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Huntzinger et al.

[11] **3,738,339**

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[54] **ELECTRONIC IGNITION SPARK ADVANCE SYSTEM**

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[73] Assignee: **General Motors Corporation,** Detroit, Mich.

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[21] Appl. No.: **205,186**

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

[51] **Int. Cl.** **F02p 5/04,** F02p 1/00

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

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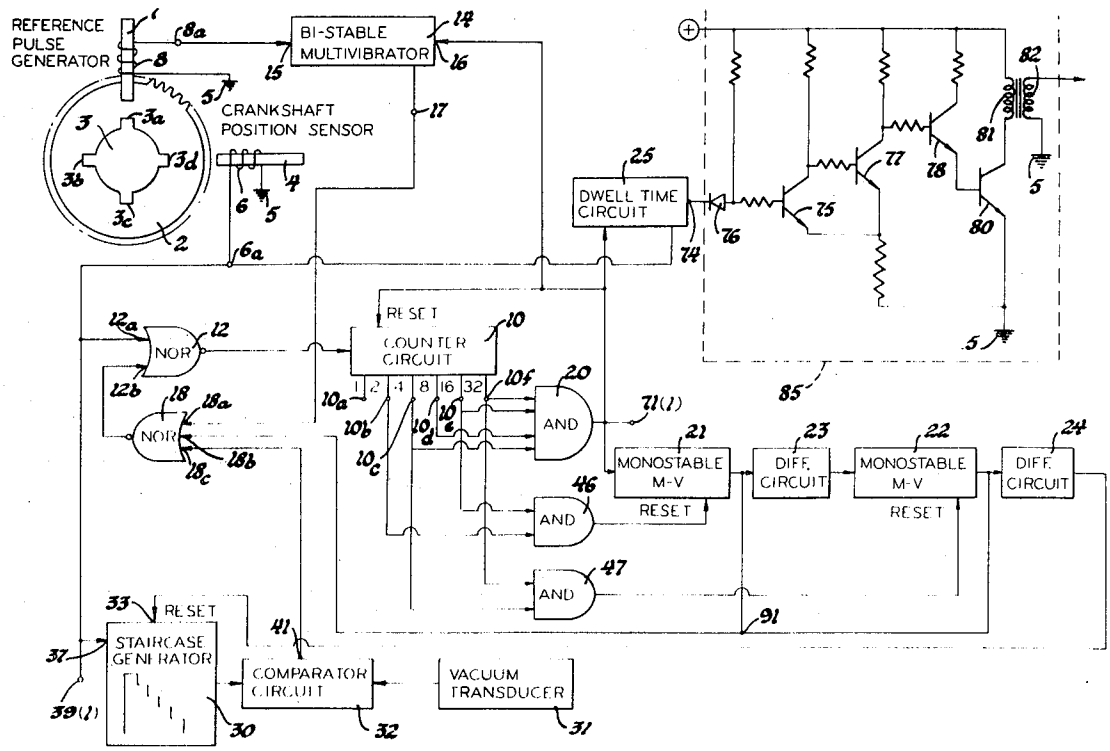
Assistant Examiner—Ronald B. Cox
Attorney—Eugene W. Christen, Creighton R. Meland and Richard G. Stahr

[57] **ABSTRACT**

An electronic ignition spark advance system for use with internal combustion engine transistor ignition systems having an ignition coil primary winding switching transistor. A reference pulse, produced a selected number of degrees before the top dead center position of each engine piston, enables an ignition spark advance gate to gate a series of crankshaft position pulses, each indicating one degree of crankshaft rotation, to a counter circuit. When the counter circuit has counted the number of crankshaft position pulses equal to the number of selected degrees before top dead center the reference pulses are produced, an ignition signal is produced which extinguishes the ignition coil primary winding switching transistor and operates circuitry which produces a signal which may disenable the ignition spark advance gate. To provide speed ignition spark advance, however, delay circuitry responsive to each ignition signal provides two consecutive delay periods during which the disenabling of the ignition spark advance gate is delayed. Consequently, the counter circuit continues to count crankshaft position pulses during the delay periods, thereby providing a speed ignition spark advance in degrees equal to the number of crankshaft position pulses counted during the delay periods at any engine speed. To provide two speed ignition spark advance limits, the first delay period is terminated with a first selected crankshaft position pulse count if it occurs before the end thereof and the second delay period is terminated with a second greater selected crankshaft position pulse count if it occurs before the end thereof. To provide vacuum ignition spark advance, a vacuum spark advance signal is provided at the conclusion of the delay periods for the number of crankshaft position pulses equal to the degrees of vacuum ignition spark advance required which enables the ignition spark advance gate to gate the crankshaft position pulses to the counter circuit after the delay periods.

5 Claims, 5 Drawing Figures



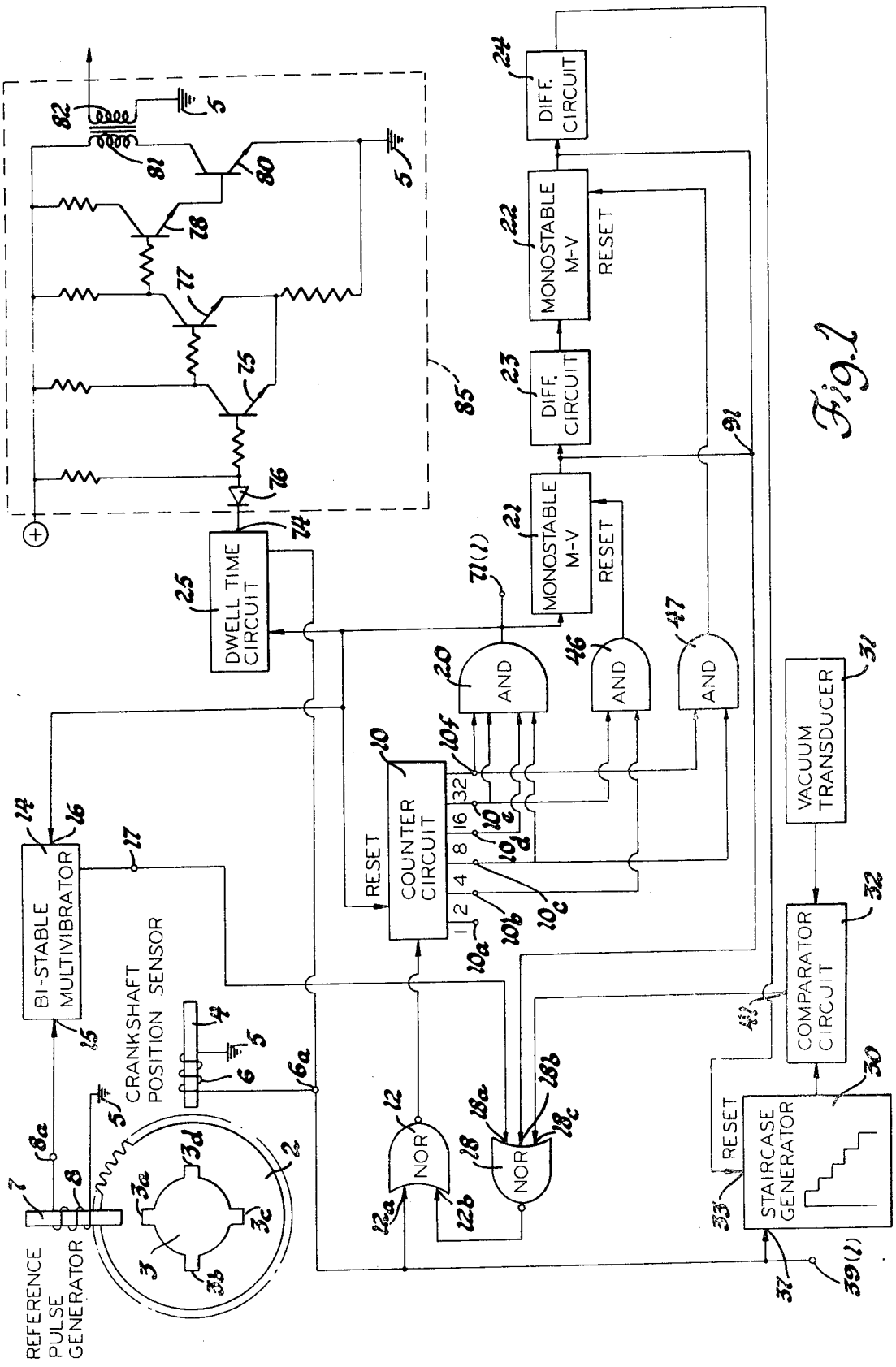

REFERENCE PULSE GENERATOR
BI-STABLE MULTIVIBRATOR
CRANKSHAFT POSITION SENSOR
COUNTER CIRCUIT
RESET
NOR
NOR
DWELL TIME CIRCUIT
MONOSTABLE M-V
RESET
MONOSTABLE M-V
RESET
DIFF. CIRCUIT
DIFF. CIRCUIT
AND
AND
AND
COMPARATOR CIRCUIT
VACUUM TRANSDUCER
STAIRCASE GENERATOR
RESET

Fig. 1

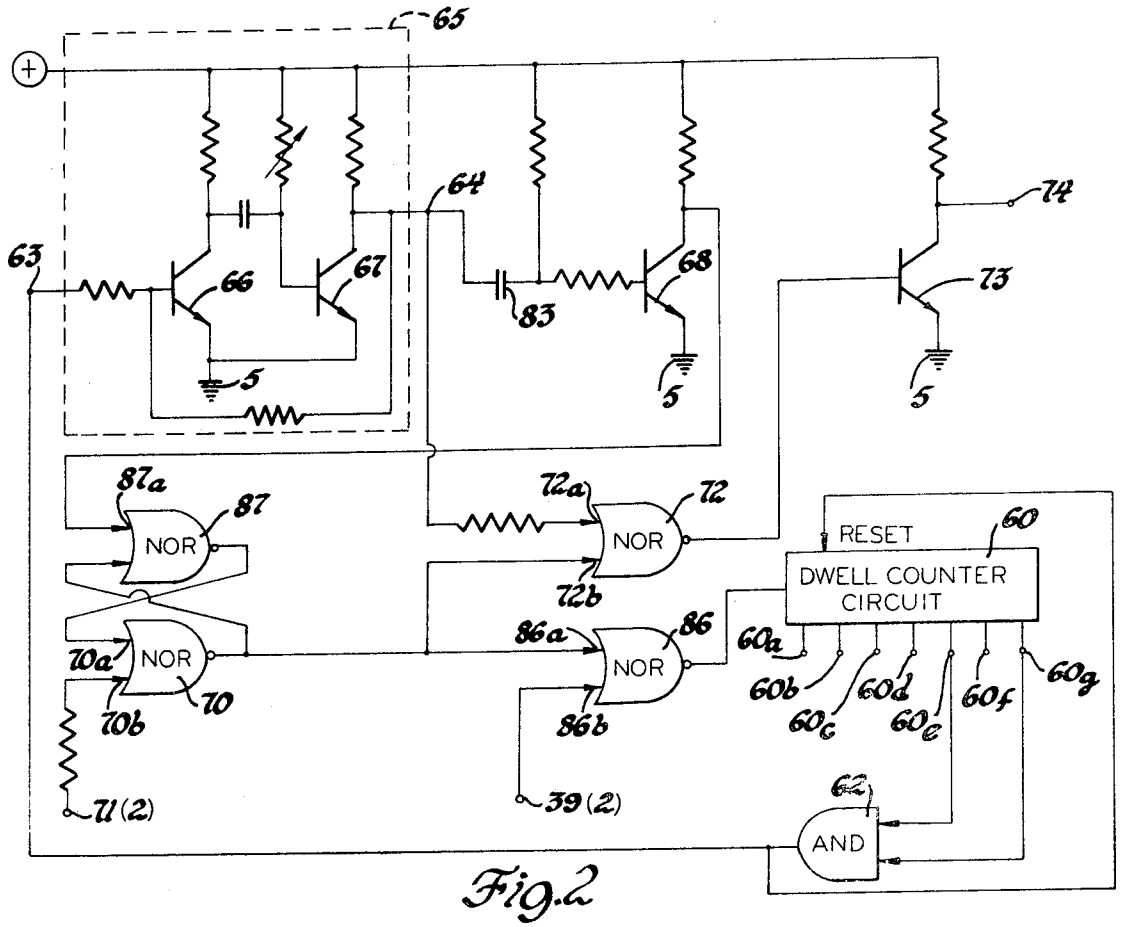

65
64
74
63
66
67
68
83
73
5
87a
87
NOR
72a
72
72b
RESET
60
DWELL COUNTER CIRCUIT
86a
86
86b
70a
70
70b
60a
60b
60c
60d
60e
60f
60g
71(2)
39(2)
62
AND

Fig.2

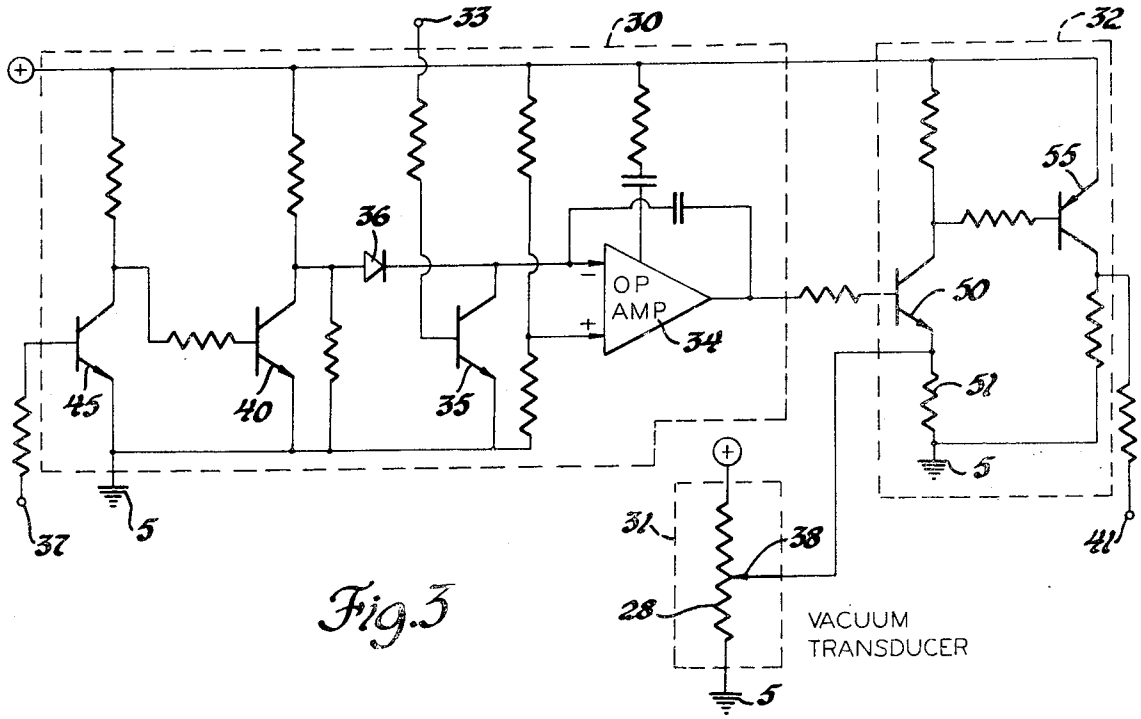

33
30
32
36
OP AMP
34
55
50
51
45
40
35
37
41
31
38
28
VACUUM TRANSDUCER
5

Fig.3

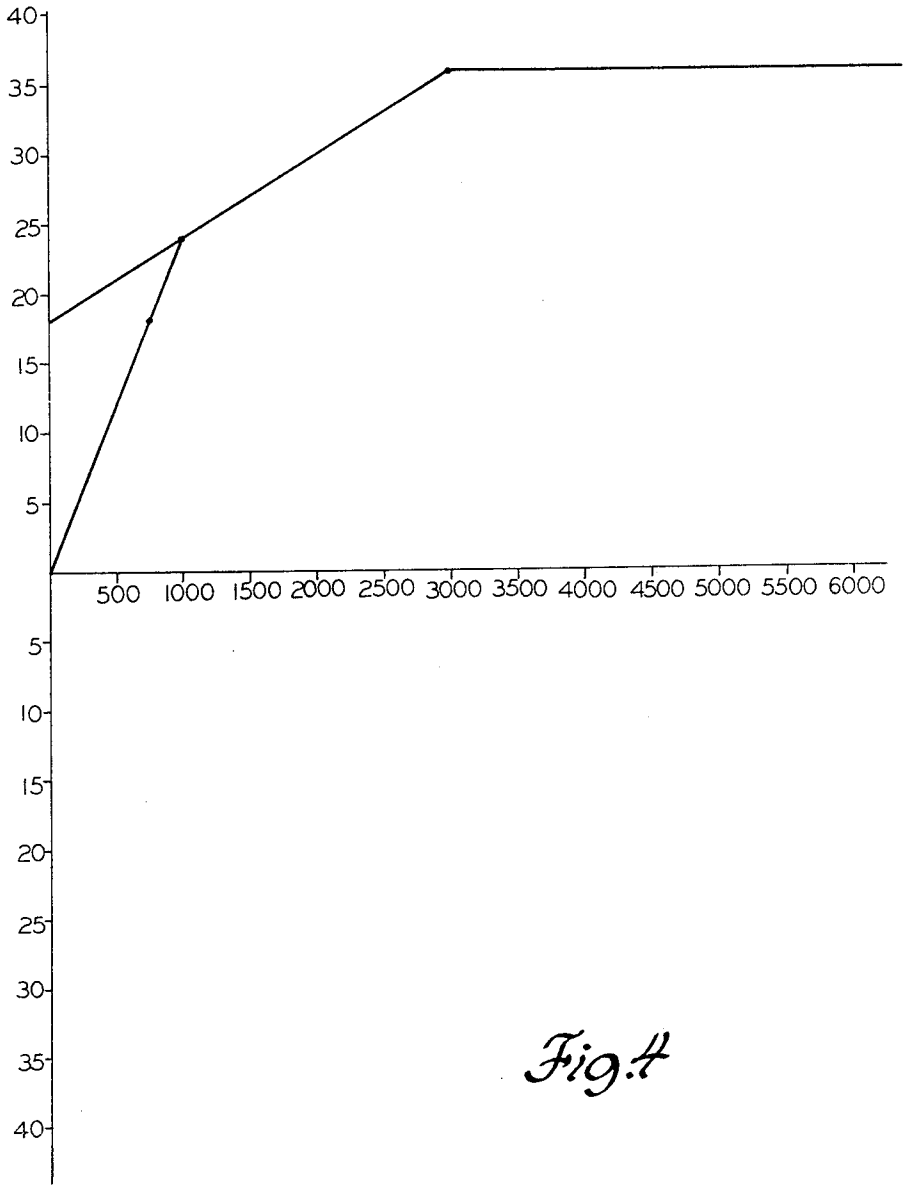

40
35
30
25
20
15
10
5
500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000
5
10
15
20
25
30
35
40

Fig.4

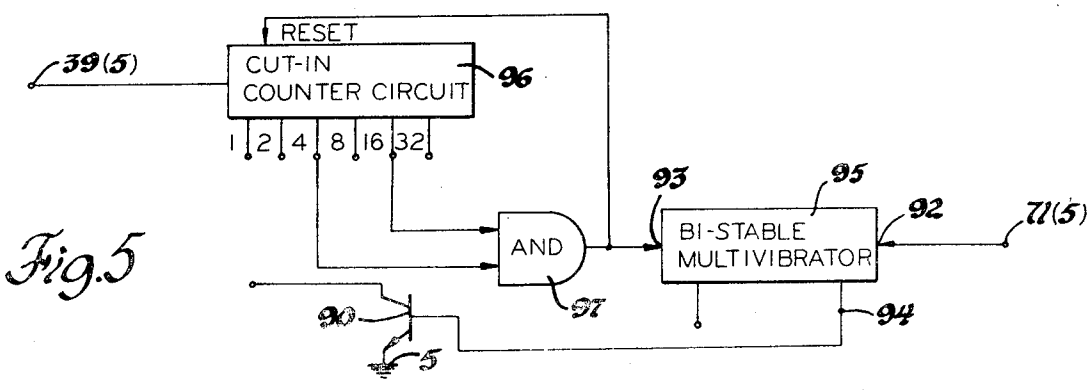

RESET
39(5)
CUT-IN
COUNTER CIRCUIT
96
1 2 4 8 16 32
93
95
AND
BI-STABLE
MULTIVIBRATOR
92
71(5)
97
90
94
5

Fig.5

ELECTRONIC IGNITION SPARK ADVANCE SYSTEM

This invention is directed to an internal combustion engine electronic ignition spark advance system and, more specifically, to an electronic ignition spark advance system which provides for both engine speed and engine vacuum ignition spark advance, as determined by engine speed.

In conventional ignition systems for internal combustion engines, the ignition breaker contacts are mounted upon a rotatable breaker plate. To obtain engine speed ignition spark advance, the breaker cam is revolved by weights which are rotated by the distributor shaft and to obtain engine vacuum ignition spark advance, the breaker plate is revolved by a vacuum motor in response to engine intake manifold vacuum. As systems of this type are subject to mechanical wear and failure, the desirability of an electronic ignition spark advance system which obviates the disadvantage of mechanical wear and failure is apparent.

It is, therefore, an object of this invention to provide an improved internal combustion engine ignition spark advance system.

It is another object of this invention to provide an improved internal combustion engine ignition spark advance system which provides ignition spark advance electronically.

It is another object of this invention to provide an improved electronic ignition spark advance system for internal combustion engines which electronically provides engine speed and engine vacuum ignition spark advance.

It is an additional object of this invention to provide an improved electronic ignition spark advance system for internal combustion engines which electronically provides engine speed and engine vacuum ignition spark advance and ignition dwell time to provide for the energization of the ignition coil primary winding for the required duration.

In accordance with this invention, an electronic ignition spark advance system for use with internal combustion engine transistor ignition systems having an ignition coil primary winding switching transistor is provided wherein a series of crankshaft position pulses, each indicating one degree of crankshaft rotation, are gated through an ignition spark advance gate, enabled in response to a reference signal produced a selected number degrees before the top dead center position of each piston, to a counter circuit and an ignition signal is produced when the counter circuit has counted the number of crankshaft position pulses equal to the number of selected degrees the reference signals are produced before top dead center which extinguishes the ignition coil primary winding switching transistor and operates circuitry which disenables the ignition spark advance gate after two consecutive delay periods in the absence of an engine vacuum spark advance signal produced at the end of the delay periods for enabling the ignition spark advance gating circuitry after the delay periods for the number of crankshaft position pulses which produce the number of degrees of engine vacuum ignition spark advance required.

For a better understanding of the present invention, together with additional objects, advantages and features thereof, reference is made to the following description and accompanying drawings in which:

FIG. 1 sets forth the electronic ignition spark advance control system of this invention in block form;

FIG. 2 sets forth the dwell circuit partially in schematic and partially in block form;

FIG. 3 sets forth in schematic form, circuitry suitable for use with the electronic ignition spark advance system of this invention for producing an engine vacuum ignition spark advance signal;

FIG. 4 sets forth a typical engine speed ignition spark advance curve; and

FIG. 5 sets forth, partially in schematic and partially in block form, ignition spark advance "cut-in" circuitry suitable for use with the electronic ignition spark advance system of this invention;

As the point of reference or ground potential is the same point electrically throughout the system, it has been represented in the drawing by the accepted schematic symbol and referenced by the numeral 5.

The electronic ignition spark advance system of this invention is designed for use in combination with an internal combustion engine and an associated transistor ignition system having an ignition coil primary winding switching transistor. In the interest of reducing drawing complexity, and since internal combustion engines are old and well known in the automotive art and, per se, forms no part of this invention, the engine has not been shown in the drawing.

One example, and without intention or inference of a limitation thereto, of an internal combustion engine transistor ignition system suitable for use with the electronic ignition spark advance system of this invention is disclosed and described in U.S. Pat. No. 3,605,713, Sept. 20, 1971, Le Masters et al, which is assigned to the same assignee as is this application.

The electronic ignition spark advance system of this invention employs conventional AND gates, NOR gates, bi-stable multivibrator circuits, monostable multivibrator circuits, differentiating circuits, counter circuits and an operational amplifier. As these circuit elements are commercially available items well known in the art, and per se, form no part of this invention, each has been illustrated in block form in the drawing. Furthermore, these devices are only examples of circuit elements suitable for use with the system of this invention, consequently, there is no intention or inference of a limitation thereto as other circuit elements having similar electrical characteristics may be substituted therefor without departing from the spirit of the invention.

In accordance with logic terminology well known in the art, throughout this specification, the logic signals will be referred to as "high" or logic 1 or "low" or logic 0 signals. For purposes of this specification, and without intention or inference of a limitation thereto, the "high" or logic 1 signals will be considered to be of a positive polarity potential and the "low" or logic 0 signals will be considered to be of zero or ground potential.

The NOR gates require a logic 0 signal upon all input terminals to produce a logic 1 output signal and the AND gates require a logic 1 signal upon all input terminals to produce a logic 1 output signal.

Referring to the drawing, a crankshaft position sensor and a reference pulse generator are provided for producing a series of crankshaft position electrical pulses, each corresponding to one degree of rotation of the engine crankshaft, and a reference electrical pulse

at a predetermined number of degrees before the top dead center position of each engine piston, respectively. These items may comprise a circular disc member 2 of magnetic material having 360 teeth about the periphery, that is, a tooth for each degree. In the drawing, only a few representative teeth have been shown in the interest of reducing drawing complexity. Disc member 2 is preferably mounted upon and rotated by the engine crankshaft but may be mounted upon and rotated by any other engine or vehicle shaft which is rotated at a speed equal to engine crankshaft speed. Carried upon and rotated with disc member 2 is a pole piece 3 of magnetic material having a salient pole tip corresponding to each two engine cylinders. For an eight cylinder engine, therefore, pole piece 3 has four salient pole tips 3*a*, 3*b*, 3*c* and 3*d*, as shown in FIG. 1. a permanent magnet 4 having a crankshaft position sensor pickup coil 6 wound thereupon is located in magnetic coupling relationship with the teeth about the periphery of disc member 2 and another permanent magnet 7 having a reference pulse generator pickup coil 8 wound thereupon is located in magnetic coupling relationship with the salient pole tips 3*a*, 3*b*, 3*c* and 3*d* of pole piece 3. As disc member 2 and pole piece 3 are rotated at engine crankshaft speed, therefore, a series of crankshaft position electrical pulses, each corresponding to one degree of engine crankshaft rotation and hereinafter referred to as crankshaft position pulses, are induced in pickup coil 6 and appear upon the output circuit which may be a terminal 6a and reference electrical pulses, hereinafter referred to as reference pulses, are induced in pickup coil 8 and appear upon the output circuit which may be a terminal 8a. Pole piece 3 is so oriented that, when each salient pole tip thereof is adjacent permanent magnet 7, the reference pulse is induced in pickup coil 8 a predetermined number of degrees before the top dead center position of the engine piston of the cylinder to which it corresponds. That is, the reference pulse generator produces a reference pulse at a selected number of degrees before the top dead center position of each engine piston. For purposes of this specification, and without intention or inference of a limitation thereto, the selected number of degrees before the top dead center position of each engine piston will be 60. It is to be specifically understood that optical sensors or any other type sensor or any combination thereof may be substituted for the magnetic crankshaft position sensor and reference pulse generator without departing from the spirit of the invention.

A counter circuit **10**, having an input terminal, a plurality of output terminals, each corresponding to a binary code bit, and a reset terminal is provided for counting the crankshaft position pulses and producing upon the output terminals thereof the binary code representation of the number of crankshaft position pulses counted thereby. As counter circuit **10** must count the number of crankshaft position pulses equal to the number of degrees the reference pulses are produced before the top dead center position of each engine piston, 60 for purposes of this specification, counter **10** must have six stages and six output terminals, **10***a*, *10b*, **10***c*, **10***d*, **10***e* and **10***f*. A logic 1 signal upon these output terminals represent the decimal values 1, 2, 4, 8, 16 and 32, respectively, as is well known in the binary arithmetic art. That is, each output terminal of counter circuit **10** corresponds to a binary code bit.

The crankshaft position pulses induced in pickup coil **6** are applied to counter circuit **10** through an ignition spark advance gate circuit, NOR gate **12** which, when enabled, gates the crankshaft position pulses to the input terminal of counter circuit **10.** The ungrounded end of pickup coil **6** is connected to the **12***a* input terminal of NOR gate **12** and the output terminal of NOR gate **12** is connected to the input terminal of counter circuit **10.**

as counter circuit **10** must begin counting crankshaft position pulses upon the occurrence of each reference pulse, NOR gate **12** must be enabled to gate crankshaft position pulses to counter circuit **10** with each reference pulse. Consequently, circuitry responsive to each of the reference pulses for producing a start count signal and a gate circuit for producing an enabling signal in response to the start count signals for enabling NOR gate **12** are provided. One example, of a circuit for producing the start count signals is a conventional bi-stable multivibrator circuit, illustrated in FIG. **1** in block form and referenced by the numeral **14,** having two input terminals **15** and **16** and an output terminal **17.** The enabling gate circuit may be a three input NOR gate **18.** To enable NOR gate **12** to gate crankshaft position pulses to the input terminal of counter circuit **10,** a logic 0 enabling signal must be present upon the output terminal of enabling NOR gate **18.** Therefore, each reference pulse is applied to input terminal **15** of bi-stable multivibrator circuit **14** for triggering this device to the state in which a logic 1 start count signal appears upon output terminal **17** thereof, which is connected to input terminal **18***a* of NOR gate **18.** With a logic 1 start count signal present upon the input terminal **18**a of NOR gate **18,** a logic 0 enabling signal is present upon the output terminal thereof which is connected to input terminal **12***b* of NOR gate **12,** a condition which enables NOR gate **12.**

Circuitry responsive to the binary code representation, upon the output terminals of counter circuit **10,** of the number of crankshaft position pulses counted by counter circuit **10** equal to the selected number of degrees before the top dead center position of each piston of the internal combustion engine at which each reference pulse is produced for producing an ignition signal is provided. This circuitry may be an ignition signal AND gate **20** having an input terminal corresponding to each logic 1 bit of this binary code representation. As the number of degrees before the top dead center position of each piston at which each reference pulse is produced has been arbitrarily selected for purposes of this specification as 60, a four input ignition signal AND gate **20** is provided.

When counter circuit **10** has counted 60 crankshaft position pulses, a logic 1 signal appears upon each of output terminals **10***c*, **10***d*, **10***e* and **10***f* thereof, the binary code representation of the numeral 60. These counter circuit **10** output terminals are connected to respective input terminals of ignition signal AND gate **20** which, with a logic 1 signal present upon each input terminal thereof, produces a logic 1 output ignition signal upon the output terminal thereof in response to a counter circuit count of **60** crankshaft position pulses.

The output terminal of ignition signal AND gate **20** is connected to the reset terminal of counter circuit **10,** to input terminal **16** of bi-stable multivibrator circuit **14** and to dwell time circuit **25.** Consequently, the logic **1** ignition signal appearing upon the output terminal of

AND gate **20** resets counter circuit **10** to zero, triggers bi-stable multivibrator circuit **14** to the condition in which a logic 0 full count signal appears upon output terminal **17** thereof and operates the dwell circuit **25** to produce a logic 1 output signal which initiates the operation of the transistor ignition system **85** to extinguish the ignition coil primary winding switching transistor, in a manner to be later explained. Bi-stable multivibrator circuit **14**, therefore, is also responsive to each ignition signal for producing a logic 0 full count signal.

In the absence of any logic 1 signals upon any one of the input terminals of enabling NOR gate **18** other than the input terminal connected to the output terminal **17** of bi-stable multi-vibrator **14**, with a logic 0 full count signal present upon output terminal **17** of bi-stable multivibrator **14**, a logic 1 disenabling signal appears upon the output terminal of enabling NOR gate **18** which is applied to input terminal **12***b* of NOR gate **12**. While a logic 1 disenabling signal is applied to input terminal **12***b* of NOR gate **12**, a logic 0 signal is maintained upon the output terminal thereof regardless of the logic signal applied to the other input terminal **12***a*. Consequently, the ignition signal operates circuitry which produces a full count signal which may disenable NOR gate **12** as bi-stable multivibrator **14** and NOR gate **18** produce a logic 1 disenabling signal, in response to each ignition signal, which is applied to one of the input terminals of NOR gate **12**. With these conditions, each cylinder would be fired when the piston is at top dead center as the ignition spark advance NOR gate **12** would be enabled by each reference pulse, produced 60° before top dead center, to gate crankshaft position pulses to counter circuit **10** and would be disenabled 60° later in response to the ignition signal produced by AND gate **20** when counter circuit **10** has counted 60 crankshaft position pulses.

To obtain engine speed ignition spark advance, it is necessary that delay circuitry responsive to each ignition signal be provided for producing two consecutive delay periods during which the disenabling of the ignition spark advance gate is delayed. Consequently, a first delay circuit responsive to each of the ignition signals produced by AND gate **20** for producing a first engine speed ignition spark advance signal of a preselected duration for delaying the disenabling of the ignition spark advance NOR gate **12** for the duration thereof and a second delay circuit responsive to the end of each of the first engine speed ignition spark advance signals for producing a second engine speed ignition spark advance signal of a predetermined duration for further delaying the disenabling of spark advance NOR gate **12** for the duration thereof are provided. These delay periods permit counter circuit **10** to continue to count crankshaft position pulses during the delay periods. The count of crankshaft position pulses during the delay periods is retained by counter circuit **10**. With the next reference pulse, NOR gate **12** is again enabled to gate crankshaft position pulses into counter circuit **10**. However, as counter circuit **10** already has a crankshaft position pulse count retained therein, less than 60 crankshaft position pulses are now required for the counter circuit **10** to count 60 by an amount equal to the count retained therein. Consequently, the next ignition signal is produced by AND gate **20** before the piston of the cylinder to be fired has reached top dead center by a number of degrees of engine speed ignition spark advance equal to the count of the crankshaft position pulses retained in counter circuit **10**. For example, if the count of crankshaft position pulses retained in counter circuit **10** is 20, the engine speed ignition spark advance would be 20°. This delay circuitry may be two conventional monostable multivibrator circuits, illustrated in block form in FIG. **1** and referenced by the numerals **21** and **22**, each having an input, an output and a reset terminal. The monostable multivibrator circuit is normally in the stable state, in which a logic 0 is present upon the output terminal thereof, and is triggered to the alternate state, in which a logic 1 signal is present upon the output terminal thereof, upon the application of a logic 1 signal to the input terminal thereof. This device remains in the alternate state for a selectable period of delay time as determined by the timing circuitry, after which it spontaneously returns to the stable state. In the alternate state, the output transistor is not conductive but may be triggered conductive before the expiration of the selected period of delay time by applying a logic 1 signal to the base electrode thereof through the reset terminal. The logic 1 ignition signal produced by AND gate **20** is applied to the input terminal of monostable multivibrator **21**, connected to the output terminal of AND gate **20**, which produces the first logic 1 engine speed ignition spark advance signal. That is, the logic 1 ignition signal triggers monostable multivibrator **21** to the alternate state for a delay period as determined by the timing circuitry thereof. The logic 1 first engine speed ignition spark advance signal appearing upon the output terminal of monostable multivibrator circuit **21** while in the alternate state is applied to input terminal **18***b* of NOR gate **18**, connected to the output terminal of monostable multivibrator **21**, which produces a logic 0 enabling signal upon the output terminal thereof. At the conclusion of the delay period designed into monostable multivibrator **21**, this device spontaneously returns to the stable state in which a logic 0 signal appears upon the output terminal thereof. The trailing edge of the logic 1 first engine speed ignition spark advance signal present upon the output terminal of monostable multivibrator **21** while in the alternate state is differentiated to produce a logic 1 signal by a conventional differentiating circuit, represented in FIG. **1** in block form and referenced by the numeral **23**. The logic 1 signal produced by differentiating circuit **23** is applied to the input terminal of monostable multivibrator circuit **22**, connected to the output terminal of differentiating circuit **23**, which produces the second engine speed ignition spark advance signal. That is, the logic 1 signal produced by differentiating circuit **23** triggers monostable multivibrator circuit **22** to the alternate state for a delay period as determined by the timing circuitry thereof. The logic 1 second engine speed ignition spark advance signal appearing upon the output terminal of monostable multivibrator circuit **22** while in the alternate state is also applied to input terminal **18***b* of NOR gate **18**, connected to the output terminal of monostable multivibrator circuit **22**, which produces a logic 0 enabling signal upon the output terminal thereof. At the conclusion of the delay period designed into monostable multivibrator **22**, this device spontaneously returns to the stable state in which a logic 0 signal appears upon the output terminal thereof.

To provide an engine vacuum ignition spark advance, engine vacuum sensitive circuitry responsive to the end of the second engine speed ignition spark advance sig-

nal for producing an engine vacuum ignition spark advance signal is provided. This circuitry may include a conventional staircase generator **30**, FIG. **3**, a vacuum transducer **31** and a potential comparator circuit **32**. Upon the application of a logic 1 signal to the reset terminal **33** of staircase generator **30**, transistor **35** is triggered conductive to place ground upon the inverting input terminal of operational amplifier **34**, thereby producing a maximum positive polarity potential signal upon the output terminal thereof, as shown in FIG. **1**. Transistor **40** is normally conducting to place substantially ground potential upon the anode of diode **36**. Upon each application of a logic 1 crankshaft position pulse to input terminal **37** of staircase generator **30**, connected to the ungrounded end of pickup coil **6** of FIG. **1**, transistor **45** conducts to drain base current from transistor **40** to extinguish this device. Each time transistor **45** is extinguished by each crankshaft position pulse, a positive polarity signal is applied to the inverting input terminal of operational amplifier **34** through diode **36**, to reduce the magnitude of the potential upon the output terminal thereof by increments, as shown in FIG. **1**. That is, the positive polarity potential upon the output terminal of operational amplifier **34** is stepped down by the crankshaft position pulses. The vacuum transducer may be a potentiometer **28** connected across a direct current supply potential source, not shown. The movable contact **38** thereof is operated by engine intake manifold vacuum in a manner well known in the automotive art to produce a potential across the movable contact **38** and ground of a magnitude proportional to engine vacuum. The engine vacuum transducer potential is applied to the junction between the emitter electrode of transistor **50** and emitter resistor **51** and the positive potential upon the output terminal of operational amplifier **34** is applied to the base electrode of transistor **50**. While the output potential of operational amplifier **34** is of a positive magnitude greater than the engine vacuum transducer potential, type NPN transistor **50** and type PNP transistor **55** conduct. While transistor **55** is conductive, a logic 1 engine vacuum advance signal is present upon the output terminal **41** of potential comparator circuit **32**. When the crankshaft position pulses have stepped the output potential of operational amplifier **34** to a magnitude substantially equal to or less than the vacuum transducer potential, transistors **50** and **55** extinguish. With transistor **55** not conducting a logic **0** signal is present upon output terminal **41** of potential comparator circuit **32**.

The trailing edge of the logic 1 second engine speed ignition spark advance signal present upon the output terminal of monostable multivibrator **22** while in the alternate state is differentiated to produce a logic 1 signal by a conventional differentiating circuit, represented in FIG. **1** in block form and referenced by the numeral **24**, each time monostable multivibrator **22** returns to the stable state. The logic 1 second engine speed ignition spark advance signal produced by differentiating circuit **24** is applied to the reset terminal **33** of staircase generator **30**, connected to the output terminal of differentiating circuit **24**.

To provide two engine speed ignition spark advance limits, first and second count limit circuits responsive to the binary representation, upon the output terminals of counter circuit **10**, of a first selected number and a second selected greater number, respectively, of crankshaft position pulses counted by counter circuit **10** for producing, respectively, a first engine speed ignition spark advance limit signal which terminates the first engine speed ignition spark advance signal if counter circuit **10** counts the first selected number of crankshaft position pulses prior to the end thereof and a second engine speed ignition spark advance limit signal which terminates the second engine speed ignition spark advance signal if counter circuit **10** counts the second selected greater number of crankshaft position pulses prior to the end thereof are provided. The output terminals of counter circuit **10** upon which logic 1 signals representing the first selected number of crankshaft position pulses and the second selected greater number of crankshaft position pulses counted by counter circuit **10** are applied to the input terminals of a first count limit AND gate **46** and the input terminals of a second count limit AND gate **47**, respectively, each of which produces a logic 1 count limit signal upon the output terminal thereof when counter circuit **10** has reached the first and second crankshaft position pulse count limits, respectively. The logic 1 first count limit signal produced by first count limit AND gate **46** is applied to the reset terminal of monostable multivibrator circuit **21**, connected to the output terminal of first count limit AND gate **46**, and the logic 1 second count limit signal produced by second count limit AND gate **47** is applied to the reset terminal of monostable multivibrator circuit **22**, connected to the output terminal of second count limit AND gate **47**.

Just prior to each reference pulse, a logic 0 full count signal is present upon output terminal **17** of bi-stable multi-vibrator **14**, and a logic 0 signal is present upon the output terminal of each of monostable multivibrator circuits **21** and **22** and voltage comparator circuit **32**. Consequently, a logic 1 disenabling signal is present upon the output terminal of NOR gate **18** to disenable NOR gate **12**.

Upon the occurrence of a reference pulse, bi-stable multivibrator circuit **14** is triggered to the state in which a logic 1 start count signal is present upon the output terminal **17** thereof, applied to input terminal **18**a of NOR gate **18**, and a logic 0 signal is present upon the output terminals of monostable multivibrator circuits **21** and **22** and potential comparator circuit **32**. The logic 1 start count signal upon input terminal **18***a* of NOR gate **18** produces a logic 0 enabling signal upon the output terminal thereof which is applied to input terminal **12***b* of NOR gate **12** to enable this device to gate crankshaft position pulses to the input terminal of counter circuit **10**, consequently counter circuit **10** counts these pulses.

Upon a count of 60 crankshaft position pulses, AND gate **20** produces a logic 1 ignition signal pulse which resets counter circuit **10**, initiates the operation of the transistor ignition system **85** to extinguish the ignition coil primary winding switching transistor in a manner to be later explained, triggers bi-stable multivibrator **14** to the state in which a logic 0 full count signal is present upon output terminal **17** thereof and triggers monostable multivibrator **21** to the alternate state in which a logic 1 first engine speed ignition spark advance signal is present upon the output terminal thereof which is applied to input terminal **18***b* of NOR gate **18**. The logic 1 first engine speed ignition spark advance signal upon input terminal **18***b* of NOR gate **18** produces a logic 0 enabling signal upon the output terminal thereof which

enables NOR gate 12 to continue to gate crankshaft position pulses to the input terminal of counter circuit 10, consequently, counter circuit 10 counts these pulses.

At the conclusion of the first delay period, unless earlier terminated by first count limit AND gate 46, monostable multivibrator circuit 21 reverts to the stable state in which a logic 0 signal is present upon the output terminal thereof and monostable multivibrator circuit 22 is triggered to the alternate state in which a logic 1 second engine speed ignition spark advance signal is present upon the output terminal thereof which is applied to input terminal 18*b* of NOR gate 18. This logic 1 second engine speed ignition spark advance signal upon input terminal 18*b* of NOR gate produces a logic 0 enabling signal upon the output terminal thereof which enables NOR gate 12 to continue to gate crankshaft position pulses to the input terminal of counter circuit 10, consequently counter circuit 10 counts these pulses.

At the conclusion of the second delay period, unless earlier terminated by second count limit AND gate 47, monostable multivibrator circuit 22 reverts to the stable state in which a logic 0 signal is present upon the output terminal thereof and the trailing edge of the logic 1 signal is differentiated by differentiator circuit 24 to produce a logic 1 signal which is applied to the reset terminal of staircase generator 30. This logic 1 signal resets the output potential of operational amplifier 34 to a high positive magnitude, consequently, potential comparator circuit 32 produces a logic 1 engine vacuum ignition spark advance signal which is applied to input terminal 18*c* of NOR gate 18. This logic 1 engine vacuum ignition spark advance signal upon input terminal 18*c* of NOR gate 18 produces a logic 0 enabling signal upon the output terminal thereof which enables NOR gate 12 to continue to gate crankshaft position pulses to the input terminal of counter circuit 10, consequently, counter circuit 10 counts these pulses.

Each crankshaft position pulse applied to input terminal 37 of staircase generator 30 steps the output potential of operational amplifier 34 lower until it is of a magnitude equal to the output potential of vacuum transducer 31. At this time transistors 50 and 55 extinguish to place a logic 0 signal upon output terminal 41 of potential comparator circuit 32 which is applied to input terminal 18*c* of NOR gate 18, FIG. 1. This logic 0 signal upon input terminal 18*c* of NOR gate 18, along with the logic 0 signals present upon input terminal 18*a* from output terminal 17 of bi-stable multivibrator 14 and upon input terminal 18b from the output terminals of monostable multivibrator circuits 21 and 22 produces a logic 1 disenabling signal upon the output terminal thereof which disenables NOR gate 12, consequently, NOR gate 12 gates no more crankshaft position pulses to the input terminal of counter circuit 10.

From this description, it is apparent that the enabling gate circuit, NOR gate 18, is responsive to the start count signals, the first and second engine speed ignition spark advance signals and the engine vacuum ignition spark advance signals for producing an enabling signal for the ignition spark advance gate circuit, NOR gate 12, and to the full count signals for producing a disenabling signal for the ignition spark advance NOR gate 12 in the absence of the first and second engine speed ignition spark advance signals and the engine vacuum ignition spark advance signals.

The crankshaft position pulses counted by counter circuit 10 during both delay periods and the period of the logic 1 engine vacuum spark advance signal is retained by counter circuit 10 until the next reference pulse and this number of crankshaft position pulses is the number of degrees of ignition spark advance.

For proper operation of a transistor ignition system, it is necessary that the ignition coil primary winding switching transistor be turned "on" for a sufficient dwell time period in advance of the ignition signal to provide for sufficient energization of the ignition coil primary winding to produce the required high energy ignition potential.

Consequently, dwell circuitry responsive to a preselected number of crankshaft position pulses for initiating the operation of the associated transistor ignition system to trigger the ignition coil primary winding switching transistor conductive prior to the ignition signal and to each of the ignition signals for initiating the operation of the associated transistor ignition system to extinguish the ignition coil primary winding switching transistor is provided.

In FIG. 2, an electronic dwell time circuit which anticipates the next ignition signal and initiates the operation of the transistor ignition system 85 to trigger the ignition coil primary winding switching transistor to conduction before the next ignition signal, suitable for use with the electronic ignition spark advance circuit of this invention, is set forth in schematic form. Between each ignition signal at any engine speed, there are ninety degrees of engine crankshaft rotation. Therefore, the crankshaft position pulses are counted by a conventional dwell time counter circuit 60 having an input terminal and a plurality of output terminals, each corresponding to a binary code bit, as explained in regard to counter circuit 10. As dwell time counter circuit 60 may be required to count as many as eighty-eight crankshaft position pulses, it must have seven stages and seven output terminals 60*a*, 60*b*, 600*c*, 60*d*, 60*e* 60*f* and 60*g*. For purposes of this specification, it will be assumed that dwell time counter circuit 60 counts 80 crankshaft position pulses between ignition signals, consequently, output terminals 60*e* and 60*g* thereof, a logic 1 signal on both indicating in binary form the numeral 80, are connected to respective input terminals of AND gate 62. At a crankshaft position pulse count of 80, there are 10° of engine crankshaft rotation remaining before the next ignition signal. To insure that at least the minimum dwell time is obtained before each ignition signal, a predetermined minimum dwell time is provided by a conventional monostable multivibrator 65, for example 2.0 milliseconds.

With monostable multivibrator 65 in the stable state transistor 66 is not conducting, transistor 67 is conducting and transistor 68 is conducting. Upon the application of a logic 1 ignition signal to input terminal 70*b* of NOR gate 70 through input terminal 71(2), connected to the output terminal of the ignition signal AND gate 20 of FIG. 1 through point 71(1), a logic 0 signal is produced upon the output terminal thereof. With a logic 0 signal upon the output terminal of NOR gate 70 and transistor 67 conducting, a logic 0 signal is applied to input terminals 72*a* and 72*b* of NOR gate 72, connected to the output terminals of monostable multivibrator circuit 65 and NOR gate 70, respectively, a condition which produces a logic 1 signal upon the output terminal thereof which triggers transistor 73 conductive. With transistor 73 conducting, base current is drained from transistor 75 of the ignition circuit 85,

FIG. 1, through diode 76 and the collector-emitter electrodes of conducting transistor 73, connected to diode 76 through terminal 74, to extinguish transistor 75. With transistor 75 extinguished, base current is supplied to transistor 77, consequently, transistor 77 conducts through the collector-emitter electrodes. Conducting transistor 77 drains base current from transistor 78 to extinguish transistor 78. With transistor 78 extinguished, base drive current is not supplied through the collector-emitter electrodes thereof to the base electrode of ignition coil primary winding switching transistor 80, consequently, this device extinguishes to interrupt the energizing circuit for ignition coil primary winding 81. The resulting ignition coil primary winding collapsing magnetic field induces a high energy ignition potential in ignition coil secondary winding 82 which is directed to the spark plug of the engine cylinder to be fired through the ignition distributor, not shown, in a manner well known in the automotive art.

The logic 0 signal upon the output terminal of NOR gate 70 is also applied to input terminal 86*a* of NOR gate 86, connected to the output terminal of NOR gate 70, to enable NOR gate 86 to gate crankshaft position pulses, applied to input terminal 86*b* thereof through terminal 39(2) connected to terminal 39(1) of FIG. 1, to the input terminal of dwell time counter circuit 60.

Upon a count of 80 crankshaft position pulses by dwell time counter circuit 60, a logic 1 signal appears upon each of output terminals 60*e* and 60*g* thereof. These logic 1 signals are applied to respective input terminals of AND gate 62 to produce a logic 1 signal upon the output terminal thereof. This logic 1 signal is applied to the reset terminal of dwell time counter circuit 60 and to the input terminal 63 of monostable multivibrator 65, both connected to the output terminal of AND gate 62, to reset dwell time counter circuit 60 to zero and to trigger monostable multivibrator circuit 65 to the alternate state.

With monostable multivibrator circuit 65 in the alternate state, transistors 66 and 68 are conductive and transistor 67 is not conductive. With transistor 67 not conducting, a logic 1 signal is present upon the output terminal 64 of monostable multivibrator 65 which is applied to input terminal 72*a* of NOR gate 72, connected to the output terminal 64 of monostable multivibrator 65, to produce a logic 0 signal upon the output terminal thereof. This logic 0 signal is applied to the base electrode of transistor 73, connected to the output terminal of NOR gate 72, to extinguish transistor 73. With transistor 73 extinguished, a positive potential is present upon output terminal 74 which reverse biases diode 76 of the ignition circuit, FIG. 1. With diode 76 reverse biased, base current is supplied to transistor 75, consequently, transistor 75 conducts through the collector-emitter electrodes. Conducting transistor 75 drains base current from transistor 77 to extinguish this device. With transistor 77 extinguished, base current is supplied to transistor 78, consequently, transistor 78 supplies through the collector-emitter electrodes. Conducting transistor 78 supplied base current to ignition coil primary winding switching transistor 80, consequently, this device conducts through the collector-emitter electrodes to complete the energizing circuit for ignition coil primary winding 81.

At the conclusion of the designed delay period of monostable multivibrator 65, for example 2.0 milliseconds, this device reverts to the stable state with transistor 67 conducting. Upon the conduction of transistor 67 after the delay period, the base electrode of transistor 68 is substantially grounded through capacitor 83 to extinguish transistor 68 until capacitor 83 has become charged. While transistor 68 is extinguished, a logic 1 signal is applied to input terminal 87*a* of NOR gate 87, connected to the collector electrode of transistor 68, to produce a logic 0 signal upon the output terminal thereof. This logic 0 signal is applied to input terminal 70*a* of NOR gate 70, connected to the output terminal of NOR gate 87, and the logic 0 signal present upon the output terminal of the ignition signal AND gate 20, FIG. 1, is applied to input terminal 70*b* of NOR gate 70 through terminals 71(1) of FIG. 1 and 71(2) of FIG. 2 to produce a logic 1 signal upon the output terminal thereof which is applied to input terminal 72*b* of NOR gate 72 and input terminal 86*a* of NOR gate 86. This logic 1 signal maintains a logic 0 signal upon the output terminal of NOR gate 72 and produces a logic 0 signal upon the output terminal of NOR gate 86 to disenable NOR gate 86. Consequently, the ignition coil primary winding switching transistor 80 of FIG. 1 remains conductive and NOR gate 86 gates no more crankshaft position pulses to dwell time counter circuit 60.

Upon the occurrence of the next logic 1 ignition signal ten degrees later, the sequence of events hereinabove described are repeated to extinguish the ignition coil primary winding switching transistor 80 of FIG. 1 to produce a high energy ignition potential to fire the next spark plug and start the next counting sequence to energize the coil to provide sufficient dwell time. This circuit functions to energize the coil 10° in advance of the crankshaft position at which there is a minimum of 2.0 milliseconds before the next ignition signal. Thus this dwell time circuit produces a dwell time of 3.66 milliseconds at an engine speed of 1000 RPM and a dwell time of 2.27 milliseconds at an engine speed of 6000 RPM.

The operation of first and second count limit AND gates 46 and 47 to terminate the respective first and second delay periods early does not alter the operation of the electronic ignition spark advance circuit as hereinabove described. These devices establish the ignition spark advance curve over a range of engine speeds from zero to maximum in a manner now to be explained.

A typical internal combustion ignition spark advance curve is set forth in FIG. 4. For purposes of this specification and without intention or inference of a limitation thereto, it will be assumed that the internal combustion engine with which the electronic ignition spark advance system of this invention is to be used requires an ignition spark advance of 18° at an engine speed of 750 RPM, 36° at engine speeds of 3000 RPM and higher and a first limit of 24° ignition spark advance at an engine speed of 1000 RPM. To produce 18° ignition spark advance at an engine speed of 750 RPM, the total of the first and second delay periods must be 18° divided by 4.5° per millisecond which is 4 milliseconds. The points 18° at 750 RPM, 24° at 1000 RPM and 36° at 3000 RPM are plotted. A straight line is drawn through the 36° and 24° points to the vertical axis and another straight line originating at zero is drawn through the 18° and 24° points. The point at which the first line intersects the vertical axis indicates the first count limit, in this case 18. With a first count limit of

18, to obtain 24° ignition spark advance at an engine speed of 1000 RPM, the first count limit, 6° more advance is required. To count 6° at 1000 RPM requires 6° divided by 6° per millisecond or 1 millisecond. This is the second delay period to be produced by monostable multivibrator circuit 22. Therefore, the first delay period is the total delay of 4 milliseconds minus the first delay period of 1 millisecond or 3 milliseconds. This is the delay period produced by monostable multivibrator circuit 21. The second count limit is 36 as no more ignition spark advance is required at engine speeds of 3000 RPM and higher. Consequently, upon the count of 36 crankshaft position pulses by counter circuit 10, second count limit AND gate 47 terminates the second delay period, a condition which disenables ignition spark advance NOR gate 12. Therefore, at engine speeds of 3000 RPM and higher, counter circuit 10 counts a maximum of 36 crankshaft position pulses which results in a maximum ignition spark advance of 36°.

In the event it is desired that ignition spark advance begin at a selected engine speed greater than zero, a "cut-in" circuit may be employed. A "cut-in" circuit suitable for use with the circuit of this invention is set forth in schematic form in FIG. 5. This circuit operates to disenable ignition spark advance NOR gate 12 during a portion of the delay periods to reduce the number of crankshaft position pulses counted during the delay periods. The collector electrode of transistor 90 is connected to junction 91 of FIG. 1 to place a logic 0 signal upon input terminal 18*b* of NOR gate 18 while conducting during the delay periods. This results in a logic 1 signal upon the output terminal of NOR gate 18 which disenables the ignition spark advance NOR gate 12. Each logic 1 ignition signal produced by AND gate 20, FIG. 1, is applied to input terminal 92 of a conventional bistable multivibrator circuit 95, connected to the output terminal of AND gate 20 through terminals 71(5) of FIG. 5 and 71(1) of FIG. 1, to trigger bi-stable multivibrator 95 to the state in which a logic 1 signal is present upon output terminal 94 thereof. This logic 1 signal is applied to the base electrode of transistor 90, connected to output terminal 94, to trigger transistor 90 conductive. Conducting transistor 90 applies a logic 0 signal to input terminal 18*b* of NOR gate 18 which results in a logic 1 signal upon the output terminal thereof. This logic 1 signal disenables ignition spark advance NOR gate 12, consequently, counter circuit 10 does not count crankshaft position pulses while transistor 90 is conducting. Crankshaft position pulses are counted by conventional "cut-in" counter circuit 96, being applied to the input terminal thereof through terminals 39(5) of FIG. 5 and 39(1) of FIG. 1. When "cut-in" counter circuit 96 has counted the number of crankshaft position pulses which will result in the beginning of ignition spark advance at the selected engine speed greater than zero, AND gate 97 produces a logic 1 output signal which is applied to input terminal 93 of bi-stable multivibrator 95, connected to the output terminal of AND gate 97. This logic 1 signal triggers bistable multivibrator circuit 95 to the condition in which a logic 0 signal is present upon output terminal 94 thereof. This logic 0 signal extinguishes transistor 90. Consequently, counter circuit 10 counts crankshaft position pulses for the remainder of the delay periods.

Although specific logic circuit devices and circuit elements have been set forth in this specification, it is to be specifically understood that alternate logic elements and circuit elements having similar electrical characteristics may be substituted therefor.

While a preferred embodiment of the present invention has been disclosed and described, it will be obvious to those skilled in the art that various modifications and substitutions may be made without departing from the spirit of the invention which is to be limited only within the scope of the appended claims.

What is claimed is:

1. An electronic ignition spark advance system comprising in combination with an internal combustion engine and an associated transistor ignition system having an ignition coil primary winding switching transistor, means for producing a series of crankshaft position pulses, each corresponding to one degree of rotation of the crankshaft of said internal combustion engine, means for producing a reference pulse a selected number of degrees before the top dead center position of each piston of said internal combustion engine, a counter circuit having an input terminal and a plurality of output terminals, each corresponding to a binary code bit for counting said crankshaft position pulses and producing upon said output terminals thereof the binary code representation of the number of said crankshaft position pulses counted thereby, an ignition spark advance gate circuit which, when enabled, gates said series of crankshaft position pulses to said input terminal of said counter circuit, means responsive to the binary code representation, upon said output terminals of said counter circuit, of the number of said crankshaft position pulses counted by said counter circuit equal to said selected number of degrees before the top dead center position of each piston of said internal combustion engine at which each said reference pulse is produced for producing an ignition signal, means responsive to each of said reference pulses for producing a start count signal and to each of said ignition signals for producing a full count signal, first delay circuit means responsive to each of said ignition signals for producing a first engine speed ignition spark advance signal of a preselected duration, second delay circuit means responsive to the end of each of said first engine speed ignition spark advance signals for producing a second engine speed ignition spark advance signal of a predetermined duration, a first count limit circuit means responsive to the binary representation, upon said output terminals of said counter circuit, of a first selected number of crankshaft position pulses counted by said counter circuit for producing a first engine speed ignition spark advance limit signal which terminates said first engine speed ignition spark advance signal if said counter circuit counts said first selected number of crankshaft position pulses prior to the end thereof, a second count limit circuit means responsive to the binary representation, upon said output terminals of said counter circuit, of a second selected greater number of crankshaft position pulses counted by said counter circuit for producing a second engine speed ignition spark advance limit signal which terminates said second engine speed ignition spark advance signal if said counter circuit counts said second selected number of crankshaft position pulses prior to the end thereof, circuit means responsive to the end of said second engine speed ignition spark advance signal for producing an engine vacuum ignition spark advance signal, an enabling gate circuit responsive to said start count

signals, said first and second engine speed ignition spark advance signals and said engine vacuum ignition spark advance signals for producing an enabling signal for said ignition spark advance gate circuit and to said full count signals for producing a disenabling signal for said ignition spark advance gate circuit in the absence of said first and second engine speed and engine vacuum ignition spark advance signals, and dwell circuit means responsive to a preselected number of said crankshaft position pulses for initiating the operation of said transistor ignition system to trigger said ignition coil primary winding switching transistor conductive and to each of said ignition signals for initiating the operation of said transistor ignition system to extinguish said ignition coil primary winding switching transistor.

2. An electronic ignition spark advance system comprising in combination with an internal combustion engine and an associated transistor ignition system having an ignition coil primary winding switching transistor, means for producing a series of crankshaft position pulses, each corresponding to one degree of rotation of the crankshaft of said internal combustion engine, means for producing a reference pulse a selected number of degrees before the top dead center position of each piston of said internal combustion engine, a counter circuit having an input terminal and a plurality of output terminals, each corresponding to a binary code bit for counting said crankshaft position pulses and producing upon said output terminals thereof the binary code representation of the number of said crankshaft position pulses counted thereby, an ignition spark advance NOR gate which, when enabled, gates said series of crankshaft position pulses to said input terminal of said counter circuit, an ignition signal AND gate responsive to the binary code representation, upon said output terminals of said counter circuit, of the number of said crankshaft position pulses counted by said counter circuit equal to said selected number of degrees before the top dead center position of each piston of said internal combustion engine at which each said reference pulse is produced for producing an ignition signal, means responsive to each of said reference pulses for producing a start count signal and to each of said ignition signals for producing a full count signal, first delay circuit means responsive to each of said ignition signals for producing a first engine speed ignition spark advance signal of a preselected duration, second delay circuit means responsive to the end of each of said first engine speed ignition spark advance signals for producing a second engine speed ignition spark advance signal of a predetermined duration, a first count limit circuit means responsive to the binary representation, upon said output terminals of said counter circuit, of a first selected number of crankshaft position pulses counted by said counter circuit for producing a first engine speed ignition spark advance limit signal which terminates said first engine speed ignition spark advance signal if said counter circuit counts said first selected number of crankshaft position pulses prior to the end thereof, a second count limit circuit means responsive to the binary representation, upon said output terminals of said counter circuit, of a second selected greater number of crankshaft position pulses counted by said counter circuit for producing a second engine speed ignition spark advance limit signal which terminates said second engine speed ignition spark advance signal if said counter circuit counts said second selected number of crankshaft position pulses prior to the end thereof, circuit means responsive to the end of said second engine speed ignition spark advance signal for producing an engine vacuum ignition spark advance signal, an enabling NOR gate responsive to said start count signals, said first and second engine speed ignition spark advance signals and said engine vacuum ignition spark advance signals for producing an enabling signal for said ignition spark advance gate circuit and to said full count signals for producing a disenabling signal for said ignition spark advance gate circuit in the absence of said first and second engine speed and engine vacuum ignition spark advance signals, and dwell circuit means responsive to a preselected number of said crankshaft position pulses for initiating the operation of said transistor ignition system to trigger said ignition coil primary winding switching transistor conductive and to each of said ignition signals for initiating the operation of said transistor ignition system to extinguish said ignition coil primary winding switching transistor.

3. An electronic ignition spark advance system comprising in combination with an internal combustion engine and an associated transistor ignition system having an ignition coil primary winding switching transistor, means for producing a series of crankshaft position pulses, each corresponding to 1° of rotation of the crankshaft of said internal combustion engine, means for producing a reference pulse a selected number of degrees before the top dead center position of each piston of said internal combustion engine, a counter circuit having an input terminal and a plurality of output terminals, each corresponding to a binary code bit for counting said crankshaft position pulses and producing upon said output terminals thereof the binary code representation of the number of said crankshaft position pulses counted thereby, an ignition spark advance NOR gate which, when enabled, gates said series of crankshaft position pulses to said input terminal of said counter circuit, an ignition signal AND gate responsive to the binary code representation, upon said output terminals of said counter circuit, of the number of said crankshaft position pulses counted by said counter circuit equal to said selected number of degrees before the top dead center position of each piston of said internal combustion engine at which each said reference pulse is produced for producing an ignition signal, a bistable multivibrator circuit responsive to each of said reference pulses for producing a start count signal and to each of said ignition signals for producing a full count signal, a first monostable multivibrator circuit responsive to each of said ignition signals for producing a first engine speed ignition spark advance signal of a preselected duration, a second monostable multivibrator circuit responsive to the end of each of said first engine speed ignition spark advance signals for producing a second engine speed ignition spark advance signal of a predetermined duration, a first count limit AND gate responsive to the binary representation, upon said output terminals of said counter circuit, of a first selected number of crankshaft position pulses counted by said counter circuit for producing a first engine speed ignition spark advance limit signal which terminates said first engine speed ignition spark advance signal if said counter circuit counts said first selected number of crankshaft position pulses prior to the end thereof, a second count limit AND gate responsive to the binary

representation, upon said output terminals of said counter circuit, of a second selected greater number of crankshaft position pulses counted b said counter circuit for producing a second engine speed ignition spark advance limit signal which terminates said second engine speed ignition spark advance signal if said counter circuit counts said second selected number of crankshaft position pulses prior to the end thereof, circuit means responsive to the end of said second engine speed ignition spark advance signal for producing an engine vacuum ignition spark advance signal, an enabling NOR gate responsive to said start count signals, said first and second engine speed ignition spark advance signals and said engine vacuum ignition spark advance signals for producing an enabling signal for said ignition spark advance gate circuit and to said full count signals for producing a disenabling signal for said ignition spark advance gate circuit in the absence of said first and second engine speed and engine vacuum ignition spark advance signals, and dwell circuit means responsive to a preselected number of said crankshaft position pulses for initiating the operation of said transistor ignition system to trigger said ignition coil primary winding switching transistor conductive and to each of said ignition signals for initiating the operation of said transistor ignition system to extinguish said ignition coil primary winding switching transistor.

4. An electronic ignition spark advance system comprising in combination with an internal combustion engine and an associated transistor ignition system having an ignition coil primary winding switching transistor, a crankshaft position sensor for producing a series of crankshaft position pulses, each corresponding to 1° of rotation of the crankshaft of said internal combustion engine, a reference pulse generator for producing a reference pulse a selected number of degrees before the top dead center position of each piston of said internal combustion engine, a counter circuit having an input terminal and a plurality of output terminals, each corresponding to a binary code bit, for counting said crankshaft position pulses and producing upon said output terminals thereof the binary code representation of the number of said crankshaft position pulses counted thereby, an ignition spark advance NOR gate having input terminals and an output terminal for gating said series of crankshaft position pulses to said input terminal of said counter circuit, an ignition signal AND gate having input terminals and an output terminal for producing an ignition signal, means for connecting said output terminals of said counter circuit upon which appear the binary code representation of the number of said crankshaft position pulses counted by said counter circuit equal to said selected number of degrees before the top dead center position of each piston of said internal combustion engine at which each said reference pulse is produced to respective input terminals of said ignition signal AND gate, a bi-stable multivibrator circuit having two input terminals and an output terminal for producing a start count signal in response to said reference signals and a full count signal in response to said ignition signals, means for applying said reference signals and said ignition signals to respective input terminals of said bi-stable multivibrator circuit, a first monostable multivibrator circuit having an input, an output and a reset terminal responsive to each of said ignition signals for producing a first engine speed ignition spark advance signal of a preselected duration, means for applying said ignition signals to said input terminal of said first monostable multivibrator circuit, a second monostable multivibrator circuit having an input, an output and a reset terminal responsive to the end of each of said first engine speed ignition spark advance signals for producing a second engine speed ignition spark advance signal of a predetermined duration, means for differentiating the trailing edge of each of said first engine speed ignition spark advance signals, means for applying said differentiated trailing edge of each said first engine speed ignition spark advance signals to said input terminal of said second monostable multivibrator circuit, a first count limit AND gate having input terminals and an output terminal for producing a first engine speed ignition spark advance limit signal, means for connecting said output terminals of said counter circuit upon which appear the binary representation of a first selected number of crankshaft position pulses counter by said counter circuit to respective said input terminals of said first count limit AND gate, means for applying said first engine speed ignition spark advance limit signal to said reset terminal of said first monostable multivibrator circuit, a second count limit AND gate having input terminals and an output terminal for producing a second engine speed ignition spark advance limit signal, means for connecting said output terminals of said counter circuit upon which appear the binary representation of a second selected greater number of crankshaft position pulses counted by said counter circuit to respective said input terminals of said second count limit AND gate, means for applying said second engine speed ignition spark advance limit signal to said reset terminal of said second monostable multivibrator circuit, means for differentiating the trailing edge of said second engine speed ignition spark advance signals, engine vacuum sensitive circuit means having an input and an output terminal for producing an engine vacuum ignition spark advance signal, means for applying said differentiated trailing edge of said second engine speed ignition spark advance limit signal to said input terminal of said engine vacuum sensitive circuit means, an enabling NOR gate having input terminals and an output terminal for producing an enabling signal for said ignition spark advance NOR gate, means for applying both said start count and said full count signals, both said first and second engine speed ignition spark advance signals and said engine vacuum ignition spark advance signal to respective input terminals of said enabling NOR gate, means for applying said crankshaft position pulses and said enabling signal to respective input terminals of said ignition spark advance NOR gate, dwell circuit having two input circuit means responsive to a preselected number of said crankshaft position pulses for initiating the operation of said transistor ignition system to trigger said ignition coil primary winding conductive and to each of said ignition signals for initiating the operation of said transistor ignition system to extinguish said ignition coil primary winding switching transistor, and means for applying said crankshaft position pulses and said ignition signals to respective said input terminals of said dwell circuit means.

5. An electronic ignition spark advance system comprising in combination with an internal combustion engine and an associated transistor ignition system having an ignition coil primary winding switching transistor, a crankshaft position sensor having output circuit means

for producing a series of crankshaft position pulses, each corresponding to 1° of rotation of the crankshaft of said internal combustion engine, a reference pulse generator having output circuit means for producing a reference pulse a selected number of degrees before the top dead center position of each piston of said internal combustion engine, a counter circuit having an input terminal, a plurality of output terminals, each corresponding to a binary code bit, and a reset terminal for counting said crankshaft position pulses and producing upon said output terminals thereof the binary code representation of the number of said crankshaft position pulses counted thereby, an ignition spark advance NOR gate having input terminals and an output terminal for gating said series of crankshaft position pulses to said input terminal of said counter circuit, an ignition signal AND gate having input terminals and an output terminal for producing an ignition signal, means for connecting the said output terminals of said counter circuit upon which appear the binary code representation of the number of said crankshaft position pulses counted by said counter circuit equal to said selected number of degrees before the top dead center position of each piston of said internal combustion engine at which each said reference pulse is produced to respective input terminals of said ignition signal AND gate, a bi-stable multivibrator circuit having two input terminals and an output terminal, for producing a start count signal in response to said reference signals and a full count signal in response to said ignition signals, means for connecting said output circuit means of said reference pulse generator to one of said input terminals of said bi-stable multivibrator circuit, means for connecting said output terminal of said ignition signal AND gate to the other said input terminal of said bi-stable multivibrator circuit and to said reset terminal of said counter circuit, a first monostable multivibrator circuit having an input, an output and a reset terminal responsive to each of said ignition signals for producing a first engine speed ignition spark advance signal of a preselected duration, means for connecting said output terminal of said ignition signal AND gate to said input terminal of said first monostable multivibrator circuit, a second monostable multivibrator circuit having an input, an output and a reset terminal responsive to the end of each of said first engine speed ignition spark advance signals for producing a second engine speed ignition spark advance signal of a predetermined duration, means including a differentiator circuit for connecting said output terminal of said first monostable multivibrator circuit to said input terminal of said second monostable multivibrator circuit, a first count limit AND gate having input terminals and an output terminal for producing a first engine speed ignition spark advance limit signal, means for connecting said output terminals of said counter circuit upon which appear the binary representation of a first selected number of crankshaft position pulses counted by said counter circuit to respective said input terminals of said first count limit AND gate, means for connecting said output terminal of said first count limit AND gate to said reset terminal of said first monostable multivibrator circuit, a second count limit AND gate having input terminals and an output terminal for producing a second engine speed ignition spark advance limit signal, means for connecting said output terminals of said counter circuit upon which appear the binary representation of a second selected greater number of crankshaft position pulses counted by said counter circuit to respective said input terminals of said second count limit AND gate, means for connecting said output terminal of said second count limit AND gate to said reset terminal of said second monostable multivibrator circuit, engine vacuum sensitive circuit means having an input and an output terminal for producing an engine vacuum ignition spark advance signal, means including a differentiator circuit for connecting said output terminal of said second monostable multivibrator circuit to said input terminal of said engine vacuum sensitive circuit means, an enabling NOR gate, having input terminals and an output terminal for producing an enabling signal for said ignition spark advance NOR gate, means for connecting said output terminal of said bi-stable multivibrator circuit, said output terminals of both said first and second multivibrator circuits and said output terminal of said engine vacuum sensitive circuitry to respective said input terminals of said enabling NOR gate, means for connecting said output circuit means of said crankshaft position sensor and said output terminal of said enabling NOR gate to respective input terminals of said ignition spark advance NOR gate, and dwell circuit having two input circuit means responsive to a preselected number of said crankshaft position pulses applied to one said input circuit means for initiating the operation of said transistor ignition system to trigger said ignition coil primary winding switching transistor conductive and to each of said ignition signals applied to the other one of said input circuit means for initiating the operation of said transistor ignition system to extinguish said ignition coil primary winding switching transistor.

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