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Barr et al.

[11] **3,731,659**

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[54] ELECTRONIC FUEL INJECTION SYSTEM HAVING DECELERATION FUEL CONTROL

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[52] **U.S. Cl.** ..... **123/32 EA**

[51] **Int. Cl.** **F02m 51/00**

[58] **Field of Search** ..... 123/32 EA

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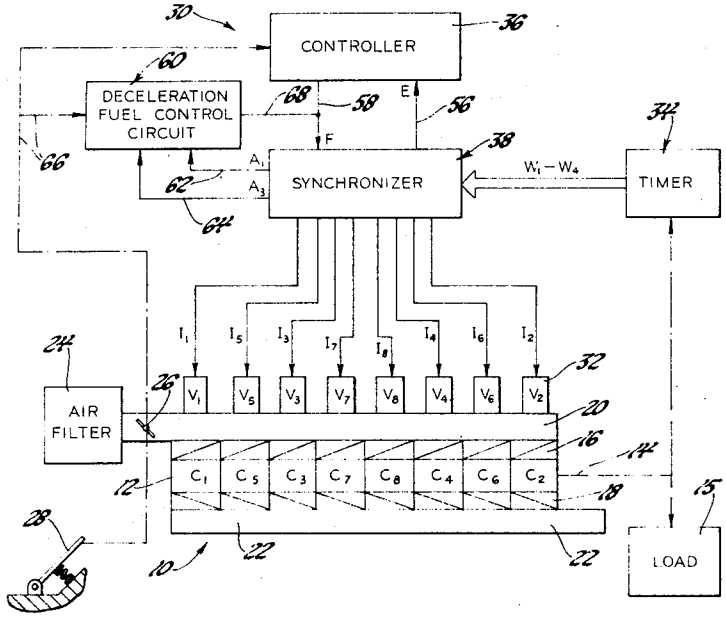
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[57] **ABSTRACT**

Fuel is completely withheld from an internal combustion engine in response to a decrease in the demand for power from the engine when the engine speed is above the idle speed of the engine.

4 Claims, 6 Drawing Figures



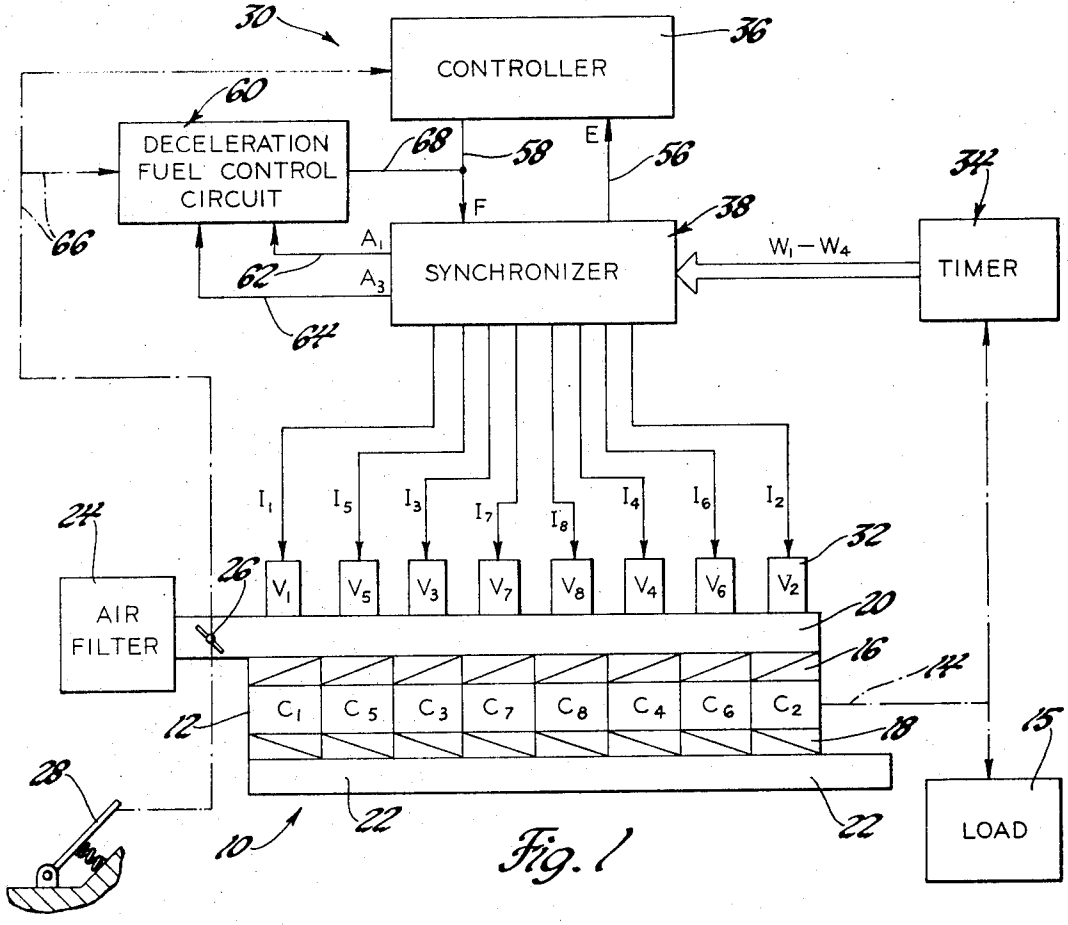


Fig. 1

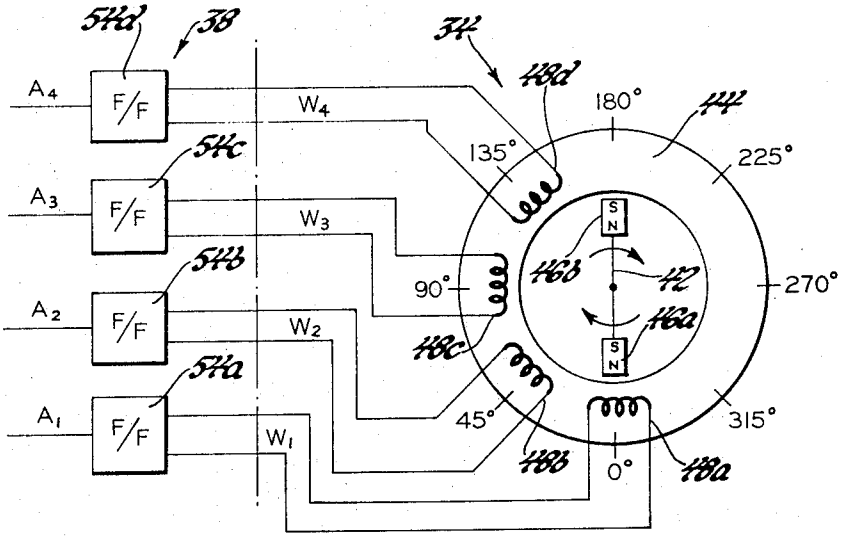


Fig. 2

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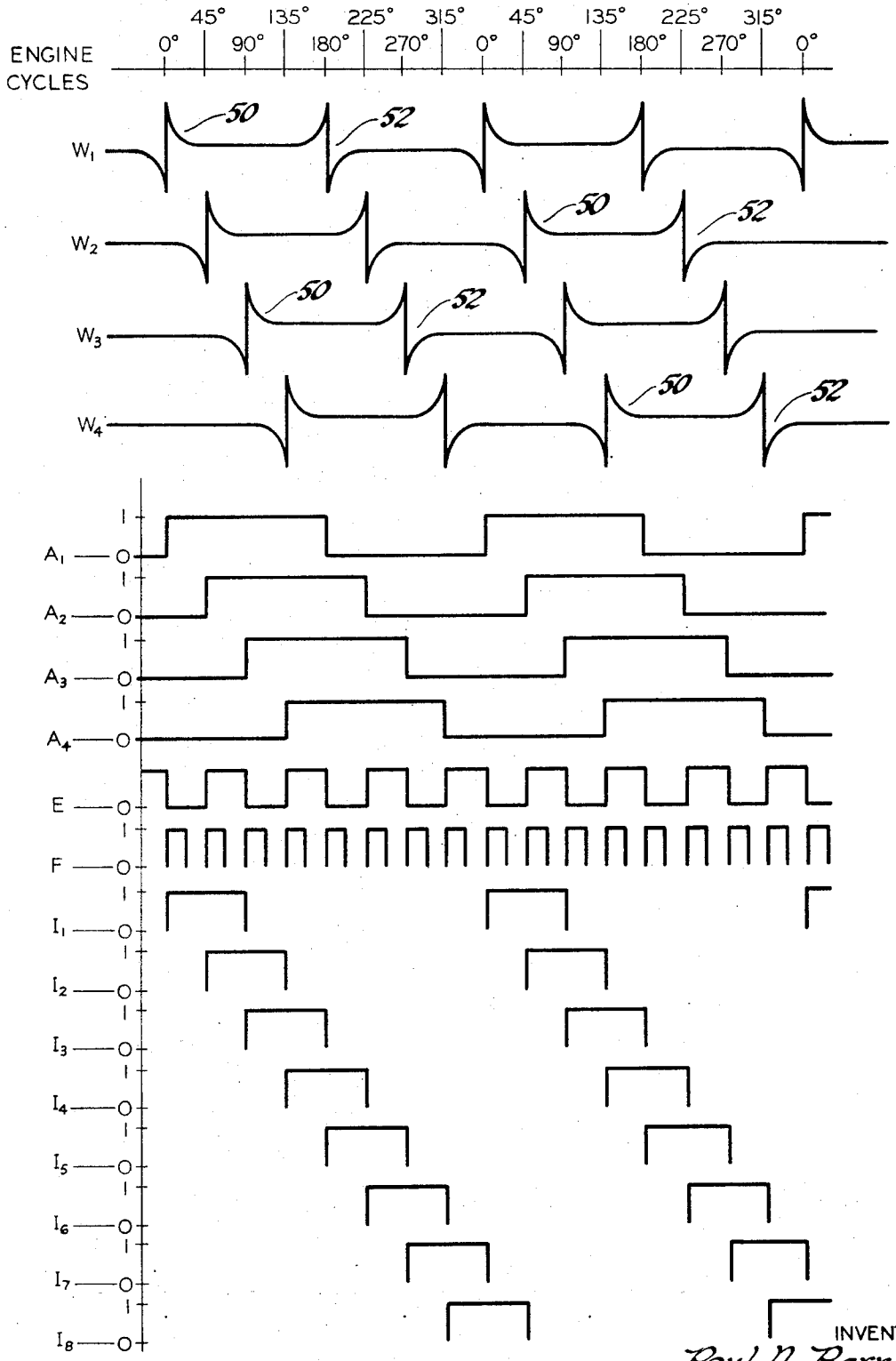


Fig. 3

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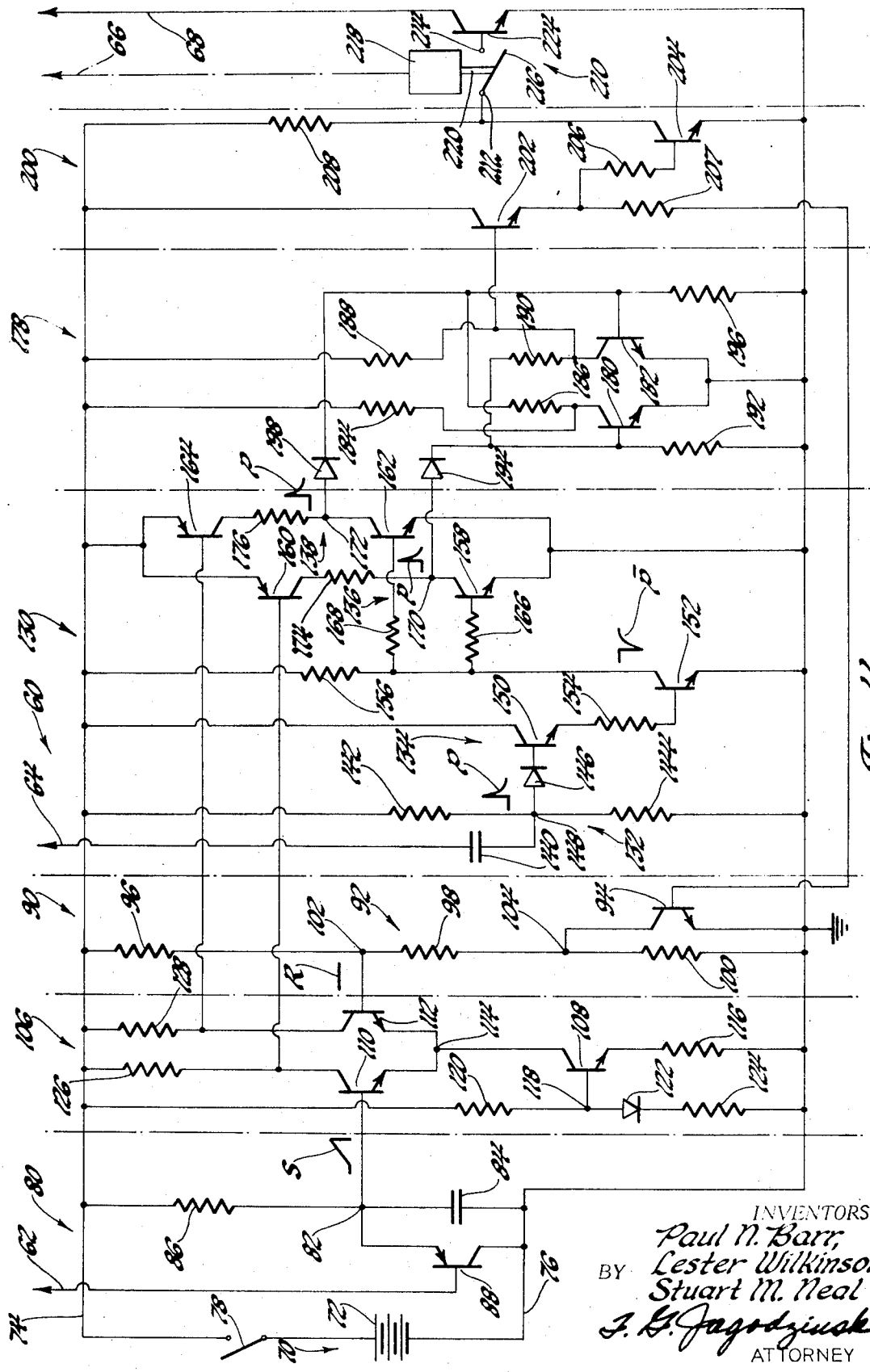


Fig. 4

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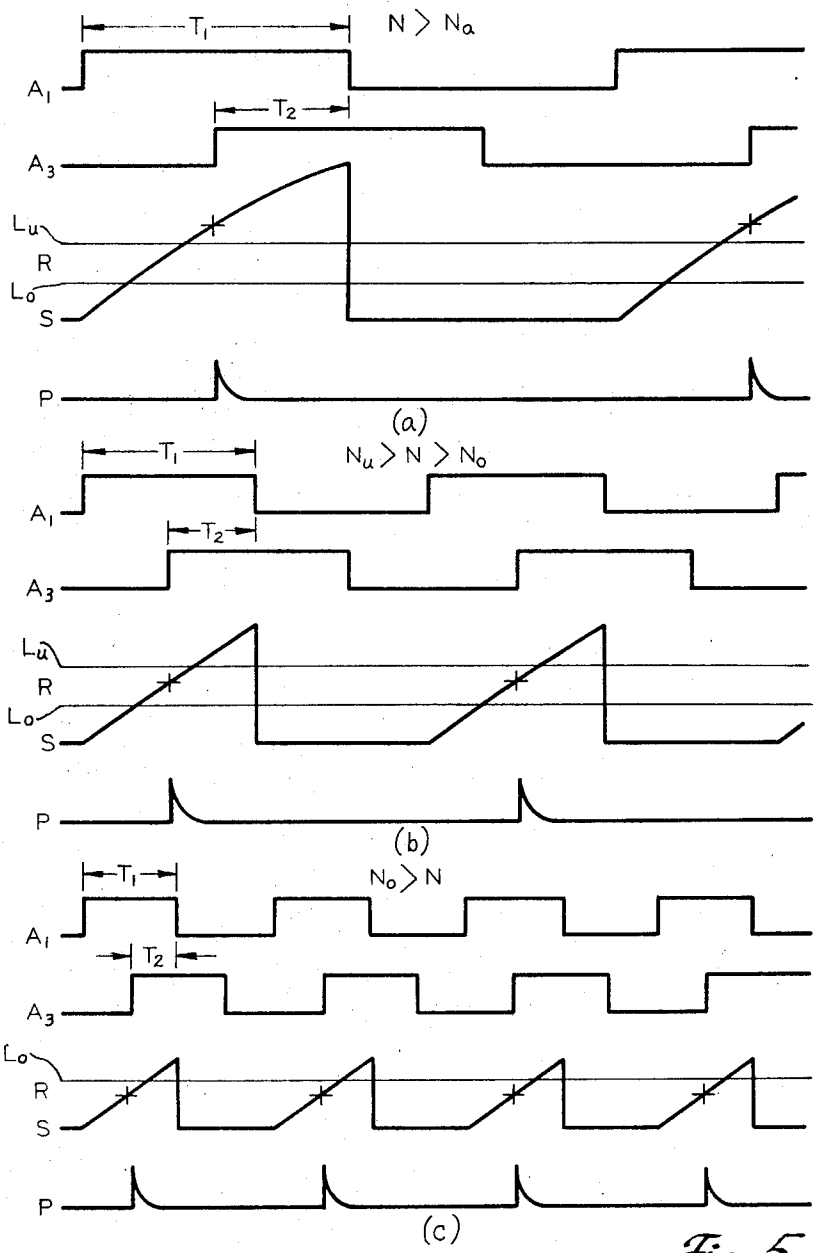


Fig. 5

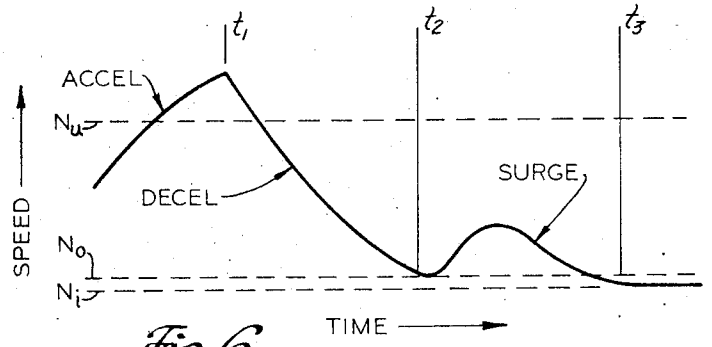


Fig. 6

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ELECTRONIC FUEL INJECTION SYSTEM HAVING DECELERATION FUEL CONTROL

This invention relates to a fuel supply system for an internal combustion engine. More particularly, the invention relates to an electronic fuel injection system for completely withholding fuel from the engine in response to a decrease in the demand for power from the engine when the engine speed is above the idle speed of the engine.

Typically, in an internal combustion engine, the power output of the engine is controlled by the relative location of an adjustable throttle member between a high power position and a low power position. As the throttle member is moved toward the high power position, the demand for power from the engine increases. Conversely, as the throttle member is moved toward the low power position, the demand for power from the engine decreases. Ordinarily, the engine speed, as represented by the frequency of the engine cycles, increases in the former condition and decreases in the latter condition. For reasons of fuel consumption economy and exhaust emission control, it is often desirable to completely withhold fuel from the engine in the latter condition, provided that the engine speed is above the idle speed of the engine. The present invention provides a simple but effective technique for accomplishing this desired result.

According to a preferred embodiment of the invention, fuel is completely withheld from the engine when the amplitude of a speed signal is below the amplitude of a reference signal at the initiation of a timing pulse. The amplitude of the speed signal increases over the duration of a first fixed portion of each engine cycle so that the amplitude of the speed signal is inversely related to the speed of the engine. The timing pulse is initiated at the expiration of a second fixed portion of each engine cycle terminating within the first fixed portion. The amplitude of the reference signal is substantially constant at a first reference level as the throttle member is moved toward the high power position and is substantially constant at a second reference level as the throttle member is moved toward the lower power position. The second reference level corresponds to a lower speed limit just above the idle speed of the engine. The first reference level corresponds to an upper speed limit above the surge speed of the engine which is experienced as fuel is reapplied to the engine after having been withheld from the engine.

These and other aspects and advantages of the invention may be best understood by reference to the following detailed description of the preferred embodiment when considered in conjunction with the drawings.

In the drawings:

FIG. 1 is a block diagram of an electronic fuel injection system incorporating the principles of the invention.

FIG. 2 is a schematic diagram of a portion of the electronic fuel injection illustrated in FIG. 1.

FIG. 3 is a graphic diagram of several waveforms useful in explaining the operation of the electronic fuel injection system illustrated in FIG. 1.

FIG. 4 is a schematic diagram of a deceleration control circuit incorporated within the electronic fuel injection system illustrated in FIG. 1.

FIG. 5 is a graphic diagram of several waveforms useful in explaining the operation of the deceleration fuel control circuit.

FIG. 6 is a graphic diagram of a typical engine operating curve during deceleration of the engine.

Referring to FIG. 1, an internal combustion engine 10 for an automotive vehicle includes a group of eight combustion chambers or cylinders 12 which are identified C_1–C_8. Preferably, the engine 10 is V–8 having a first bank of cylinders C_1–C_5–C_3–C_7 and a second bank of cylinders C_8–C_4–C_6–C_2. However, it will be understood that the engine 10 may have more or less than eight cylinders 12 as desired. An output shaft or crankshaft 14 is rotatably driven in response to the occurrence of combustion within the cylinders 12 through a suitable mechanism (not shown) which normally includes a plurality of pistons and a plurality of connecting rods. A load 15, representing the drive vehicle, is connected to the crankshaft 14 through a suitable linkage. An ignition system (not shown), which conventionally includes a spark coil, a spark distributor, and spark ignitors, defines the ignition order of the cylinders 12 during each engine cycle. For the sake of convenience, it is assumed that the ignition order is C_1–C_{2a}–C_3–C_4–C_5–C_6–C_7–C_8 per engine cycle.

A plurality of intake valves 16 each cooperate with a different associated one of the cylinders 12 for regulating the entry of combustion ingredients or air/fuel mixture into the cylinders 12 before combustion to charge the cylinders 12. Similarly, a plurality of exhaust valves 18 each c-operate with a different associated one of the cylinders 12 for regulating the exit of combustion products or exhaust gases from the cylinders 12 after combustion to discharge the cylinders 12. An induction passage or intake manifold 20 communicates with the cylinders 12 through the intake valves 16 for transmitting air/fuel mixture through the intake valves 16 into the cylinders 12. An expulsion passage or exhaust manifold 22 communicates with each of the cylinders 12 through the exhaust valves 18 for receiving exhaust gases from the cylinders 12 through the exhaust valves 18. Conventionally, the exhaust manifold 22 is part of an exhaust system (not shown) which normally includes a muffler and an exhaust pipe. The intake valves 16 and the exhaust valves 18 are driven from the crankshaft 14 through a suitable linkage (not shown) which normally includes a camshaft, a plurality of rocker arms, and a plurality of valve lifters.

Air and fuel are combined within the intake manifold 20 to form the air/fuel mixture. Air is drawn into the intake manifold 20 through an air filter 24 which is disposed across the mouth of the intake manifold 20. A throttle valve 26 is pivotally mounted within the mouth of the intake manifold 20 just downstream from the air filter 24 for regulating the amount of air drawn into the intake manifold 20. A control element provided by the vehicle accelerator pedal 28 is connected with the throttle 26 through a suitable linkage for defining the relative location of the throttle valve 26 between a fully opened position and a fully closed position. In the fully opened position, a maximum amount of air is drawn into the intake manifold 20. Conversely, in the fully closed position, a minimum amount of air is drawn into the intake manifold 20.

An electronic fuel injection system 30 includes a group of eight fuel injectors 32 which are identified V_1–V_{8a}. The fuel injectors 32 are mounted on the intake manifold 20 for individually applying fuel to corresponding ones of the eight cylinders 12 through the

intake valves 16. Alternately, the fuel injectors 32 may be mounted for direct communication with the cylinders 12. Preferably, each of the fuel injectors 32 is provided by an electromagnetic valve including a plunger which is driven to a fully opened position against a spring bias when a solenoid is energized and which is driven to a fully closed position by the spring bias when the solenoid is deenergized.

A fuel supply system (not shown), which normally includes a fuel tank, a fuel pump, and a fuel pressure regulator, delivers fuel to the fuel injectors 32 at a constant pressure. A fuel control system successively energizes each of the fuel injectors 32 in accordance with a predetermined injection order during each engine cycle. Since the injection order of the fuel injectors 32 must be synchronized with the ignition order of the cylinders 12, the injection order is V_1–V_2–V_3–V_4–V_5–V_6–V_7–V_8. As the fuel injectors 32 are individually energized, fuel is deposited into the intake manifold 20 in individual atomized loads generally located adjacent to the intake valves 16 through which the atomized fuel loads are drawn into corresponding ones of the cylinders 12.

The fuel control system includes a timer 34, a controller 36, and a synchronizer 38. The timer 34 is connected between the crankshaft 14 of the engine 10 and the synchronizer 38 for providing timing information defining the start of injection for each of the fuel injectors 32 per engine cycle. The controller 36 is connected between the throttle valve 26 of the engine 10 and the synchronizer 38 for providing control information defining the period of injection for each of the fuel injectors 32 per engine cycle. The synchronizer 38 is connected with each of the fuel injectors 32 for energizing the fuel injectors at time instants determined by the timer 34 and for time durations determined by the controller 36.

Referring to FIG. 2, the timer 34 is provided by a magnetic pick-up transducer including a rotor 42 and a stator 44. The rotor 42 is supported at a center point for 360° rotation in a clockwise direction with respect to the stator 44. A pair of permanent magnets 46_a and 46_b are mounted on opposite ends of the rotor 42. A group of four windings 48_a, 48_b, 48_c, and 48_d are mounted on the stator 44. The permanent magnets 46_a and 46_b are oppositely poled with respect to the windings 48_a–48_d. That is, the permanent magnet 46_a presents a north pole to the windings 48_a–48_d while the permanent magnet 46_b presents a south pole to the windings 48_a–48_d.

The rotor 42 is driven from the crankshaft 14 through a suitable linkage so that the rotor 42 makes one complete revolution relative to the stator 44 per engine cycle. Hence, the angle markings to the outside of the stator 44 indicate successive 45° increments in both the position of the rotor 42 and the cycle of the engine 10. The windings 48_a–48_d are located at peripheral points on the stator 44 successively spaced at angles of 45° with respect to the center point of the rotor 42. Specifically, the winding 48_a is located at the 0° point, the winding 48_b is located at the 45° point, the winding 48_c is located at the 90° point and the winding 48_d is located at the 135° point. As the rotor 42 is turned relative to the stator 44, the permanent magnets 46_a and 46_b are alternately carried into and out of magnetic coupling relationship with the windings 48_a–48_d so as to produce a corresponding set of four input signals W_1–W_4 as shown in FIG. 3.

Referring to FIGS. 2 and 3, the input signals W_1–W_4 each include alternate first and second pulse pairs 50 and 52. The first pulse pairs 50 are developed in the input signals W_1–W_4 as the permanent magnet 46_a successively sweeps past the windings 48_a–48_d, respectively. Alternately, the second pulse pairs 52 are developed in the input signals W_1–W_4 as the permanent magnet 46_b successively sweeps past the windings 48_a–48_d. The first pulse pairs 50 each exhibit a sharp negative-to-positive polarity transition while the second pulse pairs 52 each exhibit a sharp positive-to-negative polarity transition. The negative-to-positive polarity transitions in the first pulse pairs 50 of the input signals W_1–W_4 successively occur at the 0° point, the 45° point, the 90° point, and the 135° point in each engine cycle, respectively, as the centerline of the permanent magnet 46_a successively aligns with the centerlines of the windings 48_a–48_{b7}, respectively. Similarly, the positive-to-negative polarity transitions in the second pulse pairs 52 of the input signals W_1–W_4 successively occur at the 180° point, the 225° point, the 270° point, and the 315° point in each engine cycle, respectively, as the centerline of the permanent magnet 46_b successively aligns with the centerlines of the windings 48_a–48_d, respectively.

For the sake of convenience, it is assumed that each 360° engine cycle is coextensive with the injection order V_1–V_8 of the fuel injectors 32. That is, the beginning or 0° point of each engine cycle coincides with the start of injection for the first fuel injector V_1 in the injection order V_1–V_8. Accordingly, the negative-to-positive polarity transitions in the first pulse pairs 50 of the input signals W_1–W_4 define the start of injection for the fuel injectors V_1–V_4 in the first half of the injection order, respectively. Conversely, the positive-to-negative polarity transitions in the second pulse pairs 52 of the input signals W_1–W_4 define the start of injection for the fuel injectors V_5–V_8 in the second half of the injection order, respectively.

A more detailed description of the illustrated timer or magnetic pick-up transducer 34 may be obtained by reference to U.S. patent application Ser. No. 36,055. However, it is to be noted that various alterations and modifications may be made to the timer 34 without affecting the invention. For example, the windings 48_a–48 may be replaced by Hall-effect devices or any other suitable magnetic signal generating arrangement. Further, the magnetic pick-up transducer 34 may be entirely replaced by a multiple contact relay switch, a photoelectric pick-up transducer or some other equivalent contrivance.

Referring again to FIG. 2, the synchronizer 38 includes a group of four bistable multivibrators or flip-flops 54_a–54_d. The group of input windings 48_a–48_d of the magnetic pick-up transducer 34 are connected to corresponding ones of the group of flip-flops 54_a–54_d of the synchronizer 38, respectively. The flip-flops 54_a–54 are responsive to the input signals W_1–W_4 to provide a corresponding set of four symmetrical timing signals A_1–A_4, respectively, as shown in FIG. 3. The timing signals A_1–A_4 are square waves each exhibiting periodic magnitude permutations or amplitude transitions between a relatively high level and a relatively low

level. Thus, the timing signals A_1–A_4 shift to the high level in response to the occurrence of the negative-to-positive polarity transitions in the first pulse pairs **50** of the input signals W_1–W_4, respectively. Alternately, the timing signals A_1–A_4 shift to the low level in response to the occurrence of the positive-to-negative polarity transitions in the second pulse pairs **52** of the input signals W_1–W_4, respectively. As a result, the timing signals A_1–A_4 each contain two magnitude permutations or amplitude transitions per engine cycle.

More particularly, in the timing signal A_1, a low-to-high level transition occurs at the 0° point and a high-to-low level transition occurs at the 180° point in each engine cycle marking the start of injection for the fuel injectors V_1 and V_5, respectively. In the timing signal A_2, a low-to-high level transition occurs at the 45° point and a high-to-low level transition occurs at the 225° point in each engine cycle marking the start of injection for the fuel injectors V_2 and V_6, respectively. In the timing signal A_3, a low-to-high level transition occurs at the 90° point and a high-to-low level transition occurs at the 270° point marking the start of injection for the fuel injectors V_3 and V_7, respectively. In the timing signal A_4, a low-to-high level transition occurs at the 135° point and a high-to-low level transition occurs at the 315° point in each engine cycle marking the start of injection for the fuel injectors V_4 and V_8, respectively. Accordingly, the magnitude permutations or level transitions in the set of timing signals A_1–A_4 are successively spaced at intervals of 180° or one-half of an engine cycle within each of the timing signals A_1–A_4 and are successively displaced at intervals of 45° or one-eighth an engine cycle between each of the timing signals A_1–A_4.

The synchronizer **38** multiplexes the set of timing signals A_1–A_4 to obtain a single timing signal E as shown in FIG. **3**. Like the timing signals A_1–A_4, the timing signal E exhibits periodic magnitude permutations or amplitude transitions between a relatively high level and a relatively low level. Specifically, the timing signal E shifts to the relatively low level in response to each of the level transitions in the timing signals A_1 and A_3 and shifts to the relatively high level in response to each of the level transitions in the timing signals A_2 and A_4. Accordingly, the magnitude permutations or amplitude transitions in the single timing signal E are successively spaced at intervals of 45° or one-eighth of an engine cycle. Hence, during each engine cycle, the timing signal E contains eight level transitions successively defining the start of injection for each of the eight fuel injectors V_1–V_8.

Referring to FIG. **1**, the single timing signal E is applied from the synchronizer **38** to the controller **36** via a timing line **56**. The controller **36** is responsive to the single timing signal E to provide a single pulse train F as shown in FIG. **3**. The single pulse train F contains eight bilevel control pulses per engine cycle synchronized with the eight level transitions per engine cycle in the timing signal E. That is, the control pulses in the single pulse train F are each initiated in response to the occurrence of a corresponding one of the level transitions in the single timing signal E. As previously described, the occurrence of each of the eight level transitions in the timing signal E defines the start of injection for a corresponding one of the eight fuel injectors **32** according to the injection order V_1–V_8 during each engine cycle. Likewise, the duration of each of the eight control pulses defines the period injection for a corresponding one of the fuel injectors **32** according to the injection order V_1–V_8 during each engine cycle.

More specifically, the controller **36** determines the duration of each of the control pulses in the single pulse train F as a function of at least one operating parameter of the engine **10**. As illustrated, the controller **36** is responsive to the relative position of the throttle valve **26**. Alternately, the controller **36** may be responsive to the negative pressure or vacuum within the intake manifold **20**. Moreover, the duration of the control pulses in the single pulse train F may be defined by the controller **36** in response to additional engine operating parameters such as engine temperature and battery voltage. In any event, since the controller **36** is only incidental to the present invention, it is not described in detail. A more detailed description of one embodiment of the controller **36** may be obtained from U.S. patent application Ser. No. 36,055.

In order to achieve satisfactory performance in most V-**8** engines such as the engine **10**, it is necessary that the period of injection for the fuel injectors V_1–V_8 approach a maximum duration of 180° or one half of an engine cycle at relatively high speeds and relatively high loads. In other words, the individual injection periods for the fuel injectors V_1–V_8 must overlap one another. However, the control pulses in the single pulse train F cannot overlap one another. The maximum time available between successive level transitions in the single timing signal F is 45° or one-eighth of an engine cycle. Consequently, the controller **36** determines the duration of the control pulses in the single pulse train F as a fraction or a percentage of the maximum time available between successive level transitions in the single timing signal F. As a result, the duration of the control pulses in the single pulse signal F is less than the desired period of injection for the fuel injectors V_1–V_8 by a factor of four.

Referring to FIG. **1**, the single control pulse train F is applied from the controller **36** to the synchronizer **38** over a control line **58**. The synchronizer **38** separates the individual control pulses from the single pulse train F and expands the duration of the separated control pulses by a factor of four to conform the actual duration of the control pulses with the desired period of injection for the fuel injectors V_1–V_8. As a result, the synchronizer **38** provides a series of eight pulse trains I_1–I_8 as shown in FIG. **3**. The control pulses in the series of pulse trains I_1–I_8 are successively initiated at intervals of 360° or one engine cycle within each of the pulse trains I_1–I_8 and are successively displaced at intervals of 45° or one-eighth of an engine cycle between each of the pulse trains I_1–I_8. Hence, the eight pulse trains I_1–I_8 each contain control pulses for a corresponding one of the eight fuel injectors V_1–V_8.

The synchronizer **38** applies the pulse trains I_1–I_8 to energize corresponding ones of the fuel injectors V_1–V_8 for the duration of the control pulses in the pulse trains I_1–I_8. Thus, the fuel injectors V_1–V_8 are opened for the duration of the control pulses in the pulse trains I_1–I_8 to inject fuel at a constant rate to the C_1–C_8 of the engine **10** through the intake manifold **20** and the intake valves **16**.

For a more detailed description of one embodiment of the synchronizer **38**, reference may be made to copending U.S. patent application A–15,367. However, at this point, it is to be understood that the generalized electronic fuel injection system so far illustrated is shown only to facilitate a more complete understanding of the invention. As will become more apparent later, the invention may be effectively applied to virtually any type of an electronic fuel injection system.

Referring to FIG. **1**, the power output of the engine **10** is defined by the relative position of the throttle valve **26** as controlled by the vehicle accelerator pedal **28**. As the throttle valve **26** is moved toward the fully opened position or the high power position, more air is drawn into the intake manifold **20** to increase the demand for power from the engine **10**. As a result, the controller **36** increases the duration of the control pulses applied to the fuel injectors **32** thereby increasing the amount of fuel injected into the intake manifold **20**. Assuming the load **15** on the engine **10** remains relatively constant, the engine speed increases as the engine **10** accelerates in response to the increased quantity of air/fuel mixture applied from the intake manifold **20**. Conversely as the throttle valve **26** is moved toward the fully closed position or the low power position, a minimum amount of air is drawn into the intake manifold **20** thereby decreasing the demand for power from the engine **10**. Accordingly, the controller **36** decreases the duration of the control pulses applied to the fuel injectors **30** thereby decreasing the amount of fuel injected into the intake manifold **20**. Again, assuming the load **15** on the engine **10** remains relatively constant, the engine speed decreases as the engine **10** decelerates in response to the decreased quantity of air/fuel mixture applied from the intake manifold **20**.

During deceleration of the engine **10**, any fuel consumed within the cylinders **12** is largely wasted since the load **15** is actually driving the engine **10** rather than vice versa. In addition, during deceleration of the engine **10**, the exhaust gases expelled from the cylinders **12** contain a higher proportion of deleterious exhaust emissions than at other times. Hence, it is desirable to disable the electronic fuel injection system **30** to completely stop the injection of fuel into the intake manifold **20** during deceleration of the engine **10**. However, as the speed of the engine **10** approaches the desired idle speed, it is necessary to again apply fuel to the engine **10** to maintain the idle speed and prevent the engine **10** from stalling. Accordingly, the present invention provides a deceleration fuel control circuit **60** for completely withholding fuel from the engine **10** in response to a decrease in the demand for power from the engine **10** when the engine speed is above the idle speed of the engine **10**.

Referring to FIG. **1**, the deceleration fuel control circuit **60** includes a pair of electrical inputs connected to the synchronizer **38** over a pair of input lines **62** and **64** and a mechanical input connected to the throttle valve **26** through a suitable linkage **66**. More specifically, as shown in FIG. **2**, the input line **62** is connected to the output of the flip-flip 54_a in the synchronizer **38** while the input line **64** is connected to the output of the flip-flop 54_c in the synchronizer **38**. Further, the deceleration fuel control circuit **60** includes an electrical output connected to the control line **58** over an output line **68**.

In operation, the deceleration fuel control circuit **60** is responsive to the timing signals A_1 and A_3 on the input lines **62** and **64** to determine the speed of the engine **10**. Further, the deceleration fuel control circuit **60** is responsive through the linkage **66** to movement of the throttle valve **26** toward the low power position when the engine speed is above the idle speed of the engine **10** to ground the control line **58** through the output line **68**. As a result, the electronic fuel injection system **30** is disabled to completely withhold fuel from the engine **10**.

Referring to FIG. **4**, an electrical power supply **70** is provided for the deceleration fuel control circuit **60**. The power supply **70** includes a source of direct current voltage **72** which may be provided by the vehicle battery. The voltage source **72** applies a supply voltage between a high potential line **74** and a low potential line **76** through a control switch **78** which may be provided by the vehicle ignition switch. Of course, it will be readily appreciated that the supply voltage provided by the power supply **70** may also be applied to energize the controller **36** and the synchronizer **38** of the electronic fuel injection system **30**.

Referring to FIGS. **4** and **5**, the deceleration fuel control circuit **60** includes a speed signal generator **80** for providing a speed signal S at a junction **82**. The speed signal generator **80** includes a capacitor **84**, a resistor **86**, and a PNP junction transistor **88**. The capacitor **84** is connected between the junction **82** and the low potential line **76**. The resistor **86** is connected between the junction **82** and the high potential line **74**. The emitter electrode of the transistor **88** is connected directly to the junction **82** while the collector electrode of the transistor **88** is connected directly to the low potential line **76**. The base electrode of the transistor **88** is connected directly to the output of the flip-flop 54_a in the synchronizer **38** via the input line **62**.

The timing signal A_1, as shown in FIG. **5**, is applied to the base electrode of the transistor **88** via the input line **62**. Hence, the synchronizer **38** acts as a timing signal generator. The timing signal A_1 alternately shifts between a relatively high level and a relatively low level. Specifically, the timing signal A_1 is at the high level for the duration of a first fixed portion of each engine cycle as represented by the time period T_1 which is approximately equal to 180° or one-half of an engine cycle.

As the timing signal A_1 shifts from the relatively high level to the relatively low level, the transistor **88** is rendered fully conductive. With the transistor **88** turned on, the capacitor **84** discharges through the transistor **88**. In this condition, the amplitude of the speed signal S at the junction **82** is effectively clamped at a base level L_b defined by the ground potential on the low potential line **76**. As the timing signal A_1 shifts from the relatively low level to the relatively high level, the transistor **88** is rendered fully nonconductive. With the transistor **88** turned off, the capacitor **84** charges through the resistor **86**. In this condition, the amplitude of the speed signal S at the junction **82** increases from the base level L_b toward a maximum level L_m defined by the supply potential on the high potential line **74**.

Thus, the amplitude of the speed signal S unidirectionally increases from the base level L_b toward the maximum level L_m over the duration of the time

period T_1. More particularly, the amplitude of the speed signal S increases in accordance with an RC time constant provided by the resistor **86** and the capacitor **84**. Preferably, this RC time constant is selected such that the increase in the amplitude of the speed signal S is substantially linear over the time period T_1. Alternately, the resistor **86** may be replaced by a constant current source.

A reference signal generator **90** includes a voltage divider network **92** and an NPN junction transistor **94**. The voltage divider network **92** includes biasing resistors **96**, **98**, and **100**. The resistor **96** is connected between a junction **102** and the high potential line **74**. The resistor **98** is connected between the junction **102** and a junction **104**. The resistor **100** is connected between the junction **104** and the low potential line **76**. The emitter electrode of the transistor **94** is connected directly to the low potential line **76**. The collector electrode of the transistor **94** is connected directly to the junction **104**.

The reference signal generator **90** develops a reference signal R at the junction **102**. The amplitude of the reference signal R is substantially constant at either an upper reference level L_u or a lower reference level L_o depending upon the conductive condition of the transistor **94**. When the transistor **94** is fully conductive, the reference signal R is at the lower reference level L_o as defined by the voltage divider action of the resistors **96** and **98**. When the transistor **94** is rendered fully nonconductive, the amplitude of the reference signal R is substantially constant at the upper reference level L_u as defined by the voltage divider action of the resistors **96**, **98**, and **100**. The significance of the upper reference level L_u and the lower reference level L_o will be more fully described later. At this point, it is sufficient to note that the transistor **94** is normally turned on so that the amplitude of the reference voltage R is normally at the lower reference level L_o.

A differential switch or differential amplifier **106** includes NPN junction transistors **108**, **110**, and **112**. The collector electrode of the transistor **108** is connected directly to a junction **114** between the emitter electrodes of the transistors **110** and **112**. The emitter electrode of the transistor **108** is connected through a biasing resistor **116** to the low potential line **76**. The base electrode of the transistor **108** is connected directly to a junction **118**. A biasing resistor **120** is connected between the junction **118** and the high potential line **74**. A temperature compensating diode **122** and a biasing resistor **124** are connected in series between the junction **118** and the low potential line **76**. The base electrode of the transistor **110** is connected directly to the junction **82** in the speed signal generator **80**. The base electrode of the transistor **112** is connected directly to the junction **102** in the reference signal generator **90**. The collector electrode of the transistor **110** is connected through a biasing resistor **126** to the high potential line **74**. Similarly, the collector electrode of the transistor **112** is connected through a biasing resistor **128** to the high potential line **74**.

In the differential amplifier **106**, the transistor **108** is rendered conductive in a constant current mode through the biasing action of the resistors **116**, **120**, and **124**. Hence, the transistor **108** provides a constant current sink for the transistors **110** and **112** at the junction **114**. In the conventional manner, the differential amplifier **106** is operable between first and second states. In the first state, the transistor **112** is rendered fully conductive while the transistor **110** is rendered fully nonconductive. Conversely, in the second state, the transistor **110** is rendered fully conductive and the transistor **112** is rendered fully nonconductive. The differential amplifier **106** switches from the first state to the second state when the amplitude of the speed signal S at the junction **82** exceeds the amplitude of the reference signal R at the junction **102**. Alternately, the differential amplifier **106** switches from the second state to the first state when the amplitude of the reference signal R at the junction **102** exceeds the amplitude of the speed signal S at the junction **82**.

A timing pulse generator **130** includes a differentiator **132**, a pulse amplifier **134**, and first and second logic gates **136** and **138**. The differentiator **132** includes a coupling capacitor **140**, a pair of biasing resistors **142** and **144**, and a diode **146**. The capacitor **140** is connected between a junction **148** and the output of the bistable flip-flop 54_c in the synchronizer **38** via the input line **64**. The biasing resistor **142** is connected between the junction **148** and the high potential line **74**. The biasing resistor **144** is connected between the junction **148** and the low potential line **76**.

The pulse amplifier **134** includes NPN junction transistors **150** and **152**. The base electrode of the transistor **150** is connected through the diode **146** to the junction **148** in the differentiator **132**. The collector electrode of the transistor **150** is connected directly to the high potential line **74**. The emitter electrode of the transistor **150** is connected through a biasing resistor **154** to the base electrode of the transistor **152**. The emitter electrode of the transistor **152** is connected directly to the low potential line **76**. The collector electrode of the transistor **152** is connected through a biasing resistor **156** to the high potential line **74**.

The first logic gate **136** includes an NPN junction transistor **158** and a PNP junction transistor **160**. Similarly, the second logic gate **138** includes an NPN junction transistor **162** and a PNP junction transistor **164**. The base electrode of the transistor **158** is connected through a biasing resistor **166** to the collector electrode of the transistor **152**. The base electrode of the transistor **162** is connected through a biasing resistor **168** to the collector electrode of the transistor **152**. The emitter electrodes of the transistors **158** and **162** are connected together directly to the low potential line **76**. The collector electrode of the transistor **158** is connected directly to a junction **170** while the collector electrode of the transistor **162** is connected directly to a junction **172**. The base electrode of the transistor **160** is connected directly to the collector electrode of the transistor **110** in the differential amplifier **106**. The base electrode of the transistor **164** is connected directly to the collector electrode of the transistor **112** in the differential amplifier **106**. The emitter electrodes of the transistors **160** and **164** are connected together directly to the high potential line **74**. The collector electrode of the transistor **160** is connected through a biasing resistor **174** to the junction **170** while the collector electrode of the transistor **164** is connected through a biasing resistor **176** to the junction **172**.

The timing signal A_3, as shown in FIG. 5, is applied to the differentiator 132 over the input line 64. Like the timing signal A_1, the timing signal A_3 alternately shifts between a relatively high level and a relatively low level. However, the timing signal A_3 is displaced 90° or one-quarter of an engine cycle with respect to the timing signal A_1. As a result, the timing signal A_3 shifts from the low level to the high level at the midpoint of the time period T_1 during which the timing signal A_1 is at the high level. In other words, the timing signal A_3 exhibits a low-to-high level transition at the expiration of a second fixed portion of each engine cycle as represented by the time period T_2 which is equal to 90° or one-quarter of an engine cycle. Thus, the time period T_2 is contained within and terminates within the time period T_1. Regardless of the frequency of the timing signals A_1 and A_3, the relationship between the time periods T_1 and T_2 remains the same. Thus, as the speed of the engine 10 increases, the time periods T_1 and T_2 both proportionally decrease.

In the differentiator 132, the capacitor 140 combines with the resistors 142 and 144 to differentiate the timing signal A_3. As a result, timing pulses P of positive polarity are developed at the junction 148 when the timing signal A_3 shifts from the low level to the high level. In particular, a timing pulse P is initiated as the timing signal A_3 undergoes a low-to-high level transition. When a timing pulse P is absent from the junction 148, the transistor 150 is rendered relatively nonconductive through the biasing action of the diode 146 and the resistors 142 and 144. With the transistor 150 relatively nonconductive, the transistor 152 is rendered fully nonconductive through the biasing action of the resistor 154 and the transistor 150. However, when a timing pulse P is present at the junction 148, the transistor 150 is momentarily rendered highly conductive. With the transistor 150 momentarily highly conductive, the transistor 152 is momentarily fully conductive. With the transistor 152 momentarily turned on, the timing pulse P at the junction 148 is amplified and inverted to provide an inverse timing pulse $\bar{P}$ at the collector electrode of the transistor 152.

When the differential amplifier 106 is in the first state, the transistor 112 is rendered fully conductive and the transistor 110 is rendered fully nonconductive. With the transistor 112 turned on, the transistor 164 in the logic gate 138 is rendered fully conductive through the biasing action of the transistors 108 and 112 and the resistors 116 and 128. With the transistor 110 turned off, the transistor 160 in the logic gate 136 is rendered fully nonconductive through the biasing action of the resistor 126. Conversely, when the differential amplifier 106 is in the second state, the transistor 110 is rendered fully conductive and the transistor 110 turned on, the transistor 160 in the logic gate 136 is rendered fully conductive through the biasing action of the transistors 108 and 110 and the resistors 116 and 126. With the transistor 112 turned off, the transistor 164 in the logic gate 138 is rendered fully nonconductive through the biasing action of the resistor 128.

When the transistor 152 is turned off so that an inverse timing pulse $\bar{P}$ is not present at the collector electrode of the transistor 152, the transistor 158 in the logic gate 136 is conditioned to turn on through the biasing action of the resistors 156 and 166 while the transistor 162 in the logic gate 138 is conditioned to turn on through the biasing action of the resistors 156 and 168. If the differential amplifier 106 is in the second state so that the transistor 160 is turned on, the transistor 158 is rendered fully conductive in response to the absence of an inverse timing pulse $\bar{P}$. With the transistor 158 turned on the junction 170 is effectively clamped to the ground potential on the low potential line 76 through the transistor 158. On the other hand, if the differential amplifier 106 is in the first state so that the transistor 164 is turned on, the transistor 162 in the logic gate 138 is rendered fully conductive in response to the absence of an inverse timing pulse $\bar{P}$. With the transistor 162 turned on, the junction 172 is effectively clamped to the ground potential on the low potential line 76 through the transistor 162. Hence, regardless of the state of the differential amplifier 106, no timing pulses are developed at the junctions 170 and 172 when the transistor 152 is turned off.

When the transistor 152 is turned on so that an inverse timing pulse $\bar{P}$ is present at the collector electrode of the transistor 152, the transistors 158 and 162 are both momentarily turned off. The transistor 158 in the logic gate 136 is rendered fully nonconductive through the biasing action of the resistors 156 and 166 while the transistor 162 in the logic gate 138 is rendered fully nonconductive through the biasing action of the resistors 156 and 168. With the transistor 158 momentarily turned off, the junction 170 is momentarily unclamped from the low potential line 76 to develop a timing pulse P of positive polarity at the junction 170, provided that the differential amplifier 106 is in the second state so that the transistor 160 is turned on. Similarly, with the transistor 162 momentarily turned off, the junction 172 is unclamped to develop a timing pulse P of positive polarity at the junction 172, provided that the differential amplifier 106 is in the first state so that the transistor 164 is turned on. Accordingly, when the differential amplifier 106 is in the first state, any timing pulses developed by the differentiator 132 are amplified by the pulse amplifier 134 and applied to the junction 172 by the second logic gate 138. Alternately, when the differential amplifier 106 is in the second state, any timing pulses developed by the differentiator 132 are amplified by the pulse amplifier 134 and applied to the junction 170 by the second logic gate 136.

A pulse switch or bistable multivibrator 178 includes a pair of NPN junction transistors 180 and 182. The emitter electrodes of the transistors 180 and 182 are connected together to the low potential line 76. The collector electrode of the transistor 180 is connected through a biasing resistor 184 to the high potential line 74 and is connected through a biasing resistor 186 to the base electrode of the transistor 182. The collector electrode of the transistor 182 is connected through a biasing resistor 188 to the high potential line 74 and is connected through a biasing resistor 190 to the base electrode of the transistor 180. The base electrode of the transistor 180 is connected through a biasing resistor 192 to the low potential line 76 and is connected through a coupling diode 194 to the junction 170 in the timing pulse generator 130. The base electrode of the transistor 182 is connected through a biasing resistor

196 to the ground line 76 and is connected through a coupling diode 198 to the junction 172 in the timing pulse generator 130.

When a timing pulse P appears at the junction 172, it is coupled through the diode 198 and the resistor 196 to the base electrode of the transistor 182. As a result, the transistor 182 is rendered fully conductive. With the transistor 182 turned on, the transistor 180 is rendered fully nonconductive through the biasing action of the transistor 182 and the resistor 190. With the transistor 180 turned off, the transistor 182 is maintained turned on through the biasing action of the resistors 184, 186, and 196. This is the first state of the bistable multivibrator 178. Alternately, when a timing pulse P appears at the junction 170, it is coupled through the diode 194 and the resistor 192 to the base electrode of the transistor 180. Consequently, the transistor 180 is rendered fully conductive. With the transistor 180 turned on, the transistor 182 is rendered fully nonconductive through the biasing action of the transistor 180 and the resistor 186. With the transistor 182 turned off, the transistor 180 is maintained turned on through the biasing action of the resistors 188, 190, and 192. This is the second state of the bistable multivibrator 178.

It will now be apparent that whether the bistable multivibrator 178 resides in the first state or in the second state is dependent upon the relative relationship between the amplitude of the speed signal S and the amplitude of the reference signal R at the initiation of each timing pulse P. Thus, each timing pulse P which is initiated when the amplitude of the speed signal S exceeds the amplitude of the reference signal R, is applied to trigger the bistable multivibrator 178 to the second state. Alternately, each timing pulse P which is initiated when the amplitude of the reference signal R exceeds the amplitude of the speed signal S is applied to trigger the bistable multivibrator 178 to the first state. Of course, once the bistable multivibrator 178 is triggered to one of the first and second states, it remains in that state until it is triggered to the other of the first and second states.

A buffer switch 200 includes a pair of NPN junction transistors 202 and 204. The base electrode of the transistor 202 is connected directly to the collector electrode of the transistor 182 in the bistable multivibrator 178. The collector electrode of the transistor 202 is connected directly to the high potential line 74. The emitter electrode of the transistor 202 is connected through a biasing resistor 206 to the base electrode of the transistor 204 and through a biasing resistor 207 to the base electrode of the transistor 94 in the reference signal generator 90. The emitter electrode of the transistor 204 is connected directly to the low potential line 76. The collector electrode of the transistor 204 is connected through a biasing resistor 208 to the high potential line 74.

When the bistable multivibrator 178 is in the first state, the transistor 182 is rendered fully conductive. With the transistor 182 turned on, the transistor 202 is rendered relatively nonconductive. With the transistor 202 relatively nonconductive, the transistor 204 is rendered fully nonconductive through the biasing action of the resistor 206 and the transistor 202. Similarly, the transistor 94 is rendered fully nonconductive through the biasing action of the resistor 207 and the transistor 202. With the transistor 94 turned off, the reference signal R is at the upper reference level L_u. When the bistable multivibrator 178 is in the second state, the transistor 182 is rendered fully nonconductive. With the transistor 182 turned off, the transistor 202 is rendered highly conductive, the transistor 204 is rendered fully conductive through the biasing action of the resistor 206 and the transistor 202. Likewise, the transistor 94 is rendered fully conductive through the biasing action of the resistor 207 and the transistor 202. With the transistor 94 turned on, the reference signal R is at the lower reference level L_o.

A control switch or throttle switch 210 is schematically illustrated as including a pair of switch terminals 212 and 214 and a switch arm 216. The arm 216 is pivotably movable about the terminal 212 into and out of electrical contact with the terminal 214. When the throttle switch 210 is in a closed position, the arm 216 is in electrical contact with the terminal 214. When the throttle switch 210 is in an opened position, the arm 216 is out of electrical contact with the terminal 214. A conventional dashpot device 218 is connected to the switch arm 216 through a push rod 220 and is connected to the throttle valve 26 through the linkage 66. The dashpot device 218 is responsive to movement of the throttle valve 26 toward the closed position at a predetermined rate to place the throttle switch 210 in the closed position.

The terminal 212 of the throttle switch 210 is connected directly to the collector electrode of the transistor 204 in the buffer switch 200. The terminal 214 of the throttle switch 210 is connected directly to the base electrode of an output transistor 224. The emitter electrode of the transistor 224 is connected directly to the low potential line 76. The collector electrode of the transistor 224 is connected directly to the control line 58 between the controller 36 and the synchronizer 38 through the output line 68.

When the throttle switch 210 is in the opened position in response to acceleration or steady running of the engine 10, the transistor 224 is rendered fully nonconductive. With the transistor 224 turned off, the control line 58 is uneffected by the deceleration fuel control circuit 60. Accordingly, the electronic fuel injection system 30 is placed in an enabled condition. However, when the throttle switch 210 is in the closed position in response to deceleration of the engine 10, the conductive condition of the transistor 224 is dependent upon the conductive condition of the transistor 204 in the buffer switch 200. If the transistor 204 is turned on, the transistor 224 remains fully nonconductive through the biasing action of the transistor 204. Conversely, if the transistor 204 is turned off, the transistor 224 is rendered fully conductive through the throttle switch 210 and the biasing action of the resistor 208. With the transistor 224 turned on, the control line 58 is effectively clamped to the ground potential on the low potential line 74 through the output line 68 and the transistor 224. Consequently, the electronic fuel injection system 30 is placed in a disabled condition in which no control pulses are applied from the controller 36 to the synchronizer 38. Thus, the fuel injectors 32 are deenergized to completely withhold fuel from the engine 10.

The general operation of the deceleration fuel control circuit **60** may be best understood by reference to FIGS. **4**, **5**, and **6**. FIG. **6** depicts a typical deceleration operating curve for the engine **10** in terms of speed and time. Before time t_1, the accelerator pedal **28** of the engine **10** is actuated to pivot the throttle valve **26** toward the fully opened position or the high power position thereby to increase the demand for power from the engine **10**. With the throttle valve **26** moved toward the fully opened position, the throttle switch **210** is placed in the opened position. With the throttle switch **210** in the opened position, the transistor **224** is turned off to enable the electronic fuel injection system **30**. In the enabled condition, the electronic fuel injection system **30** applies fuel to the engine **10**. Further, with the throttle valve **26** moved toward the fully opened position, the speed of the engine **10** increases.

Initially, the engine speed increases from below an upper speed level N_u before the time t_1. With the speed of the engine **10** below the upper speed level N_u, the amplitude of the speed signal S always exceeds the amplitude of the reference signal R at the initiation of each of the timing pulses P as shown by the (+) in FIG. **5***b*. Hence, the timing pulses P are applied to trigger the bistable multivibrator **178** to the second state. With the bistable multivibrator **178** in the second state, the transistor **94** is turned on to define the amplitude of the reference signal R at the lower reference level L_o. The lower reference level L_o is set such that the amplitude of the speed signal S at the initiation of each of the timing pulses P just falls below the lower reference level L_o as the speed of the engine **10** increases through the upper speed level N_u.

As the engine **10** accelerates before time t_1, the engine speed increases through the upper speed level N_u. With the speed of the engine **10** above the upper speed level N_u, the amplitude of the reference signal R at the lower reference level L_o always exceeds the amplitude of the speed signal S at the initiation of each of the timing pulses P as shown by the (+) in FIG. **5***c*. Thus, the timing pulses P are applied to trigger the bistable multivibrator **178** to the first state. With the bistable multivibrator **178** in the first state, the transistor **94** is turned off to define the amplitude of the reference signal R at the upper reference level L_u. The upper reference level L_u is set such that the amplitude of the speed signal S at the initiation of each of the timing pulses P just rises above the upper reference level L_u as the speed of the engine **10** decreases through a lower speed limit N_o.

At time t_1, the accelerator pedal **28** of the engine **10** is actuated to pivot the throttle valve **26** toward the fully closed position or the low power position to decrease the demand for power from the engine **10**. With the throttle valve **26** moved toward the fully closed position, the throttle switch **210** is placed in the closed position. With the throttle switch **210** in the closed position and the bistable multivibrator in the second state, the transistor **224** is turned on to disable the electronic fuel injection system **30**. In the disabled condition, the electronic fuel injection system **30** completely withholds fuel from the engine **10**. Moreover, with the throttle valve **26** moved toward the fully closed position, the speed of the engine **10** decreases.

As the engine decelerates after time t_1, the engine speed decreases through the upper speed level N_u toward the lower speed level N_o. At time t_2, the engine speed decreases through the lower speed level N_o. With the speed of the engine **10** below the lower speed level N_o, the amplitude of the speed signal S at the initiation of each of the timing pulses P always exceeds the amplitude of the reference signal R at the upper reference level L_u as shown by the (+) in FIG. **5***a*. Hence, the timing pulses P are applied to trigger the bistable multivibrator **178** to the second state. With the bistable multivibrator **178** in the second state, the transistor **224** is turned off to enable the electronic fuel injection system **30** even though the throttle switch **210** remains in the closed position. In the enabled condition, the electronic fuel injection system **30** again applies fuel to the engine **10**.

In addition, with the bistable multivibrator **178** in the second state after time t_2, the transistor **94** is turned on to define the amplitude of the reference signal R at the lower reference level L_o. Further, as fuel is applied to the engine **10** after time t_2, the engine **10** experiences a transient surge condition. That is, the speed of the engine **10** initially rapidly increases above the lower speed level N_o and subsequently gradually decreases below the lower speed level N_o. However, the peak speed of the engine **10** during this transient surge condition is well below the upper speed level N_u. Thus, with the amplitude of the reference signal R at the lower reference level L_o, the amplitude of the speed signal S always exceeds the amplitude of the reference signal R at the initiation of each of the timing pulses P during the transient surge condition. Therefore, the transistor **224** remains turned off to continuously enable the electronic fuel injection system **30**. At time t_3, the speed of the engine **10** finally stabilizes at an idle speed level N_i which is slightly below the lower speed level N_o. Hence, a hysteresis is provided between the upper and lower speed levels N_u and N_o to prevent the speed of the engine **10** from hunting or oscillating about the lower speed level N_o.

It will now be appreciated that the present invention provides a simple but effective technique for completely withholding fuel from an internal combustion engine in response to a decrease in the demand for power from the engine when the engine speed is above the idle speed of the engine. However, it is to be understood that the preferred embodiment of the invention is shown for illustrative purposes only and that various modifications and alterations may be made to the preferred embodiment without departing from the spirit and scope of the invention.

What is claimed is:

1. In an internal combustion engine exhibiting periodic engine cycles having a frequency proportional to the speed of the engine and including a throttle member operable to decrease the demand for power from the engine, the combination comprising: fuel injection means for applying fuel to the engine when enabled and for withholding fuel from the engine when disabled; means for developing a speed signal having an amplitude which increases over the duration of a first fixed portion of each engine cycle such that the amplitude of the speed signal is inversely related to the speed of the engine; means for developing a timing

signal having magnitude permutations each occurring at the expiration of a second fixed portion of each engine cycle which terminates within the first fixed portion; and means for disabling the fuel injection means to withhold fuel from the engine in response to a decrease in the demand for power from the engine when the amplitude of the speed signal at the occurrence of a magnitude permutation in the timing signal is below a reference level corresponding to an engine speed above the idle speed of the engine.

2. In an internal combustion engine exhibiting periodic engine cycles having a frequency proportional to the speed of the engine and including a throttle member operable to decrease the demand for power from the engine, the combination comprising: fuel injection means for applying fuel to the engine when in an enabled condition and for withholding fuel from the engine when in a disabled condition; means for developing a speed signal having an amplitude which increases over the duration of a first fixed portion of each engine cycle such that the amplitude of the speed signal is inversely related to the speed of the engine; means for developing timing pulses each initiated at the expiration of a second fixed portion of each engine cycle which terminates within the first fixed portion; means including a throttle switch operable from a deactuated position to an actuated position in response to a decrease in the demand for power from the engine; and means for placing the fuel injection means in the disabled condition to withhold fuel from the engine when the throttle switch is in the actuated position and the amplitude of the speed signal at the initiation of a timing pulse is below reference level corresponding to an engine speed above the idle speed of the engine.

3. In an internal combustion engine exhibiting periodic engine cycles having a frequency proportional to the speed of the engine and including a throttle member operable to decrease the demand for power from the engine, the combination comprising: fuel injection means for applying fuel to the engine when in an enabled condition and for withholding fuel from the engine when in a disabled condition; speed signal generator means for developing a speed signal having an amplitude which increases over the duration of a first fixed portion of each engine cycle such that the amplitude of the speed signal is inversely related to the speed of the engine; reference signal generator means for developing a reference signal having an amplitude which is substantially constant at a reference level corresponding to an engine speed above the idle speed of the engine; differential switching means operable to a first state when the amplitude of the reference signal exceeds the amplitude of the speed signal and operable to a second state when the amplitude of the speed signal exceeds the amplitude of the reference signal; timing pulse generator means for developing timing pulses each initiated at the expiration of a second fixed portion of each engine cycle which terminates within the first fixed portion; means including a throttle switch operable from a first position to a second position in response to a decrease in the demand for power from the engine; and means for placing the fuel injection means in the disabled condition to withhold fuel from the engine when the throttle switch is in the second position and the differential switching means is in the first state at the initiation of a timing pulse.

4. In an internal combustion engine exhibiting periodic engine cycles having a frequency proportional to the speed of the engine and including a throttle member movable to decrease the demand for power from the engine, the combination comprising: fuel injection means for applying fuel to the engine when in an enabled condition and for withholding fuel from the engine when in a disabled condition; speed signal generator means for developing a speed signal having an amplitude which increases from a base level toward a maximum level over the duration of a first fixed portion of each engine cycle such that the amplitude of the speed signal is inversely related to the speed of the engine; reference signal generator means for developing a reference signal having an amplitude which is substantially constant; differential switching means operable to a first state when the amplitude of the reference signal exceeds the amplitude of the speed signal and operable to a second state when the amplitude of the speed signal exceeds the amplitude of the reference signal; timing pulse generator means for developing timing pulses each initiated at the expiration of a second fixed portion of each engine cycle which terminates within the first fixed portion; means including a throttle switch operable from a first position to a second position in response to movement of the throttle member to decrease the demand for power from he engine; bistable switching means operable to a first state from a second state when the throttle switch is in the second position and the differential switching means is in the first state at the initiation of a timing pulse; means for placing the fuel injection means in the disabled condition to withhold fuel from the engine when the bistable switching means is in the first state; and the reference voltage generator means including means for defining the amplitude of the reference signal at a lower reference level located between the base level and the maximum level at a point corresponding to an engine speed slightly above the idle speed of the engine when the bistable switching means is in the first state and for defining the amplitude of the reference signal at an upper reference level located between the base level and the maximum level at a point corresponding to an engine speed above the peak speed of the engine experienced when fuel is reapplied to the engine after having been withheld from the engine when the bistable switching means is in the second state.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,731,659 Dated May 8, 1973

Inventor(s) Paul N. Barr et al

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

Column 2, line 15 "drive should read -- driven --; line 22, "C_{2a}" should read -- C_2 --; line 28, "c-operate" should read -- cooperate --; line 65, "V_{8a}" should read -- V_8 --. Column 3, line 18, "$-V_{6-7}-V_8$" should read -- $-V_6-V_7-V_8$ --. Column 4, line 22, "48_a-48_{b7}" should read -- 48_a-48_d --; line 50, "48_a-48" should read -- 48_a-48_d --; line 63, "54_a-54" should read -- 54_a-54_d --. Column 5 line 53, "V_1-V_{8a}" should read -- V_1-V_8 --. Column 6, line 42, after "four" insert -- (4) --; line 48, after "four" insert -- (4) --; line 63, "I_1-I_{8a}" should read -- I_1-I_8 --. Column 18, line 36, "he" should read -- the--.

Signed and sealed this 9th day of April 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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