

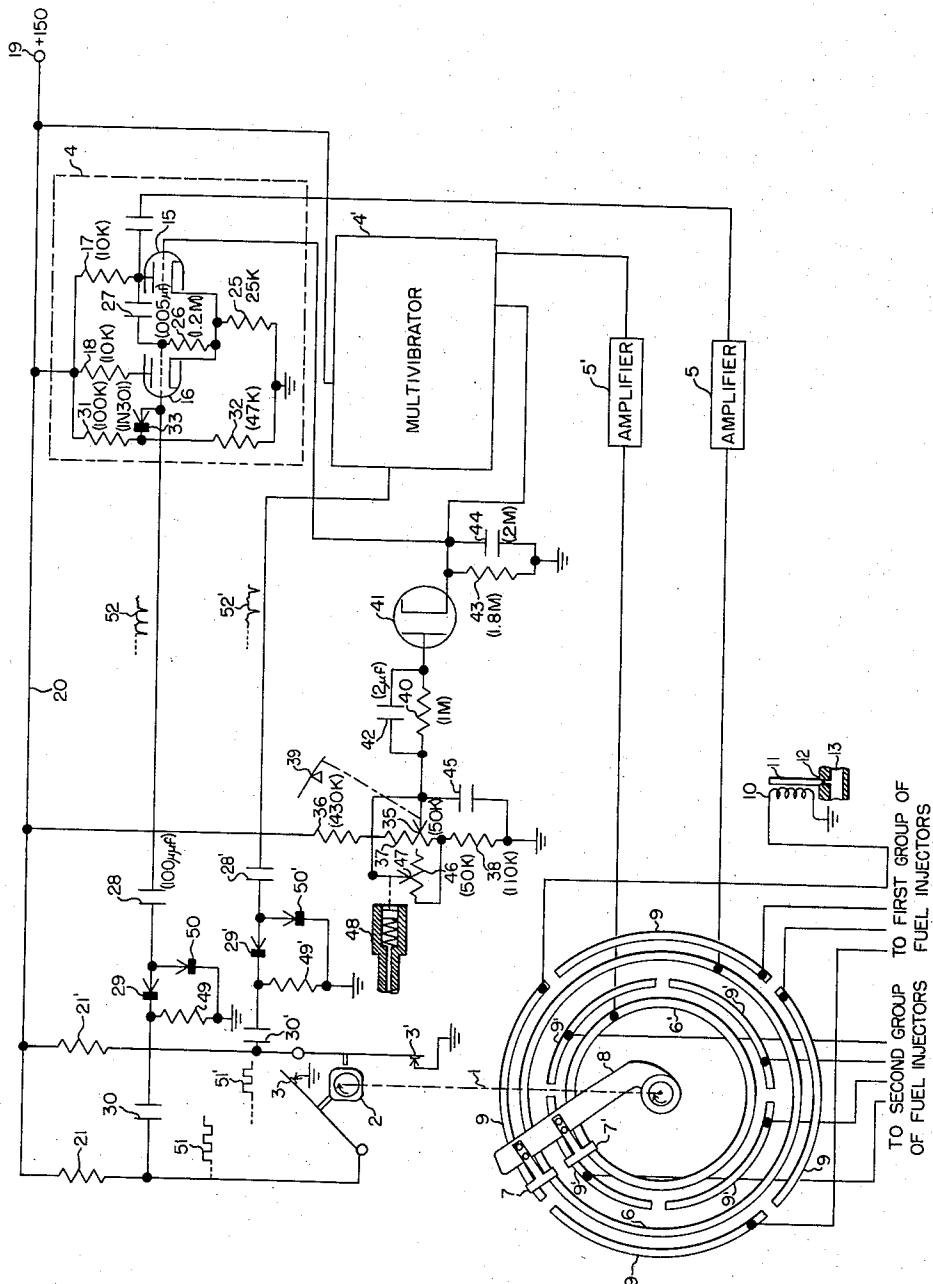
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DUAL MODULATOR FOR FUEL INJECTION SYSTEM

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DUAL MODULATOR FOR FUEL INJECTION SYSTEM

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3 Claims. (Cl. 123—32)

This invention relates to a system for supplying fuel in measured amounts to the individual cylinders of an internal combustion engine in timed relation to engine operation. It relates more specifically to a system conforming to the principles of operation followed by the system disclosed in U. S. patent application Serial No. 567,688, filed February 24, 1956, in the names of Robert W. Sutton et al., for "Fuel Injection System." In that system a magnetically actuated valve for each cylinder is opened for the duration of a pulse of current, the time of occurrence of which is synchronized with engine rotation. The amount of fuel injected is regulated by the duration of the pulse, the pressure on the fuel being constant.

In a system of this type it is necessary to make full utilization of the time available for each valve to remain open. For example, an eight-cylinder engine operating at a speed of fifty-two hundred R. P. M. provides a maximum actual open time for its fuel injection valves of approximately two milliseconds. Since it is desired to maintain a ratio of four-to-one between maximum and minimum open times for the valves, it is apparent that the time required to open each valve must be reduced to a minimum. A method for accomplishing the reduction in valve operating time is disclosed in my U. S. patent application Serial No. 608,798, filed September 10, 1956. However, there are circumstances under which the reduction in valve operating time to a practical minimum is inadequate, although still useful. The most obvious case is that where the interval between propelling explosions is further reduced, as by an increase in peak speed, an increase in the number of cylinders or a change from a four-stroke cycle to a two-stroke cycle. A less obvious case arises from the fact that minor differences between valves become quite prominent when the valves are operated to open for a fraction of a millisecond, in the present state of the art. A marked improvement in the regularity and reliability of operation of the valves may be had by constructing the valves and arranging the circuit to obtain the least practical minimum operating time, but then operating the valves so that the minimum open period is significantly greater, up to perhaps twice this least practical period. In turn, this may require that the maximum operating period shall be greater than the interval between successive explosions at the maximum engine speed.

It is accordingly an object of this invention to provide, in a system such as that referred to above, the means for increasing the time available for valve open periods without infringing on the engine design factors.

It is a further object to provide means for improving the reliability and metering accuracy of a system such as that referred to above.

These and other objects and advantages of the invention are realized by dividing the valves into two or more groups selected so that successive valve operations proceed regularly from one group to another in an orderly

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pattern, and further, by providing for each group a separate driver, each driver triggered by pulses from a separate contactor device. However, I stop short of complete multiplication of the system, which would introduce new problems of a practical nature almost as severe as those we are avoiding. In particular, I avoid multiplication of the pulse width control devices, and prefer to operate the contactor devices by means of a single cam, with the distributor in the form of a multiple commutator driven by the same shaft that carries the cam.

The single figure shows schematically a system in which the valves have been divided into two groups. The system shown has been chosen as typical, but any system in which pulse width is responsive to and regulated by the value of an electrical current or potential may be divided similarly. To avoid confusing the drawing with unnecessary detail the valves have been shown only partially and schematically, and the mechanical connections between parts have been merely indicated in conventional fashion.

Referring more particularly to the drawing, there is shown a shaft 1, which may be the usual distributor shaft, having secured thereon for rotation therewith a cam 2. The cam is shown as four-lobed to conform to an eight-cylinder engine. The cam 2 drives the movable contact of a single pole, single throw switch 3, and an identical switch 3' so located as to operate alternately with switch 3.

One contact of the switch 3 is connected, in a manner to be described later, to the control grid of one tube of a multivibrator 4, and the other contact is connected to the potential reference plane designated by the grounding symbol. The output of the multivibrator is coupled to an amplifier 5, which has its output applied by way of an annular contact member 6 to a wiping contact element 7 carried by an arm 8 of non-conductive material secured on the shaft 1 for rotation therewith.

The contact 7 makes sequential wiping contact with four contact segments 9. Each of the segments 9 is connected through a respective solenoid 10 to ground. Each solenoid actuates a valve rod 11 which is received in a seat 12 connecting with a portion of the manifold 13 adjacent a respective cylinder of the engine, the structure being shown in detail in U. S. patent application Serial No. 637,852 filed February 4, 1957, in the names of Robert W. Sutton, Stephen G. Woodward and Curtis A. Hartman.

Similarly, a contact of switch 3' is connected to an identical multivibrator shown generally by the block 4', which feeds an amplifier 5'. The output of amplifier 5' is connected by annular contact member 6' to a wiping contact element 7' carried by the shaft 1. The contact 7' also makes sequential wiping contact with four contact segments 9', each of which is connected through a respective solenoid 10' to ground.

The multivibrator 4 is composed of a pair of triodes 15 and 16 having their plates connected respectively through resistors 17 and 18 to the positive terminal 19 of a source of regulated supply voltage. This terminal is also connected by way of a conductor 20 and a resistor 21 to the first mentioned contact of switch 3. The cathodes of tubes 15 and 16 are connected together and by a resistor 25 to ground. They are also connected to the grid of tube 16 by a resistor 26. This grid is also connected to the plate of tube 15 by way of a capacitor 27 and to the first mentioned contact of switch 3 by way of a capacitor 28, a diode 29, and a capacitor 30.

The conductor 20 is connected to ground by way of a pair of resistors 31 and 32. The junction of these resistors is connected to the grid of tube 16 through a di-

ode 33, the cathode of the diode being connected to the junction of the resistors.

A connection to ground is also provided from the conductor 20 through serially connected resistors 36, 37 and 38. A movable tap 35 on resistor 37 is mechanically driven by the throttle actuating lever or accelerator 39 or by the throttle. The movable tap 35 is connected by way of a resistor 40 and a diode 41 to the control grid of tube 15. The resistor 40 is shunted by a capacitor 42. The junction of diode 41 and the grid of tube 15 is connected to ground through a resistor 43 shunted by a capacitor 44.

The tap 35 is connected to ground by way of a capacitor 45. The junction of resistors 37 and 38 is connected to the junction of capacitor 45 and tap 35 through a resistor 46 and to a movable tap 47 on that resistor. The tap 47 is driven by a piston 48 in response to manifold pressure.

The junction of capacitor 30 and diode 29 is connected to ground through a resistor 49. The other terminal of diode 29 is connected by a diode 50 to ground.

The elements comprising resistors 21 and 49, capacitors 28 and 30, and diodes 29 and 50 are connected as a pulse forming network. An identical network is similarly connected to the conductor 20, the second contactor 3' and the second multivibrator 4', the reference characters being primed.

In the operation of the system described above, the cam 2 closes the switch 3 once while the contact element 7 is sweeping each of the segments 9. The first mentioned contact of the switch is alternated by this action between ground potential and the positive potential at the adjacent terminal of the resistor 21 to provide an output of square waveform as indicated at 51. This waveform is differentiated by the capacitor 30 and the resistor 49, and the negative-going excursions thereof are applied by way of the capacitor 28, to the control grid of the tube 16, providing a waveform as at 52.

The tube 16 is normally conducting and is triggered by each negative excursion into a period of non-conduction. The tube 15, which has been cut-off while tube 16 was conducting, is, by virtue of the cathode coupling, now rendered conductive and continues to conduct for a period of time, the duration of which depends upon the bias existing in its input circuit. During this period of conduction a negative-going output pulse is applied from the plate of tube 15 to the amplifier 5, and after amplification is applied to the contact element 7, and thence, through the segment 9 in contact therewith to one of the solenoids 10. There it produces a current impulse of the same duration which holds open the associated valve 11, allowing fuel under pressure to spray into the manifold.

The bias applied to the control grid of the tube 15 depends in part on the voltage appearing at the movable tap 35 and in part on the proportion of that voltage level which is applied to the control grid.

The voltage at the movable tap 35 is determined by the values of resistors 36, 37, 38 and 46 and the positions of the movable taps 35 and 47. The voltage at the tap 35 is increased by depression of the throttle actuating pedal or accelerator 39.

The proportion of the voltage level at the tap 35 which is applied to the control grid of tube 15 is normally determined by the voltage divider composed of resistors 40 and 43. But the capacitances of capacitors 42 and 44 are selected, in accordance with the invention, to be such that these capacitors, acting as a capacitive voltage divider, will, in response to a sudden depression of pedal 39, raise the level of the voltage at the grid of tube 15 above that which would be provided by the action of the resistive voltage divider 40, 43. When the pedal is brought to rest the capacitors will discharge through the respective resistors which they shunt and the voltage

level will be determined again by the resistive voltage divider.

Since the mode of operation of the multivibrator 4 is dependent upon the values of the components in its circuitry, typical values for these elements have been applied to the drawing for consideration in connection with the following description of the operation of the circuit.

In its quiescent state the tube 16 is conducting to saturation and tube 15 cut off. The voltage dividing action of resistors 31 and 32 will provide, at the grid of tube 16, a voltage of about 48 volts, with a supply potential of 150 volts. The grid is clamped at this upper level by the diode 33, and the cathodes are about a volt higher in potential. The conduction of the tube holds the cathodes of both tubes well above the cutoff potential of tube 15 for all values of bias applied to its grid as determined by the positions of taps 35 and 47.

The application of one of the negative-going spikes of waveform 52 to the grid of tube 16 drives the tube momentarily below saturation and the voltage on its cathode and that of tube 15 rapidly declines. This initiates conduction of tube 15. The condenser 27 is charged by the plate current of tube 15, driving the grid of tube 16 more negative and this regenerative condition continues until tube 16 is cut off and tube 15 is conducting at a level determined by the bias on tube 15. This action determines the potential difference across the resistor 26, diode 33 having been cut off by the reversed potential across it.

The capacitor 27 now begins to discharge across the resistor 26 and this continues until the voltage at the grid of tube 16 rises to a level such that conduction begins again in tube 16. This raises the voltage on the cathodes and reduces conduction in tube 15. The reduced plate current of tube 15 further reduces the charge on capacitor 27 and this regenerative action persists until tube 16 is again conducting to saturation and tube 15 is cut off. The duration of the pulse is increased by an increase of the positive bias on the grid of tube 15, since this increases the change of potential at the anode of tube 15 and shortens the grid base of tube 16 by reducing its anode-to-cathode potential at the first transition. Both of these changes require a greater change in charge of capacitor 27 to initiate the second transition which terminates the pulse.

The diodes 29 and 50 make the time constant of the loop around capacitor 28 much longer for positive alternations of the square wave 51 than for the negative alternations. This permits negative spikes of short duration and large amplitude to be applied to the grid of tube 16 to initiate the pulses, while allowing the positive portions of the timing signal to be increased in duration and reduced in amplitude sufficiently as to be relatively ineffective to terminate the pulses.

The foregoing description of operation has been written with respect to one channel, but may be read with respect to the succession of similar elements designated by like primed numbers to represent the second channel, remembering that the bias control group which serves to control the pulse width is common to all channels. Each channel drives its apportioned share of the fuel injectors, each such group of fuel injectors being selected to be identified with a regularly spaced succession of cylinders in the firing order.

The time available for the operation of a valve under any given set of circumstances is multiplied directly by the number of channels. The actual time the valve may be held open is always less than the available time, the "dead time" being essentially the sum of the time required to establish the magnetic field and move the valve, and the time required for the multivibrator to attain all of the conditions pertaining to its stable state, after having timed a valve operating pulse. Since the "dead time" is a constant which does not increase with the available time, the actual time is increased by a factor somewhat

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greater than the number of channels. In the example given earlier, the change from a single to a dual channel arrangement would increase the available time by a factor of 2, from 2 milliseconds to 4 milliseconds, but would increase the actual open time by a factor of $2\frac{1}{3}$, from 1.5 milliseconds to 3.5 milliseconds

The fuel may be injected into the cylinder either directly or by way of an air induction port and valve without affecting the operation of the invention, except that in the latter case the injection valve should close before the air induction valve for most uniform fuel distribution.

What is claimed is:

1. In a system for injecting measured amounts of fuel into the cylinders of an internal combustion engine in synchronism with the rotation thereof, a first group of electromagnetically actuated fuel injection valves for sequentially releasing fuel under pressure into a group of cylinders the members of which are non-adjacent in the firing order, a second group of said valves for releasing fuel into a group of cylinders the members of which are individually successive in firing order to members of said first group of cylinders, a first source of electrical pulses having a range of controllable duration and being synchronized to engine rotation for sequentially actuating said first group of valves, and a second source of pulses for actuating said second group of valves, said pulses from said sources overlapping in time through at least a portion of their ranges of duration.

2. In a system for injecting measured amounts of fuel into the cylinders of an internal combustion engine in synchronism with the rotation thereof, a first group of electromagnetically actuated fuel injection valves for sequentially releasing fuel under pressure into a group of cylinders the members of which are non-adjacent in the firing order, a second group of said valves for releasing fuel into a group of cylinders the members of which are individually successive in firing order to members of said first group of cylinders, a first source of electrical pulses having a range of controllable duration and being synchronized to engine rotation for sequentially actuating

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said first group of valves, a second source of pulses for actuating said second group of valves, said pulses from said sources overlapping in time through at least a portion of their ranges of duration, and common means for controlling said duration of said pulses from both said sources.

3. In a system for injecting measured amounts of fuel into the cylinders of an internal combustion engine in synchronism with the rotation thereof, a first group of electromagnetically actuated fuel injection valves for sequentially releasing fuel under pressure into a group of cylinders the members of which are non-adjacent in the firing order, a second group of said valves for releasing fuel into a group of cylinders the members of which are individually successive in firing order to members of said first group of cylinders, a first means responsive to an electrical impulse to produce an electrical output pulse of controllable duration, means driven in synchronism with the rotation of said engine to generate a first series of uniformly spaced electrical impulses and apply them to said first pulse producing means, a second pulse producing means similar to said first such means, a second impulse generating means driven in synchronism with the rotation of said engine to generate a second series of uniformly spaced electrical impulses occurring immediately of the impulses of said first series, and apply the impulses of said second series to said second pulse producing means, means exercising common control over the duration of the pulses produced by said first and second pulse producing means, a first commutating means driven in synchronism with the rotation of said engine to connect the output of said first pulse producing means to a respective valve of said first group for the duration of each of the said output pulses thereof, and a second commutating means driven in synchronism with the rotation of said engine to connect the output of said second pulse producing means to a respective valve of said second group for the duration of each of the said output pulses thereof.

No references cited.