

- [54] ELECTRONIC IGNITION TIMING SYSTEM  
FOR INTERNAL COMBUSTION ENGINES

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- [73] Assignee: **GTE Sylvania Incorporated, Seneca Falls, N.Y.**

- [22] Filed: Nov. 23, 1971

- [21] Appl. No.: 201,362

- |           |         |                  |           |
|-----------|---------|------------------|-----------|
| 3,572,301 | 3/1971  | Kalippke.....    | 123/117 A |
| 3,418,989 | 12/1968 | Silverman.....   | 123/148 E |
| 3,592,178 | 7/1971  | Schiff.....      | 123/148 E |
| 3,202,146 | 8/1965  | Short.....       | 123/148 E |
| 3,621,826 | 11/1971 | Chrestensen..... | 123/148 E |
| 3,660,689 | 5/1972  | Oishi et al..... | 123/148 E |

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- [52] U.S. Cl. .... 123/148 E, 123/146.5 A, 123/117 R  
[51] Int. Cl. .... F02p 1/00  
[58] Field of Search ..... 123/148 E, 117 A,  
123/146.5 A, 117 R, 148, 117

- [56]
- References Cited**

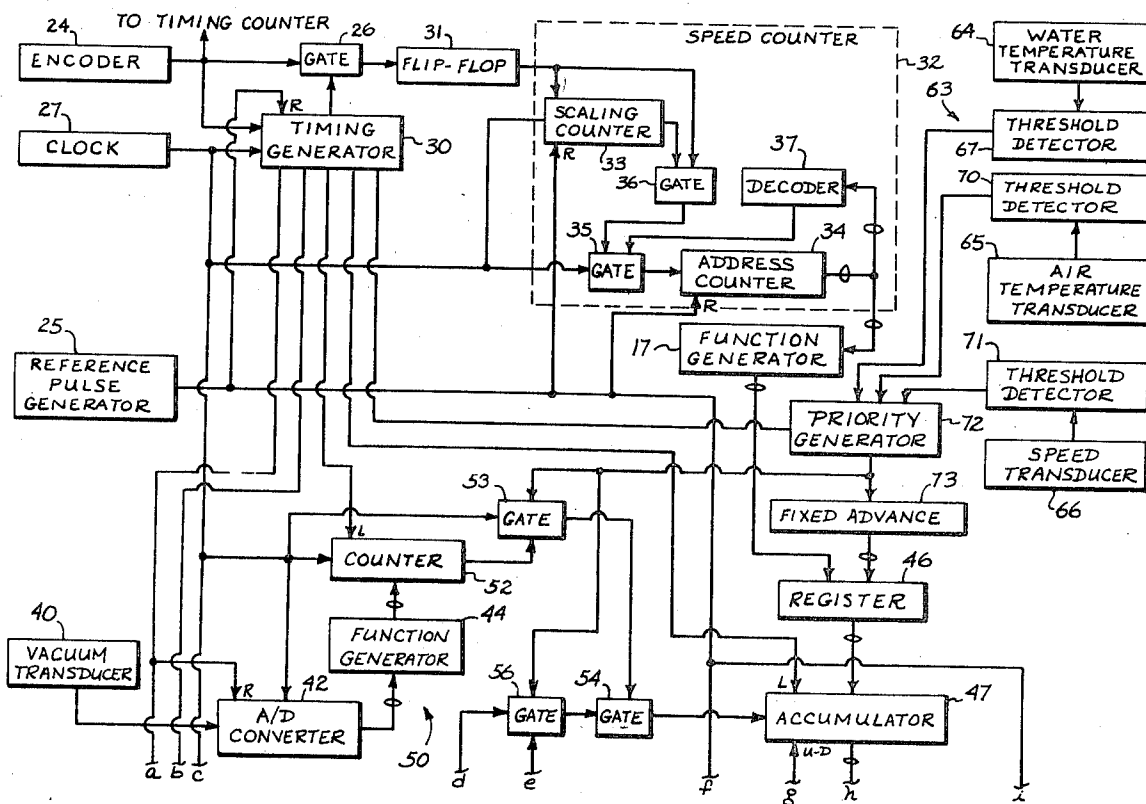
## UNITED STATES PATENTS

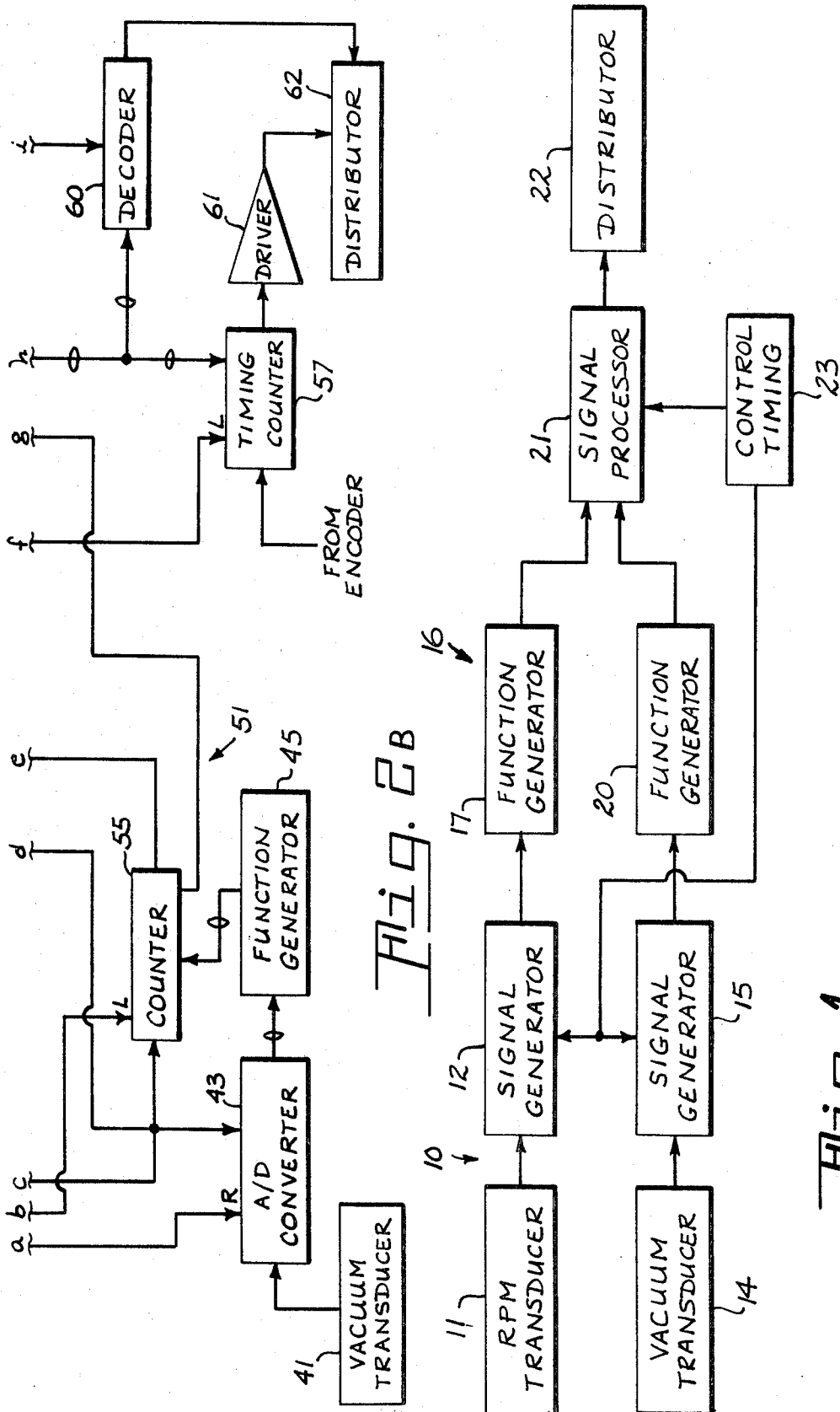
- |           |        |                |           |
|-----------|--------|----------------|-----------|
| 3,454,871 | 7/1969 | Nolting.....   | 123/148 E |
| 3,314,407 | 4/1967 | Schneider..... | 123/148 E |

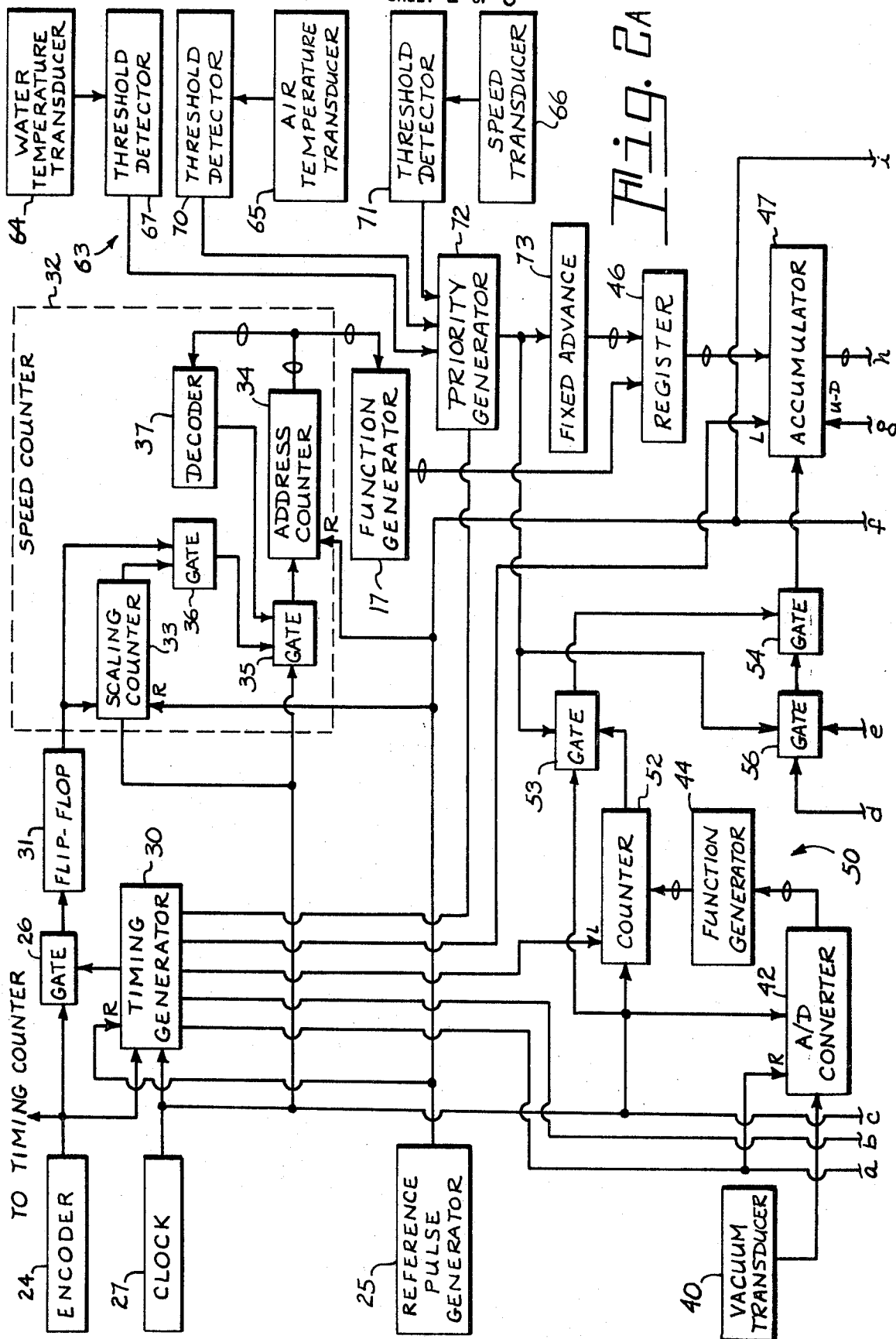
- [57] ABSTRACT

An electronic ignition timing system for internal combustion engines is disclosed which utilizes electronic circuitry to vary the timing of ignition pulses in response to engine speed and vacuum to provide optimum or improved performance by the engine. Preferably the electrical circuitry utilizes digital signals for high accuracy.

**18 Claims, 5 Drawing Figures**







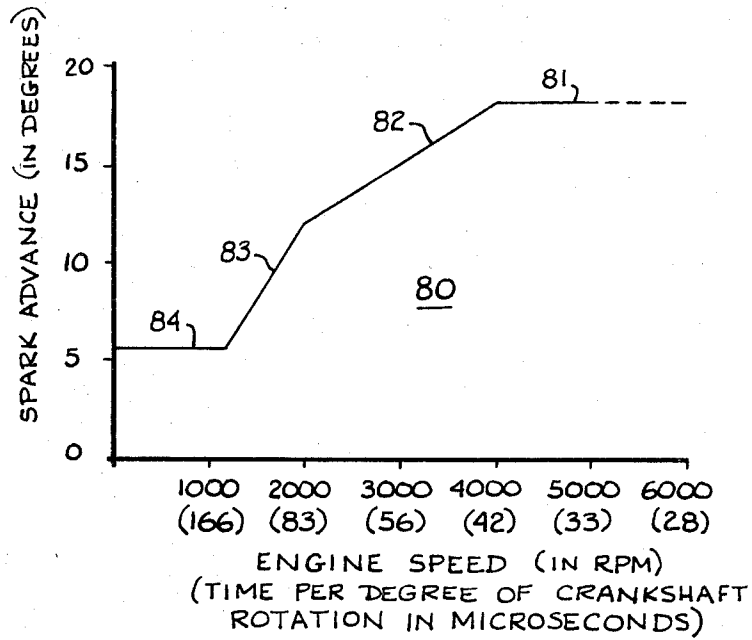


Fig. 3

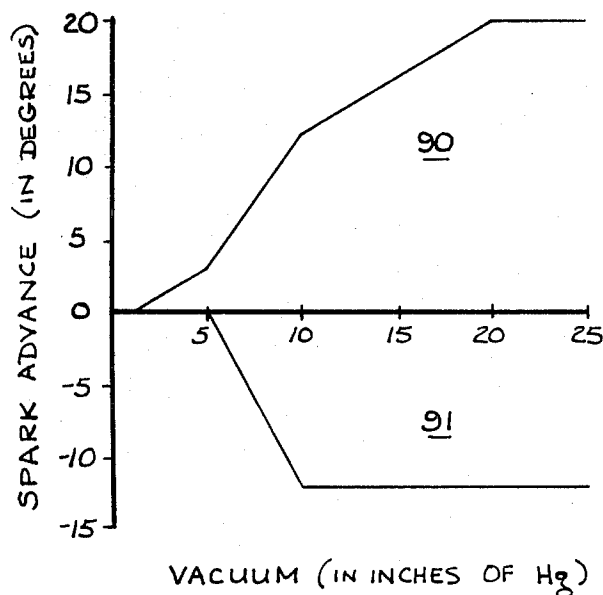


Fig. 4

# ELECTRONIC IGNITION TIMING SYSTEM FOR INTERNAL COMBUSTION ENGINES

## CROSS-REFERENCE TO RELATED APPLICATION

The copending application of Robert W. Asplund, Ser. No. 201,363, filed Nov. 23, 1971, entitled "Electronic Ignition Timing System for Internal Combustion Engines," and assigned to the same assignee as this application, discloses a system related to the system disclosed herein.

## BACKGROUND OF THE INVENTION

This invention relates to ignition timing for internal combustion engines and more specifically to the timing of ignition pulses in response to engine characteristics for providing improved performance by such engines.

Prior art ignition timing systems for internal combustion engines generally utilize mechanical devices to control spark advance. Such systems may utilize engine speed (rpm) and vacuum inputs to mechanically vary the spark advance. Such mechanical devices, however, suffer from several serious limitations. First, the mechanical complexity required to generate optimum transfer functions dictates the use of only simple transfer functions thereby providing less than satisfactory results. Second, accurate generation of even simple transfer functions with mechanical devices is difficult and expensive. Third, repeatability or accuracy within acceptable limits from device to device is difficult and expensive to achieve and in high volume production becomes virtually impossible to achieve. Fourth, mechanical wear and maladjustment limit the usefulness of such devices. These and other disadvantages of mechanical devices present problems which are exceedingly difficult, if not impossible, to overcome.

Attempts to provide electronic ignition timing systems have generally suffered from many of the same disadvantages, particularly inaccuracy, undue expense to achieve sufficient complexity of transfer functions, difficulty of adjustments and tuning, and other disadvantages.

With regard to exhaust emissions, various solutions for reducing such emissions have been proposed. Such solutions include various control devices such as catalytic burners, control valves, fuel injection, etc. These various devices or systems all suffer from numerous disadvantages. In general, they may be unduly expensive, require substantial maintenance or periodic replacement, and decrease performance and horsepower of the engine among other disadvantages, while providing less than satisfactory emission control.

The various prior art devices accordingly do not provide optimum engine performance under varying conditions. They are inaccurate, do not provide long term stability, decrease the reliability of the engine, provide poor engine response, decrease the economy of the engine, waste power, increase maintenance costs, and provide poor control of exhaust emissions among numerous other disadvantages.

## OBJECTS AND SUMMARY OF THE INVENTION

Accordingly, it is a primary object of this invention to provide an ignition timing system which obviates the above-noted and other disadvantages of the prior art.

It is a further object of this invention to provide an electronic ignition timing system that exhibits numerous advantages over the prior art.

It is a further object of this invention to provide an electronic ignition timing system which is highly accurate and stable over long periods of time to improve the performance and reliability of internal combustion engines.

It is a further object of this invention to provide an electronic ignition timing system for reducing engine emission in internal combustion engines while enhancing the reliability and performance of such engines.

It is a further object of this invention to provide an electronic ignition timing system which varies the timing of ignition pulses in response to at least two characteristics related to the amount of emissions by and the performance of an internal combustion engine.

It is a yet further object of this invention to provide an electronic ignition timing system which is highly accurate and reliable but relatively inexpensive while providing sufficient complexity of timing ignition pulses to significantly reduce engine emissions.

It is a still further object of this invention to provide an electronic ignition timing system which utilizes digital signals and pulse signals for increased accuracy.

It is a still further object of this invention to provide an electronic ignition timing system which varies the timing of ignition pulses in response to the speed and vacuum of an internal combustion engine.

In one aspect of this invention these and other objects are achieved in a system for controlling the timing of ignition pulses in an internal combustion engine in response to at least two characteristics of the engine. The system includes first and second signal generating means for generating first and second electrical signals representative respectively of first and second characteristics of the engine and signal processing means including function generating means for relating the first and second characteristics of the engine to the ignition timing of the engine. The signal processing means is connected to the first and second signal generating means for providing pulses at times responsive to the first and second electrical signals and the relationship of the first and second characteristics of the engine to the ignition timing of the engine.

In another aspect of this invention signal processing means processes first and second digital signals provided by the first and second signal generating means to provide digital timing value signals. Pulse generating means connected to the signal processing means provides pulses at times corresponding to the digital timing value signals.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating one embodiment of the invention;

FIGS. 2A and 2B are a more detailed block diagram of the preferred embodiment of the invention; and

FIGS. 3 and 4 are graphs of typical transfer functions to aid in explaining the invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

For a better understanding of the present invention, together with other and further objects, advantages, and capabilities thereof, reference is made to the following disclosure and appended claims in connection with the above-described drawings.

The basic system block diagram of a system for controlling the ignition timing of an internal combustion

engine is illustrated in FIG. 1. In the system ignition timing is controlled by controlling the timing of ignition pulses in response to at least two characteristics of the engine which are preferably related to the performance of the engine and/or the amount of emissions. A signal generating means 10, including a transducer means 11 and a signal generator 12 connected thereto, generates electrical signals representative of a first characteristic of the engine. Preferably transducer means 11 is an rpm transducer which provides signals indicative of crankshaft rotation and hence indicative of the speed or rpm of the engine while signal generator 12 converts the signals from transducer 11 to digital signals. A signal generating means 13, including a transducer means 14 and a signal generator 15 connected thereto, generates electrical signals representative of a second characteristic of the engine. Preferably transducer means 14 is a vacuum transducer which provides signals representative of manifold vacuum and/or port vacuum while signal generator 15 converts the signals from transducer 14 to digital signals.

The output signals from signal generators 12 and 15 are coupled to a signal processing means which includes a function generating means 16 which relates the first and second characteristics, that is, the speed and vacuum of the engine, to ignition timing. Preferably the relationships are determined by the desired engine performance and reduced emissions by the engine. Preferably function generating means 16 includes a function generator 17 connected to the output of signal generator 12 and a function generator 20 connected to the output of signal generator 15. The outputs of function generators 17 and 20 are connected to a signal processor 21 also included in the signal processing means which processes the signals applied thereto to provide output pulses at times responsive to the first and second electrical signals and the relationship of the speed and vacuum of the engine to the ignition timing. These output pulses are applied to a distributor 22 which directs the ignition timing pulses or firing pulses to the proper cylinders. A control timing block 23 is also connected to signal generators 12 and 15 and to signal processor 21 so that the various circuit operations are performed in the proper sequence and at the proper times.

FIG. 2 is a detailed block diagram of the preferred embodiment of the invention broken into FIGS. 2A and 2B connected by lines a-i. The rpm transducer 11 includes an encoder 24 and a reference pulse generator 25. An output of encoder 24 is connected to a first input of a gate 26 which corresponds to the input of signal generator 12. Control timing 23 includes a system clock 27 and a timing generator 30 connected to an output of clock 27. An output of reference pulse generator 25 is connected to a reset input of timing generator 30 which has an output connected to a second input of gate 26. An output of gate 26 is connected to an input of a flip-flop 31 which has an output connected to a counter means or speed (rpm) counter 32.

Speed counter 32 includes a scaling counter 33 and an address counter 34. The output of reference pulse generator 25 is connected to reset inputs of counters 33 and 34 while the output of clock 27 couples clock pulses to counter 33 and to counter 34 via a gate 35. The output of flip-flop 31 is coupled to an enable input of counter 33 and to a first input of a gate 36 which has an output coupled to an input of gate 35. An output of

counter 33 is coupled to an input of gate 36. An output of address counter 34 comprises the output of signal generator 12 which is coupled to the input of function generator 17. The output of counter 34 is also coupled to an input of a decoder 37 which has an output coupled to an input of gate 35.

Vacuum transducer 14 includes first and second vacuum transducers 40 and 41 which sense, for example, manifold and port vacuum, respectively. The outputs of transducers 40 and 41 are connected to inputs of converter means illustrated as analog-to-digital (A/D) converters 42 and 43, respectively. The output of clock 27 is connected to inputs of each of A/D converters 42 and 43, while an output of timing generator 30 is connected to reset inputs of A/D converters 42 and 43. The digital output signals of A/D converters 42 and 43 are coupled to function generator 20 which is illustrated as two function generators 44 and 45. The outputs of function generators 17, 44, and 45 are connected to signal processor 21.

In the preferred embodiment signal processor 21 includes a register 46 connected to an output of function generator 17. An output of register 46, which can be considered the output register of function generator 17, is connected to an input of an accumulating means illustrated as an accumulator 47. Accumulator 47 also receives a load input signal from timing generator 30.

The outputs of function generators 44 and 45 are connected to pulse train generators 50 and 51, respectively. Function generators 44 and 45 can include output registers similar to register 46, if desired. Pulse train generator 50 includes a counter 52 which has an input connected to the output of function generator 44, an input connected to the output of clock 27, and a load input connected to an output of timing generator 30. An output of counter 52 is connected to a first input of a gate 53 which has a second input connected to the output of clock 27 and an output connected to a first input of a gate 54. Pulse train generator 51 includes a counter 55 which has input connected to the output of function generator 45, an input connected to the output of clock 27, and a load input connected to an output of timing generator 30. An output of counter 55 is connected to a first input of a gate 56 which has a second input connected to the output of clock 27 and an output connected to a second input of gate 54. An output of gate 54 is connected to an input of accumulator 47. An output of counter 55 is connected to an up-down count input of accumulator 47.

An output of accumulator 47 is connected to a pulse generating means illustrated as a timing counter 57 and to a decoder 60. Timing counter 57 also receives inputs from encoder 24 and reference pulse generator 25 while decoder 60 receives an enable input from reference pulse generator 25. The output of timing counter 57 is coupled via a driver 61 to a distributor 62 which also receives an input from decoder 60.

Default or priority circuitry 63 includes a water temperature transducer 64, an air temperature transducer 65, and a speed transducer 66. Each transducer has an output connected to an input of a respective one of threshold detectors 67, 70, and 71. Each of threshold detectors 67, 70, and 71 has an output connected to a priority generator 72 which also receives an input from timing generator 30. An output from priority generator 72 is connected to inputs of gates 53 and 56 and to a signal generator 73 for generating a signal correspond-

ing to a fixed spark advance. Signal generator 73 has an output connected to register 46.

To understand the operation of the preferred embodiment of FIG. 2, reference will also be made to FIGS. 3 and 4 which illustrate transfer functions that can be utilized with a typical internal combustion engine of the type commonly used in automobiles. Those skilled in the art will realize, however, that the utility of this invention is not so limited.

At the start of a computation cycle reference pulse generator 25 provides a reference pulse which resets timing generator 30 and speed counter 32, for example, by resetting scaling counter 33 and address counter 34. The reference pulses are provided at periodic intervals of crankshaft rotation, for example, every 90° of rotation. Encoder 24 provides a pulse train indicating degrees of crankshaft rotation. For example, encoder 34 can be a shaft angle encoder of conventional design which provides one output pulse for each degree of crankshaft rotation. Other encoding techniques can also be used, for example, a transducer such as a tachometer and an A/D converter, and intervals other than 1° can also be used. The 1° pulses from encoder 24 are applied to gate 26 and timing generator 30. Timing generator 30 can be a counter such as a ring counter or shift register which is advanced by the 1° pulses and/or clock pulses to sequentially time the various computational operations.

An output signal from timing generator 30 enables gate 26 to couple two successive 1° pulses through gate 26. The first 1° pulse sets flip-flop 31 to provide an enable signal to scaling counter 33 and gate 36. Scaling counter 33 is a down counter which provides an output signal to gate 36 when it reaches zero. This output signal enables gate 36 which in turn enables gate 35 to couple clock pulses to address counter 34 which are counted until the second 1° pulse from gate 26 resets flip-flop 31 to inhibit gate 36 and hence gate 35. The output from address counter 34 is coupled in parallel to function generator 17 which is preferably a read-only memory (ROM) programmed in accordance with the transfer function of FIG. 3 which relates the speed of the engine as measured by crankshaft rotation to degrees of spark advance of ignition timing. ROM 17 can be programmed, for example to contain a point-by-point plot of curve 80 to FIG. 3. Curve 80 is a piecewise linear approximation of an experimentally derived curve which is based on a desired or optimum engine performance considering such factors as exhaust emissions, power, engine response; fuel economy, etc. Curve 80 will vary depending upon the characteristics of the particular engine and the desired degree of accuracy. The number of linear segments can be increased or decreased or the actual curve can be used to provide the desired accuracy. Accordingly, those skilled in the art will realize that the invention is not limited to the particular curve or the particular numerical values used in FIG. 3.

To understand the purpose of scaling counter 33 and decoder 37 note that for engine speeds above 4000 rpm the linear segment 81 of curve 80 has zero slope, that is, the degrees of spark advance for engine speeds above 4000 rpm is constant. Assuming a 1 MHz clock frequency, a maximum of 41 clock pulses will occur if the engine speed is above 4000 rpm. Thus, when scaling counter 33 is reset, it is set to a count of 41 and counts down to zero. If the engine speed is above 4000

rpm, scaling counter 33 will not reach zero and gates 36 and 35 will inhibit counting by address counter 34. Thus, address counter 34 will remain in its initial position to provide an output signal corresponding to an engine speed above 4000 rpm. This circuitry thus conserves memory space in ROM 17 since only one memory location is required for speeds above 4000 rpm.

If the engine speed is between approximately 1200 and 4000 rpm, the degrees of spark advance is continuously changing with speed as is illustrated by segments 82 and 83 of curve 80. Thus, when counter 33 reaches zero, gates 36 and 35 are enabled to couple clock pulses to address counter 34. If the second 1° pulse occurs while address counter 34 is counting, flip-flop 13 is reset to inhibit gate 36 thereby inhibiting gate 35 and preventing further counting by counter 34.

If the engine speed is less than about 1200 rpm, segment 84 of transfer curve 80 is reached. Since this segment also has zero slope, address counter 34 is stopped so that the count therein remains fixed and only one location of ROM 17 is necessary for speeds below 1200 rpm. The output signal from counter 34 is coupled in parallel to decoder 37 which detects when counter 34 reaches a count corresponding to 1200 rpm (a count of approximately 139) and provides an output signal to inhibit gate 35.

In any event, ROM 17 provides a digital output signal representative of the degrees of spark advance corresponding to the final count in counter 34. This output signal is coupled in parallel to register 46 which retains the signal for further use. A load signal from timing generator 30 causes accumulator 47 to load the digital signal from register 46 in parallel. Accumulator 47 can be an up-down counter which is preset by the signal from register 46. Alternatively, the output signal from ROM 17 can be loaded directly into accumulator 47. Accumulator 47 retains the digital signal for further additions thereto or subtractions therefrom.

Vacuum transducers 40 and 41 provide analog output signals proportional to the manifold and port vacuum, respectively, of the engine. These signals are applied to A/D converters 42 and 43, respectively. Timing generator 30 resets or starts converters 42 and 43 which then convert the vacuum signals to digital signals which are applied in parallel to function generators 44 and 45, respectively. Function generators 44 and 45 are preferably ROMs similar to ROM 17 but which translate the digital signals applied thereto in accordance with the transfer functions of FIG. 4 which relate the vacuum of the engine to degrees of spark advance of ignition timing.

In FIG. 4 curve 90 is the transfer function that relates the manifold vacuum to the desired degrees of spark advance, while curve 91 is the transfer function that relates the port vacuum to the desired degrees of spark advance. These curves are also piece-wise linear approximations to experimentally derived curves based on considerations and factors similar to those on which the curve of FIG. 3 is based. These curves will also vary depending upon the particular engine and the desired accuracy. In the embodiment of FIG. 2, the port vacuum signal indicates idle and deceleration conditions during which it is desired to modify the ignition timing. This information can also be derived from the manifold vacuum signal and/or the speed signal, if desired. Thus, by appropriate modifications the port vacuum transducer 41 and the circuitry connected thereto for pro-

cessing the port vacuum signal can be deleted, if desired. Those skilled in the art will also realize that the invention is not limited to the particular curves or numerical values used in FIG. 4.

Pulse train generators 50 and 51 convert the digital output signals from ROMs 44 and 45 to pulse trains which are counted by accumulator 47. A signal from timing generator 30 causes counter 52 to load the digital signal provided by ROM 44 in parallel. Clock pulses are counted down by counter 52 which provides an output signal to enable gate 53. Clock pulses are coupled through gates 53 and 54 to accumulator 47 and are counted thereby. When counter 52 reaches zero, the output signal therefrom inhibits gate 53 to prevent further clock pulses from reaching accumulator 47.

Next, a signal from timing generator 30 causes counter 55 to load the digital signal from ROM 45 in parallel. Counter 55 similarly counts clock pulses and enables gate 56 to couple clock pulses therethrough which are further coupled through gate 54 to accumulator 47. Since curve 91 represents negative spark advance, that is, spark retard, counter 55 also provides a control signal to accumulator 47 to cause accumulator 47 to count down (less spark advance). When counter 55 reaches zero, gate 56 is inhibited.

The final signal accumulated in accumulator 47 is a digital timing value which represents degrees of spark advance or retard from the reference pulses provided by generator 25. To convert this value to an ignition timing pulse, the next successive reference pulse from reference pulse generator 25 causes timing counter 57 to load the digital value from accumulator 47 in parallel. Timing counter 57 counts 1° pulses from encoder 24 until it counts down to zero whereupon an output pulse is provided at a time representing a number of degrees of crankshaft rotation after a reference position. This pulse energizes driver 61 which may be part of the ignition system of a typical engine. Driver 61 provides a suitable firing or spark pulse to distributor 62 which contains the usual rotor and contacts to distribute the firing pulse to the proper spark plug.

Since there may be wide differences between maximum and minimum advance which can occur, distributor 62 may direct the spark to the incorrect spark plug. To prevent improper operation decoder 60 is enabled by the reference pulse from generator 25 to decode the digital value from accumulator 47. If the magnitude of the digital value is within predetermined limits, decoder 60 provides a signal to distributor 62 to cause registration of the rotor.

Various priority or default conditions may also be desired. For example, if the engine overheats during idle, a particular spark advance may be desired. Also, if the engine is overspeeding or running too slow, a particular spark advance may be desired. Transducers 64, 65, and 66 together with threshold detectors 67, 70, and 71 provide signals to priority generator 72 if the air or water temperature or the speed exceed predetermined limits. Priority generator 72 in response to a signal from timing generator 30 provides a priority output signal. This signal causes fixed advance generator 73 to provide a digital signal representative of a fixed spark advance to register 46 in parallel to override or replace the output signal from ROM 17. The output signal from generator 72 also inhibits pulse train generators 50 and 51, for example, by inhibiting gates 53 and 56 so that

clock pulses are not coupled therethrough and the fixed advance signal is not changed.

Although the specific embodiment of FIG. 2 has been disclosed and described, those skilled in the art will realize that many modifications and changes can be made within the scope and spirit of the claimed invention. For example, speed counter 32 can count pulses from encoder 24 for a fixed period of time rather than clock pulses, or it can be a single counter rather than the preferred embodiment disclosed. As was described above, other arrangements for obtaining or translating the speed and vacuum signals can also be used. Many other modifications can also be made, some of which are illustrated or described in the above-identified copending application.

Accordingly, there has been illustrated a system for controlling the ignition timing of an internal combustion engine which exhibits many advantages over the prior art. The system relates first and second characteristics, such as the speed and vacuum of the engine to ignition timing by generating timing pulses in accordance with the selected characteristics of the engine together with transfer functions relating those characteristics to engine performance. The system is highly accurate and reliable while providing an ability to utilize complex transfer functions heretofore difficult or impossible to implement. A primary advantage over the prior art is the capability of reducing exhaust emissions without compromising and while actually enhancing engine performance. Other advantages over the prior art obtainable with a system in accordance with the invention include more reliable engines, improved engine response and driveability or operability, improved fuel economy, increased horsepower, and decreased maintenance costs. These advantages are obtained without undue expense and mechanical complexity.

While there has been shown and described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as defined by the appended claims.

What is claimed is:

1. A system for controlling the timing of ignition pulses in an internal combustion engine in response to at least two characteristics of said engine comprising:
  - first signal generating means for generating first digital signals representative of a first characteristic of said engine;
  - second signal generating means for generating second digital signals representative of a second characteristic of said engine;
  - function generating means for relating said first and second characteristics to the ignition timing of said engine;
  - an accumulator;
  - means interconnecting said first and second signal generating means, said accumulator, and said function generating means for successively accumulating in said accumulator digital values responsive to said first and second digital signals and the relationship of said first and second characteristics of the ignition timing of said engine; and
  - pulse generating means connected to said accumulator for receiving said digital values therefrom and for converting said digital values to pulses at times corresponding thereto.

2. A system as defined in claim 1 wherein said first characteristic is the speed of said engine and said second characteristic is the vacuum of said engine.

3. A system as defined in claim 2 wherein said function generating means includes a first read-only memory programmed in accordance with a transfer function relating the speed of said engine to the ignition timing of said engine and a second read-only memory programmed in accordance with a transfer function relating the manifold vacuum of said engine to the ignition timing of said engine.

4. A system as defined in claim 2 wherein said first signal generating means includes transducer means for providing a signal indicative of crankshaft rotation and counter means connected to said transducer means for converting the signal from said transducer means to said first digital signals.

5. A system as defined in claim 4 wherein the signal from said transducer means includes periodic pulses indicative of degrees of crankshaft rotation and said counter means counts clock pulses between two successive pulses of said transducer means.

6. A system as defined in claim 1 wherein said first signal generating means includes means for providing reference pulses synchronized with the speed of said engine connected to said pulse generating means whereby the times of pulses provided by said pulse generating means are varied from said reference pulses in accordance with said digital values.

7. A system for electronically controlling the timing of ignition pulses in an internal combustion engine in response to the speed and vacuum of said engine for reducing exhaust emissions and enhancing the performance of said engine comprising:

first signal generating means for generating first digital signals representative of the speed of said engine;

second signal generating means for generating second digital signals representative of the vacuum of said engine;

signal processing means including function generating means for relating the speed and vacuum of said engine to the timing of ignition pulses, accumulating means, and means connecting said signal processing means to said first and second signal generating means for processing said first and second digital signals to accumulate digital timing value signals in said accumulating means in accordance with the speed and vacuum of said engine and predetermined functions contained in said function generating means; and

pulse generating means connected to said accumulating means for providing pulses at times corresponding to said digital timing value signals.

8. A system as defined in claim 9 wherein said signal processing means includes a first function generator programmed in accordance with a transfer function relating the speed of said engine to the timing of ignition pulses to obtain reduced emissions, a second function generator programmed in accordance with a transfer function relating the vacuum of said engine to the timing of ignition pulses to obtain reduced emissions, means connecting said first and second signal generating means to said first and second function generators, respectively, and means connecting said first and second function generators to said accumulating means.

9. A system as defined in claim 7 wherein said first signal generating means includes means for providing reference pulses at predetermined intervals of engine rotation connected to said pulse generating means, said pulse generating means providing pulses at times with respect to said reference pulses corresponding to said digital timing value signals.

10. A system as defined in claim 7 wherein said first signal generating means includes transducer means for providing pulses at predetermined intervals of crankshaft rotation and counter means for counting clock pulses for an interval determined by two successive pulses from said transducer means.

11. A system as defined in claim 8 wherein said second signal generating means includes a first signal transducer for providing output signals representative of the manifold vacuum of said engine, first converter means connected to said first signal transducer and to said second function generator for converting the output signals from said first signal transducer to digital signals, a second signal transducer for providing output signals representative of the port vacuum of said engine, and second converter means connected to said second signal transducer and to said second function generator for converting the output signals from said second signal transducer to digital signals.

12. A system for electronically controlling the timing of ignition pulses in an internal combustion engine in response to the speed and vacuum of said engine comprising:

first signal generating means including transducer means for providing signals indicative of engine rotation and counter means connected thereto for converting the signals from said transducer means to first digital signals representative of the speed of said engine;

second signal generating means for generating second digital signals representative of the vacuum of said engine;

function generating means for relating the speed and vacuum of said engine to the timing of ignition pulses for obtaining reduced emissions;

means connecting said counter means and said second signal generating means to said function generating means;

accumulator means for successively accumulating digital values representative of the timing of ignition pulses of said engine in response to signals from said function generating means;

means connecting said function generating means to said accumulator means; and

pulse generating means connected to said accumulator means and to said first signal generating means for converting said digital values to pulses at times varied from reference pulses provided by said signal generating means corresponding to said digital values.

13. A system as defined in claim 12 wherein said second signal generating means includes a first signal transducer for providing output signals representative of the manifold vacuum of said engine, first converter means connected to said first signal transducer and to said function generating means for converting the output signals from said first signal transducer to digital signals, a second signal transducer for providing output signals representative of the port vacuum of said engine, a second converter means connected to said sec-

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ond signal transducer and to said function generating means for converting the output signals from said second signal transducer to digital signals.

14. A system as defined in claim 12 including means connected to said accumulator means for providing a predetermined digital value signal thereto when predetermined default conditions occur.

15. A system as defined in claim 14 wherein the signal from said transducer means includes periodic pulses indicative of degrees of crankshaft rotation and said counter means counts clock pulses between two successive pulses from said transducer means.

16. A system as defined in claim 12 wherein said function generating means includes a first read-only memory programmed in accordance with a transfer function relating the speed of said engine to the timing of ignition pulses of said engine and a second read-only

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memory programmed in accordance with a transfer function relating the manifold vacuum of said engine to the timing of ignition pulses of said engine.

17. A system as defined in claim 16 wherein said means connecting said function generating means to said accumulator means includes means for generating pulse trains connected to said second read-only memory and to said accumulator means for generating pulse trains in response to digital output signals from said second read-only memory.

18. A system as defined in claim 13 wherein said means connecting said function generating means to said accumulator means includes first and second pulse train generators connected between said function generating means and said accumulator means.

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UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,749,073 Dated July 31, 1973

Inventor(s) Robert W. Asplund

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

Col. 9 - Claim 8, line 1 - "9" should read "7"

Col. 11- Claim 15, line 1- "14" should read "12"

Signed and sealed this 27th day of November 1973.

(SEAL)  
Attest:

EDWARD M. FLETCHER, JR.  
Attesting Officer

RENE D. TEGTMEYER  
Acting Commissioner of Patents