

March 17, 1970

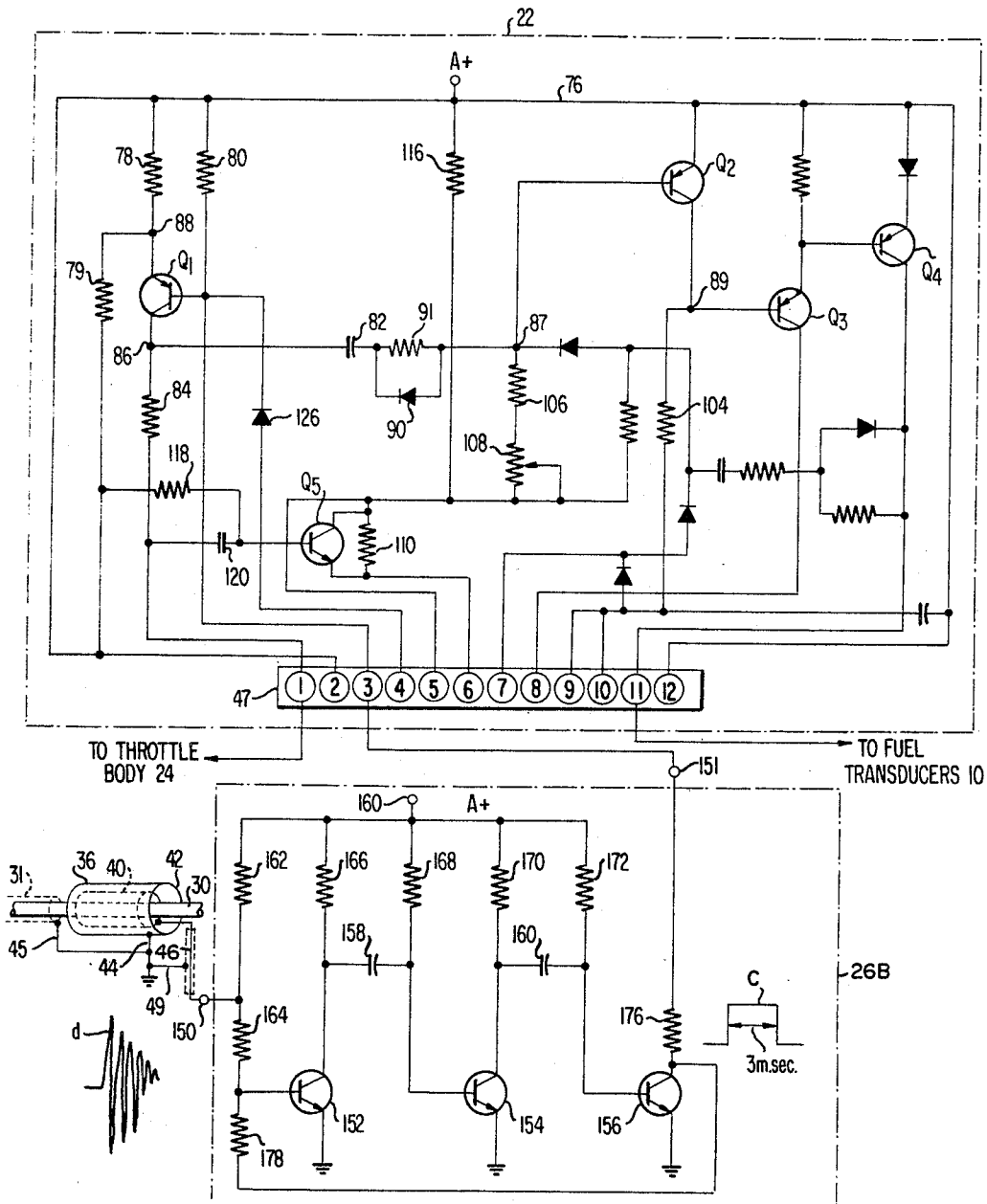
E. D. LONG ET AL

3,500,801

ACTUATOR CIRCUIT FOR ELECTRONIC PRECISION FUEL METERING SYSTEMS

Filed March 21, 1968

2 Sheets-Sheet 2



INVENTORS
E. DAVID LONG
KEITH C. RICHARDSON

BY *Brady, O. Boyle & Gates*

ATTORNEY

1

3,500,801

ACTUATOR CIRCUIT FOR ELECTRONIC PRECISION FUEL METERING SYSTEMS

Emile David Long and Keith C. Richardson, Elmira, N.Y.,
assignors to Gillett Tool Co., Inc., Buffalo, N.Y.

Filed Mar. 21, 1968, Ser. No. 715,056

Int. Cl. F02b 3/00, 33/00; F02p 1/00

U.S. Cl. 123—32

14 Claims

ABSTRACT OF THE DISCLOSURE

The present invention discloses circuit means for triggering a fuel modulator circuit once per engine cycle to control a precision fuel metering system so that a predetermined fuel charge is delivered to each of the cylinders of an engine in accordance with the selected operating engine parameters. The circuit is operable to generate an actuator pulse of predetermined constant pulse width from electrical energy coupled from a spark plug lead.

CROSS-REFERENCE TO RELATED APPLICATION

This invention is related but not limited in use to the following copending U.S. continuation patent application: Ser. No. 809,450, entitled "Electronic Modulator Circuit for Precision Fuel Metering Systems," filed on Feb. 19, 1969, in behalf of E. David Long. This application is also assigned to the assignee of the present invention.

BACKGROUND OF THE INVENTION

This invention is related in application to a precision fuel metering system wherein a plurality of fuel metering transducers are employed for simultaneously or, by adaptation, sequentially delivering measured amounts of fuel to the cylinders of an internal combustion engine, once per engine cycle, in response to a electronic modulator which measures various engine operational and environmental parameters, such as engine manifold air temperature and vacuum, engine water temperature, engine speed, throttle position, and barometric pressure. The amount of fuel fed to each cylinder is dependent upon the length of time each of the fuel metering transducers is held in the open position in response to an energizing pulse of variable pulse width generated by the electronic modulator.

It has heretofore been the practice to actuate the electronic modulator once per engine cycle mechanically by means of a cam and breaker points coupled to the engine camshaft. This concept has been successfully used; however, adaptation to an infinite variety of engines has been difficult and requires a large variety of tooling. It has also been suggested that triggering of the modulator might be accomplished by coupling a signal from a spark plug lead. This teaching is to be found in U.S. Patent No. 3,032,025 issued to E. D. Long et al. It has been found, however, that the high voltage pulse coupled from the spark plug lead cannot properly actuate the modulator in a manner to provide reliable operation of the system. In other words, in actual practice the pulse coupled from the spark plug lead left much to be desired, although in theory it appeared feasible.

SUMMARY OF THE INVENTION

The present invention comprises circuit means for generating a substantially constant width rectangular pulse of predetermined amplitude in response to the high voltage pulse coupled from a spark plug lead to reliably actuate an electronic modulator for precision fuel metering systems under all operating conditions of the engines. The circuit means contemplated includes both capacitive and inductive pickup devices for coupling energy from the

2

relatively high voltage pulse on the spark plug lead and triggering a semiconductor pulse generator which generates a rectangular pulse of sufficient pulse width which when coupled to the modulator circuit will render the modulator circuit operable for a period of time greater than is required for generating the variable pulse width wave form which energizes the fuel metering transducers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a block diagram illustrative of a precision fuel metering system utilizing the subject invention;

FIGURE 2 is an electrical schematic diagram of a first embodiment of the subject invention; and

FIGURE 3 is a schematic diagram of a preferred embodiment of the subject invention coupled to an electronic modulator circuit used in conjunction with a precision fuel metering system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIGURE 1, there is disclosed a block diagram of a precision fuel metering system incorporating the subject invention. The precision fuel metering system comprises a plurality of fuel metering transducers 10 coupled to a fuel rail 12 which is fed at one end from a fuel tank, not shown, via a fuel pump 14 and a pressure regulator 16. A fluid wave inverter 18 which has for its purpose the elimination of all modes of standing waves in the fuel rail 12 is connected to the opposite end thereof and includes an exit port to which is connected a return line 20 to the fuel tank. The wave inverter 18 is described in detail in copending U.S. continuation-in-part patent application Ser. No. 832,962 entitled Fluid Compression and Expansion Wave Converter for Precision Fuel Metering Systems, filed in the name of E. David Long and assigned to the assignee of the present invention. The precision fuel metering system is also described in greater detail in U.S. Patent 3,412,718, entitled "Precision Fuel Metering System" patented Nov. 26, 1968, in the name of E. David Long and also assigned to the assignee of the present invention.

The fuel metering transducers 10 are adapted to be simultaneously or sequentially energized once per engine cycle for a predetermined time interval to deliver a predetermined fuel charge to the engine in accordance with an energizing pulse generated by the modulator circuit 22 in accordance with engine parameters some of which are sensed by devices, not shown, located in the throttle body 24. The subject invention contemplates the addition of an electronic actuator circuit 26 in combination with an electrical energy sampling means 28 coupled to a spark plug lead 30 for generating a constant pulse width actuator pulse for reliably actuating the modulator 22 circuit once per engine cycle. FIGURE 1 also discloses a spark plug 32 mounted in an engine block 34, shown in partial section. The spark plug lead 30 is connected to the spark plug 32 and is coupled back to the engine distributor, not shown. It is the object of the present invention to actuate the modulator circuit 22 completely by electrical means as opposed to the heretofore required cam actuated contacts.

Considering the present invention in greater detail, reference is made to FIGURE 2 which illustrates schematically one embodiment of the subject invention. The energy sampling means 28 shown in FIGURE 1 is illustrated in FIGURE 2 as selectively either a capacitive element 36 or an inductive pickup 38 encircling a portion of the spark plug lead 30. The capacitive element 36 is comprised of an inner and outer conductor 40 and 42, respectively, of a selected length. A circuit lead 44 connects the outer conductor 42 to ground while a shielded signal lead 46, having a predetermined capacity to ground, couples

the inner conductor of 36 to the actuator circuit 26A. The shield of signal lead 46 is grounded by means of circuit lead 49. The inductive member 38 on the other hand is comprised of an enclosed field inductor, for example a toroidal wound coil 48 having one end coupled to ground while the opposite end is connected to circuit lead 50. Circuit lead 50 is also adapted to be coupled to the actuator circuit 26A and contains a capacitor 61 for direct current isolation purposes. Circuit lead 50 is also shielded and has a predetermined capacity to ground. Depending upon which element is desired, both elements 36 and 38 are operative to sample energy in the form of a bipolar energy pulse which decays with time from the spark plug lead 30. The capacitive element 36, however, is the preferred means of coupling to the actuator circuit.

The actuator circuit 26A shown in FIGURE 2 is comprised of a prebiased semiconductor trigger diode 52 which has one electrode connected to ground. The other electrode is connected to an input terminal 53 through circuit lead 54. A storage capacitor 56 is connected directly across the trigger diode 52 while bias resistors 57 and 59 couples a supply potential thereto by means of resistor 58. The A+ supply potential is applied from a source not shown. The common connection between the trigger diode 52, the resistor 58 and the input lead 54 is coupled to the base of an N-P-N transistor 62 by means of a coupling capacitor 64. The emitter of transistor 62 is connected directly to ground while the base is biased from the supply terminal 60 by means of resistor 66. A resistive load is provided for the transistor 62 by means of resistor 68 which is coupled between the collector and the voltage supply terminal 60. The output wave form which comprises a rectangular wave of, for example, three milliseconds duration is taken from the collector of transistor 62 and appears at output terminal 70.

In operation, transistor 62 is biased in a normally ON condition by means of the base bias resistor 66. This condition then provides an output of voltage at terminal 70 which is substantially at ground potential. In absence of an energy pulse coupled from the spark plug lead 30, capacitor 56 charges through resistor 58 to a voltage substantially equal to the bias voltage present at the junction of resistors 57 and 59. The voltage across the capacitor 56 biases the semiconductor diode 52 just below its threshold or breakdown potential. Upon the occurrence of an energy pulse, as indicated by wave form *a*, coupled to the input terminal 53, the semiconductor diode 52 conducts very heavily providing a very low resistance path to ground, whereupon capacitor 56 immediately discharges. Inasmuch as the charge across capacitor 64 cannot change instantaneously the negative going leading edge of the wave form *b* is coupled to the base of transistor 62 which immediately renders it non-conductive. When this occurs, the voltage wave form at the collector of transistor 62 rises to the supply potential A+ as indicated by wave form *c*. When the energy pulse from the spark plug lead diminishes, the semiconductor diode recovers and again becomes non-conductive, whereupon capacitor 56 begins to charge back to the potential at the junction of 57 and 58 according to the RC time constant of resistor 58 and capacitor 56. This recharging of capacitor 56 is sensed through the capacitor 64 and the voltage at the base of transistor 62 also rises so that the transistor is rendered conductive once more when capacitor 56 reaches a predetermined voltage. When transistor 62 becomes conductive once more, the collector voltage immediately drops to substantially ground potential as shown by wave form *c*. In this manner, a rectangular pulse of a constant pulse width is generated at terminal 70 for actuating the modulator each time a high voltage ignition pulse appears on the spark plug lead 30. Moreover, the actuator pulse has a pulse width of constant magnitude irrespective of the nature of the ignition pulse. All that is required is sufficient energy being coupled to the semi-conductor diode to exceed its threshold level. The pulse width of the

wave form *c* is dependent upon the RC time constant of resistor 58 and capacitor 56.

FIGURE 3 schematically illustrates the preferred embodiment of the subject invention utilized in combination with a non-regenerative modulator circuit similar to that described in copending U.S. Continuation Application, Serial No. 809,450, noted earlier. Briefly, the non-regenerative modulator designated by reference numeral 22 operates as follows: as opposed to the modulator described in Ser. No. 809,450, transistors Q1 and Q2 are both normally conductive in a saturated state. Capacitor 82 charges to a voltage which is the difference between the positive A+ supply voltage appearing on the supply bus 76 and the voltage appearing at junction 86. Pin 1 of connector 47 is coupled to junction 86 by means of resistor 84. Pin 1 is also coupled to the wiper arm of a potentiometer, not shown, which is responsive to vacuum pressure present in the throat of the throttle body 24 in FIGURE 1. The capacitor terminal is connected to junction 87 through resistor 91 and diode 90 and is at a value substantially that of the A+ supply potential due to the fact that transistor Q2 base-emitter junction is in a forward conducting mode, as is diode 90. Both act substantially as closed switches. Resistor 91 and diode 90 provide added noise immunity and stability by virtue of the switching action of diode 90 which provides a low impedance path for normal charge of capacitor 82 and a high impedance path for undesired signals.

For proper operation of the modulator circuit 22, the voltage appearing at junction 86 must be allowed to become equal to the voltage at pin 1 of connector 47 and after reaching this potential, junction 86 must be returned to substantially the emitter potential of Q1. The purpose of the present invention, as shown in the actuator circuit 26B of FIGURE 3, is to provide an actuator signal to perform this necessary control function in conjunction with transistor Q1.

Referring now to FIGURE 3, transistor 156 of the actuator circuit 26B is normally in a saturated state by virtue of resistor 172 and therefore acts like a closed switch. Transistor Q1 of the modulator circuit 22 is normally in a saturated state by virtue of base current supplied through resistor 176 and transistor 156. Upon the occurrence of the actuator signal *d*, transistor 156 in the actuator circuit 26B is turned off, thereby acting as an open switch. This turns transistor Q1 off by virtue of the reverse biasing action of resistors 79, 75 and 73 in the base-emitter junction circuit.

During the time that Q1 is turned off, for instance 3 milliseconds as shown in wave form *e* of 26B, the capacitor 82 will charge, at junction 86, to a value substantially equal to the voltage appearing at pin 1 of connector 47. Upon the termination of the actuator pulse *e*, Q1 reverts to its saturated state. Transistor Q1 acts as a closed switch connecting junction 86 to the potential existing at the junction 88 of resistors 75 and 79. Depending upon the voltage that appeared at pin 1 of connector 47 during the actuation pulse interval, (3 milliseconds), the resulting voltage immediately appears at junction 87, due to the fact that the charge on capacitor 82 cannot change instantaneously. This change of potential at junction 87 is in a positive direction. This turns transistor Q2 off whereupon capacitor 82 begins to discharge through the discharge path comprising resistor 91, diode 90, resistor 75, the conductive transistor Q1, the fixed resistor 106, the rheostat 108, and any voltage sources or other elements which may be coupled thereto through pin 5 of connector 47. Transistor Q5 is normally conductive to provide a virtual short circuit across resistor 110 and accordingly does not appear in the discharge path. However, it does have an effect when acceleration is desired at which time transistor Q5 is rendered non-conductive to add the additional resistance provided by resistor 110, thus increasing the discharge time constant of capacitor 82.

When transistor Q1 is rendered conductive and capacitor 82 begins to discharge, it will discharge until the potential at junction 87 reaches substantially a voltage equal to A+, at which time transistor Q2 will be rendered conductive once again. The voltage at the collector of transistor Q2 and junction 89 then is a rectangular wave which is variable in pulse width depending upon the voltage appearing at junction 86 at the time that transistor Q1 is turned on and the value of the discharge time constant of capacitor 82.

Transistors Q3 and Q4 provide an emitter follower and an amplification stage, respectively, which are coupled to the fuel metering transducers shown in FIGURE 1 through pin 11 of connector 47.

Returning now to the instant invention and the embodiment thereof shown in FIGURE 3, a capacitance pickup element 36 is electrostatically coupled to the spark plug lead 30 and comprises an inner sleeve 40 and an outer sleeve 42. The outer sleeve 42 is grounded by means of circuit lead 44 providing an electrical shield for the inner sleeve 40, and also a predetermined capacitance from inner sleeve 40 to ground. A shielded circuit lead 46 is attached to the inner sleeve 40 with the shield of this lead connected to ground by means of circuit lead 49. The shielded lead 46 provides an additional predetermined capacity from the inner sleeve 40 to ground providing essentially a capacitive voltage divider for energy coupled to the actuator circuit 26B from the spark plug lead 30 to the junction of resistors 162 and 164. In addition to providing the predetermined amount of capacity, the shielded lead 46 also prevents pickup of unwanted signals. To further prevent the pickup of unwanted energy, the spark plug lead 30 is shielded by shield 31 over substantially all of its length. The shield 31 furthermore is connected to ground by means of circuit lead 45.

The embodiment of the actuator circuit 26B shown in FIGURE 3 comprises three N-P-N transistors 152, 154 and 156 and are coupled together by means of capacitors 158 and 160, respectively. The base of transistor 152 is biased into a saturated conducting mode by means of two series base bias resistors 162 and 164. Input terminal 150 is coupled to the common connection between resistors 162 and 164. Resistors 162 and 164 additionally provide a resistive input impedance into which the capacitive pick-off element 36 is terminated. A collector load resistor for transistor 152 comprises resistor 166. The base bias resistor of transistor 154 is comprised of resistor 168 while the collector load is comprised of resistor 170. In a similar manner, the base bias of transistor 156 is comprised of resistor 172 while the collector load resistance is comprised of resistor 176 and the input impedance of Q1 and resistor 73 in the modulator 22. A feed back resistor 178 is coupled from the collector of transistor 156 back to the base of transistor 152 for providing a degenerative feed back which inhibits any tendency for high frequency feed back to cause instability of the circuit operation and also improves the noise rejection capabilities of the actuator circuit. A positive supply potential A+ is adapted to be coupled to the transistors 152, 154 and 156 by means of terminal 161 from a supply source, not shown.

The input circuit comprising resistor 162, resistor 164, resistor 166, transistor 152 and capacitor 158 are operated in a manner so that sufficient energy is stored in capacitor 158 to effectively stretch the ignition pulse to a required width to charge capacitor 160 through the action of transistor 154 and resistor 170. Capacitor 160 charges to substantially the supply potential A+. Transistor 156 is turned off when transistor 154 again becomes conductive and is held off by the action of capacitor 160 and resistor 172 for a period of, for example, three milliseconds.

In more detail, the input pulse from the inner sleeve 40 comprises a bipolar energy pulse wave form d which diminishes in amplitude very rapidly. Transistors 152, 154 and 156 are biased normally on into the saturated region of their respective current voltage characteristics so that

they conduct heavily and provide a virtually short circuit or closed switch condition between the collector and emitter electrodes. This being the case, capacitors 158 and 160 both have their terminals substantially shunted to ground and therefore are completely discharged. Upon the occurrence of the high voltage ignition pulse, the positive swing of the pulse will not affect transistor 152 inasmuch as it is already in its conductive state; however, the negative swing will turn transistor 152 off. Capacitor 158 begins to charge towards the supply potential A+ through the resistor 166 and the conducting transistor 154. When the ignition pulse applied to terminal 150 falls to a value wherein transistor 152 is again returned to its conductive state, capacitor 158 has stored sufficient energy to turn off transistor 154. The time that transistor 154 is in the off state is determined by the discharge path of capacitor 158 through the on transistor 152 and resistor 168. When the voltage across capacitor 158 discharges to the point where it can no longer maintain transistor 154 in the nonconducting state, the transistor 154 again conducts heavily by virtue of the bias through resistor 168, meanwhile the capacitor 160 has charged toward the supply potential A+ through resistor 170 and the conducting transistor 156. At the time transistor 154 again becomes conductive the energy stored in capacitor 160 will turn off transistor 156 for a time interval determined by the discharge path of the conducting transistor 154 and the resistor 172. By selectively choosing the time constants of the charge and discharge circuits for capacitors 158 and 160, transistor 156 is turned off and held off for a period of three milliseconds giving rise to a positive going rectangular output signal wave form c at the output terminal 151. This wave form is coupled to pin 3 of the connector 47 of the modulator circuit 22.

A three millisecond positive going rectangular wave is accordingly fed once per engine cycle to the base of transistor Q1 of modulator 22 turning it off for a period longer than is required for generating an energizing wave form for the transducers under all operating conditions of the engine. In effect, the actuator circuit has electronically actuated the modulator circuit as opposed to mechanically actuated switch contacts which were heretofore utilized. Additionally, the circuitry described by the present invention is adapted to provide reliable operation under any reasonable fault in the firing of the spark plugs. Also, the pickup device is selectively placed upon the spark plug lead to provide an effective energy transfer even under relatively badly fouled operation.

While it has been shown and described what is at present considered to be the preferred embodiments of the invention, modifications thereto will readily occur to those skilled in the art. It is not desired, therefore, that the invention be limited to the specific arrangements shown and described, but it is to be understood that all equivalents, alterations, and modifications within the spirit and scope of the invention are herein meant to be included.

What is claimed is:

1. An actuator circuit for an electronic modulator utilized in a precision fuel metering system for delivering a predetermined fuel charge to each cylinder of a spark ignition type engine once per engine cycle, comprising in combination: an electrical energy sampling means located adjacent a spark plug lead for sampling a portion of the high voltage ignition pulse appearing thereon; first electrical shielding means covering a predetermined portion of said spark plug lead; an electronic pulse generating circuit coupled to said energy sampling means, being responsive to the sampled portion of the ignition pulse to produce a substantially constant pulse width actuation signal for said electronic modulator, said electronic pulse generating circuit including, first semiconductor switch means coupled to said energy sampling means, being operative to change conductive states in response to said sampled portion of the ignition pulse, capacitor means coupled to said first semiconductor switch means, being

adapted to change its electrical charge state in accordance with the change in the conductive state of said first semiconductor switch means, and second semiconductor switch means coupled to said capacitor means, being responsive to said change of electrical charge state thereof to be rendered non-conductive for a predetermined period once per engine cycle, thereby producing said substantially constant pulse width actuation signal; a shielded circuit lead including second electrical shielding means, coupled between said electrical energy sampling means and said electronic pulse generating circuit; and circuit means connecting said first and said second electrical shielding means to a point of reference potential.

2. The invention as defined by claim 1 wherein said energy sampling comprises an inductance electrically coupled to said spark plug lead.

3. The invention as defined by claim 2 wherein said inductance element comprises an enclosed field inductor encircling said spark plug lead including two terminal ends, and circuit means for connecting one terminal end to a point of reference potential and circuit means for connecting the other terminal end to said electronic pulse generating circuit.

4. The invention as defined by claim 1 wherein said electrical device comprises a capacitive element coupled to said spark plug lead.

5. The invention as defined by claim 4 wherein said capacitive element comprises a pair of concentric cylindrical members surrounding a portion of said spark plug lead, and circuit means for connecting the outer cylindrical member of said pair to a point of reference potential and circuit means coupling the inner cylindrical member of said pair to said electronic pulse generating circuit.

6. The invention as defined by claim 1 wherein said first semiconducting switch means comprises a semiconductor trigger diode and said second semiconductor switch means comprises a transistor.

7. The invention as defined by claim 1 wherein said first and second semiconductor switch means comprises transistors normally biased in a conductive state of operation.

8. The invention as defined by claim 7 and additionally including another capacitor means and a third transistor biased in a normally conductive state coupled intermediate said capacitor means and said second transistor including circuit means for coupling said third transistor to said first capacitor means and said second capacitor means between said third transistor and said second transistor.

9. The invention as defined in claim 8 wherein said electrical energy sampling means comprises a capacitive pickup element including an inner and outer electrically conductive sleeve concentrically disposed around a portion of said spark plug lead and including means for connecting said outer sleeve to said point of reference potential and circuit means for coupling said inner sleeve to said first transistor.

10. An actuator circuit for an electronic modulator circuit utilized in a precision fuel metering system for a spark ignition type of engine, comprising in combination: an electrical energy sampling means comprising a capaci-

tive pickup element including an inner and outer electrically conductive sleeve concentrically disposed around a portion of said spark plug lead for sampling a portion of the high voltage ignition pulse appearing thereon; circuit means connecting said outer sleeve to a point of reference potential; an electronic pulse generating circuit coupled to said inner sleeve, being responsive to the sampled portion of said ignition pulse to produce a substantially constant pulse width actuation signal for said modulator circuit, said electronic pulse generating circuit including, a first transistor normally biased in a conductive state of operation, means coupling said first transistor to said inner sleeve, said first transistor being operative to become non-conductive in response to said sampled portion of said ignition pulse, first capacitor means coupled to said first transistor being adapted to change its electrical charge state in accordance with the non-conductive state of said first transistor, a second transistor normally biased in a conductive state of operation coupled to said first capacitor means, being responsive to said change of electrical charge of said first capacitor to become non-conductive for a predetermined time period, second capacitor means coupled to said second transistor being adapted to change its electrical charge state in accordance with the non-conductive state of said second transistor, and a third transistor normally biased in a conductive state coupled to said second capacitor, being responsive to said change in electrical charge state of said second capacitor to also become non-conductive for a predetermined interval, said first, second and third transistor becoming non-conductive sequentially once per engine cycle and generating a substantially constant width pulse signal thereby, for operating said modulator circuit.

11. The invention as defined in claim 10 and additionally including degenerative feedback means coupled from said third transistor back to said first transistor.

12. The invention as defined by claim 11 wherein said first and third transistors each include base, collector and emitter electrodes and wherein said degenerative feedback means comprises a resistor coupled from the collector electrode of said third transistor to the base of said first transistor.

13. The invention as defined by claim 10 wherein means coupling said first transistor to said inner sleeve comprises a shielded conductor including a shielding means connected to a point of reference potential.

14. The invention as defined by claim 10 and additionally including electrical shielding means covering a predetermined portion of said spark plug lead.

References Cited

UNITED STATES PATENTS

2,718,883	9/1955	Taylor	123—32
2,736,760	2/1956	Kane	
2,829,631	4/1958	Wilt	123—139
3,020,897	2/1962	Sekine et al.	123—32

LAURENCE M. GOODRIDGE, Primary Examiner

U.S. Cl. X.R.

123—119, 146.5, 148