement of the function each time the spark is initiated when the engine is at low speeds.

Referring now to the right half of FIG. **4** these curves are taken when the engine speed has substantially increased from idle. Again, it should be pointed out that the function curve **308** commences each time at the same point. Thus, the points **318, 320, 322** and **324** each illustrate the commencement of the function curve **308** as has above been described. It will also now be noted that the electromagnetic pickup generated curve **302** illustrates a substantially greater number of pulses per unit of time being generated. As each of these pulses is generated, the output signal from the controlled AND gate **60** also commences as is illustrated by the inverted waveform thereof at **306.** However, it will be noted that the duration of the pulses on the right half of FIG. **4** at curve **306** are substantially shorter than those on the left half. Such occurs as a result of the effective decrease in resistance in the charge path of the capacitor **190** of the controlled AND gate **60,** that is, from the function generator curve **308.** Thus as will be seen, during the time that the function generator curve is decreasing from the point **318** along its path **326,** the charge across the capacitor **190** reaches the threshold voltage at a shorter period of time than is the case on the left half of FIG. **4** so that at the point **328,** the controlled AND gate **60** changes states, thus causing the pulse in waveform **306** as illustrated at **330** to terminate, thereby shorting out the capacitor **256** and once again starting the function generator from its initial position as at **320,** and also initiating the spark as shown in waveforms **310** and **312.** The dashed lines show the function signal path if capacitor **190** were allowed to fully charge as was the case at the left half of FIG. **4.**

It will thus be recognized by those skilled in the art that as the engine speed continues to increase, the number of pulses generated by the electromagnetic pickup will increase per unit of time and the frequency of repetition of the pulses on the curve **306** will increase but the duration of each of the pulses will decrease as a result of the function generator output voltage being inserted sooner and thus closer to its point of commencement to effectively decrease the resistance in the charge path of the capacitor **190.**

Although the function generated by the electronic function generator in the preferred embodiment thus far discussed is substantially logarithmic, it will be understood by those skilled in the art that the function may be any function of voltage with respect to time as may be desired for the particular engine application. As an example, a linear ramp may be generated through the utilization of an operating amplifier having a capacitor connected in a feedback relationship therewith, as is well known in the art. The ramp can be caused to terminate at any point during the timing function thus enabling an internal combustion engine to be operated during the relatively low speed such as at idle with zero spark advance and then inserting a spark advance as herein described at some predetermined point such as for example 600 revolutions per minute of engine speed and above.

Each of the NAND gates **176, 210, 222** and **250** as well as the trailing edge monostable device **218** may be constructed of circuits well known in the prior art. For example, a quadruple **2-input** positive NAND gate, manufactured by Texas Instruments, Incorporated, of Dallas, Texas, circuit type **SN7400** may be utilized. Such a circuit is illustrated in FIG. **5A** for purposes of completeness of disclosure. It will be recognized by those skilled in the art that with the two emitters A and B connected together, as illustrated, when the input signal connected thereto goes from a low state to a high state in excess of a threshold voltage (greater than approximately 1.7 volts), the voltage appearing at the terminal marked "output" goes from a high state to a low state. Likewise, if the input voltage applied to the interconnected emitters A and B is at a high state and then is driven below the threshold voltage, the output signal appearing at the terminal marked output will go from a low state to a high state and will remain high until such a time as the signal appearing at the interconnected emitters again exceeds the threshold voltage at which time the output signal will return to its low state. Thus, by connecting the capacitor-resistor combination to the input terminals A and B interconnected together as is illustrated for the trailing edge monostable **218,** and properly selecting the resistor and capacitor values to a desired time constant, one may obtain an output signal of constant duration and amplitude as hereinabove described.

By interconnecting two of the NAND gates as illustrated in FIG. **5B,** one may obtain the variable duration pulsewidth device **182** as hereinabove described. Thus, by connecting the capacitor between the output of the second NAND gate and the emitter B of the first NAND gate as illustrated and by connecting the emitter A of the first NAND gate to receive the output signal from the first pulse generator **10,** the output voltage from the second NAND gate goes from a high to a low state when the input signal at emitter A goes from a high to a low state. The output remains low until the charge across the capacitor reaches the threshold level as above described at which time the output agains returns high.

If desired, one may utilize a commercially available AND gate also made by Texas Instruments, Incorporated, of Dallas, Texas, and referred to as the quadruple **2-input** positive AND gate, for example circuit type SN5408. For purposes of completeness of disclosure, such a circuit is illustrated in FIG. **5C,** to which reference is hereby made. With the capacitor interconnected between the output terminal and the input ter-

minal B and with the input terminal A connected to receive the input signal as previously described with respect to FIG. **5B,** the desired output voltage waveforms will result.

It will be recognized by those skilled in the art that the appropriate connections to operating potential of five volts and to ground are made to each of the gates referred to in FIG. **3** as illustrated in FIG. **5.**

SUMMARY OF SYSTEM OPERATION

From the foregoing it can be seen that as the disc **40** is rotated by the engine crankshaft **42,** a voltage signal is generated by the electromagnetic pickup **52** as each of the discontinuities pass by. This signal is then amplified by the amplifier pulse shaper **56.**

The discontinuities in disc **40** are equally spaced at its periphery and the number thereof equal the number of sparkplugs fired per revolution of the engine. For example, in an eight-cylinder reciprocating internal combustion engine, four sparkplugs fire per revolution of the engine's crankshaft. Consequently, in the specific disc **40,** four slots or indentations spaced 90° of arc apart are required.

The electromagnetic pickup **52** is positioned perpendicular to the periphery of disc **40** and for an eight-cylinder engine at 45° before top-dead center or after top-dead center with respect to the slots. Thus, the signal voltage pulse output from the first pulse generator **10** occurs exactly 45° before top-dead center with respect to the particular cylinder to be provided with a spark for ignition.

This pulse then triggers the controlled AND gate **60** which is designed to generate a pulse ten milliseconds in duration at 600 RPM engine speed. Such occurs because the resistor **196** is effectively at ground and the function generator has little or no effect at this engine speed. This pulse, because of its time duration and the spark occurring on its termination, will retard the engine timing advance exactly 36° of engine crankshaft angle. When subtracted from the 45° setting of the electromagnetic pickup **52,** there is provided a net of 9° before top-dead center basic timing advance for this engine (eight-cylinder) at **600** RPM.

Variable resistor **196** may be adjusted to add or subtract an additional 5° of engine crankshaft angle at 600 RPM thus providing an electronic means to further adjust the basic timing advance.

As the engine speed increases the function signal or control voltage **308** provided at the output of the control amplifier **200** becomes more positive and effectively shortens the duration of the pulse **306** from the controlled monostable **60.** This, in effect, will advance the engine's timing.

As the engine load decreases during cruise conditions and vacuum manifold pressure reaches 10 psi, the vacuum-actuated switch **278** closes connecting bias resistor **280** to ground which shifts control voltage **308** more positively. This shift causes a further reduction in the pulse duration of voltage output **306** at the controlled AND gate and an additional timing advance occurs. Variable bias resistor **280** may be adjusted to further provide means of control and to adjust the range of the vacuum-actuated timing advance.

The output voltage pulse **306** is applied to the trailing edge monostable **64** to generate a voltage **310.** This voltage is then applied to the power amplifier **66** which connects the primary winding **81** of the ignition coil **82** to the semiconductor switch. Current flows at all times through the primary **81** of the ignition coil **82** except at the time of the spark period voltage **312** which is 100 microseconds, thus providing the sparkplugs with energy that is constant at all engine RPM.

There has thus been disclosed an electronic ignition system providing automatic electronic spark advance at desired engine speeds which eliminates problems inherent in the prior art systems.

What is claimed is:

1. An electronic ignition system for internal combustion engines comprising:

A. electromagnetic means for generating a plurality of pulses,

1. said means generating one pulse for each spark plug which will fire during each revolution of a crankshaft in said engine, and

2. the repetition rate of said pulses being directly proportional to engine speed;

B. control means having first and second input terminals and an output terminal for providing a control signal having a duration variable with engine speed thereby to advance the firing of the spark plugs in said engine, said control signal upon termination thereof initiating the firing of a spark plug;

C. an electronic function generator means for automatically generating an electronic signal of predetermined but constant wave form having a characteristic matching the desired spark advance profile of said engine, said electronic signal commencing responsive to termination of said control signal;

D. means connecting said pulses from said electromagnetic means to said first terminal of said control means, said control signal being initiated by each of said pulses;

E. capacitive feedback means connected between said output terminal and said second input terminal for terminating said control signal a predetermined fixed time after initiation thereof in the absence of an electronic signal; and

F. means connecting said electronic signal to said second terminal for automatically advancing termination of said control signal as engine speed increases.

2. An electronic ignition system for internal combustion engines as defined in claim **1** wherein said control means includes a controlled AND gate the output signal of which changes from a first to a second state upon the application of a pulse to said first terminal, said output signal terminating when the charge on said capacitor reaches a predetermined point, the time of occurence of said point being determined by said electronic signal.

3. An electronic ignition system for internal combustion engines as defined in claim **1** wherein said function generator means includes capacitor means, means for initiating the charge cycle of said capacitor means substantially coincidental with initiation of the spark, and amplifier means coupled to receive as an input signal the charge on said capacitor means.

4. An electronic ignition system for internal combustion engines as defined in claim **3** wherein said amplifier means includes bias means, switch means connected to insert said bias means into said amplifier means, and means connecting said switch means to receive pressure signals from the intake manifold of said engine for actuating said switch means responsive to vacuum increase thereby advancing termination of said output signal.

5. An electronic ignition system for use with a direct current potential source and an ignition coil for applying electrical energy to sparkplugs to generate a spark for combustion of gases in an internal combustion engine comprising:

A. First pulse generator means for producing output pulses in timed relationship with said engine speed;

B. Second pulse generator means coupled to receive pulses from said first pulse generator means and responsive thereto to initiate production of output pulses having variable time duration and commencing with the commencement of said pulse from said first pulse generator;

C. Capacitive feedback means coupling said output pulses to the input of said second pulse generator means for terminating said output pulse a predetermined fixed time after initiation thereof, said time being determined by the charge time of said capacitor to reach a predetermined voltage level in the absence of other signals;

D. Semiconductor switch means for controlling application of said direct current to said ignition coil;

E. Means coupling the output signal of said second pulse generator means to said semiconductor switch means for initiating said spark upon termination of said second pulse generator output signal;

F. Electronic spark-advance means including:

1. electronic function generator means for providing an output signal which varies as a function of time, said variation corresponding to the desired spark advance profile of said engine;

2. initiating means connected for causing said function generator means to start to produce said output signal substantially coincidental with commencement of said spark; and

3. means coupling said output signal of said function generator to said second pulse generator means for terminating said variable duration pulse in a shorter time than without said function generator signal thereby to automatically advance commencement of said spark as said engine speed increases.

6. An electronic ignition system for internal combustion engines as defined in claim **5** wherein said electronic function generator means includes capacitor means, means for initiating the charge cycle of said capacitor means substantially coincidental with initiation of the spark, and amplifier means coupled to receive the charge on said capacitor means.

7. An electronic ignition system for internal combustion engines as defined in claim **6** wherein said coupling means includes monostable means responsive only to the trailing edge of output pulses from said second pulse generator for providing pulses of constant duration and amplitude for controlling said semiconductor switch thereby to provide a constant spark at all engine speeds.

8. An electronic ignition system for internal combustion engines as defined in claim **7** wherein said initiating means includes means coupling said pulses of constant duration and magnitude to said capacitor means for initiating commencement of said capacitor means charge cycle.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,923,029

DATED : December 2, 1975

INVENTOR(S) : Benito Polo

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 6, Line 46 after "the" "AND" should be --NAND--

Column 6, Line 63 after "244" insert --and 246--

Column 7, Line 6 after "their" omit "244 and 246"

Signed and Sealed this

ninth Day of *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks