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Mauch et al.

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[54] **FUEL INJECTION ARRANGEMENT**

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[51] **Int. Cl.**... **F02m 51/00**
[58] **Field of Search**............................... 123/32 EA

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[57] **ABSTRACT**

The arrangement includes a temperature-dependent resistor positioned in the air-intake passage of the engine. A heating current is made to flow through the resistor. The current has a first component sufficient to maintain the resistor at a predetermined temperature in the absence of air flow in the air-intake passage. The current has a second component superimposed upon but distinguishable from the first component and equal to zero in the absence of air flow; the second current component increases sufficiently in response to the cooling effect of air flow as to maintain the resistor at the predetermined temperature. A timer generates fuel-injection pulses whose pulse duration is a function of the second current component.

20 Claims, 3 Drawing Figures

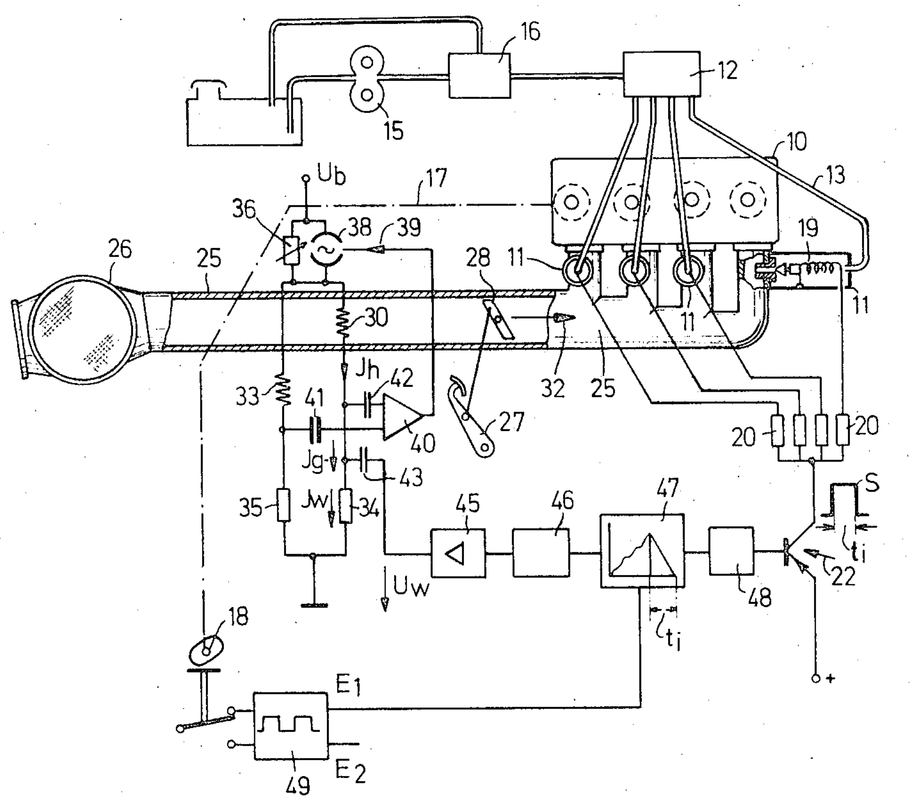
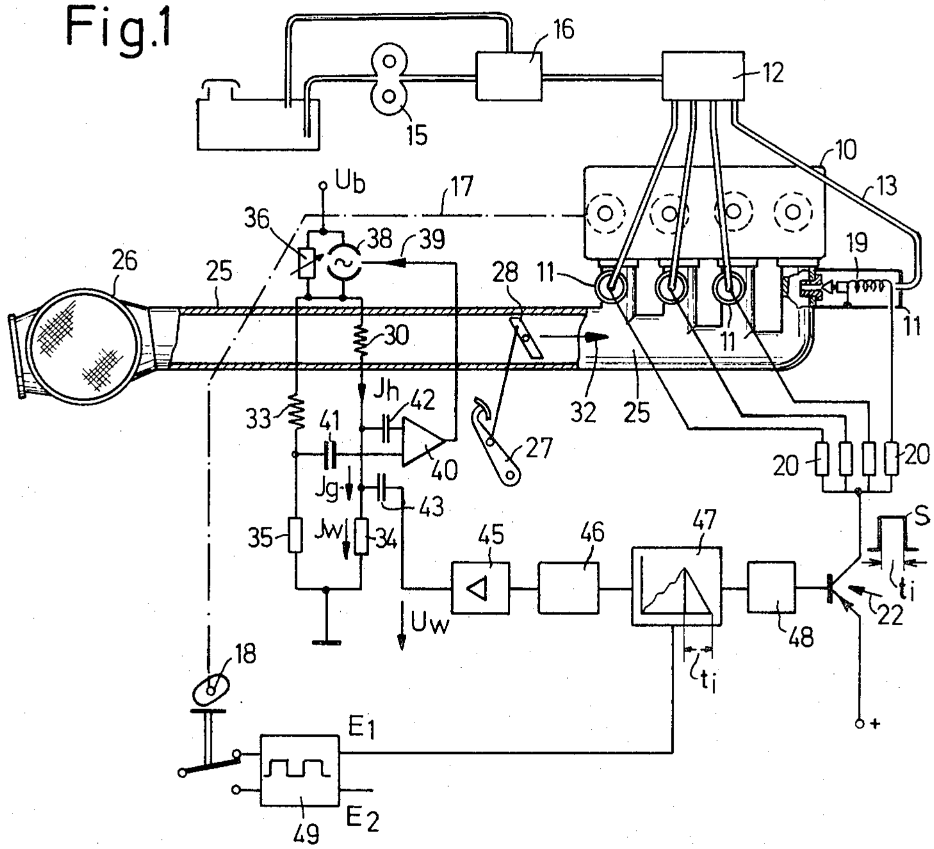


Fig.1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E1
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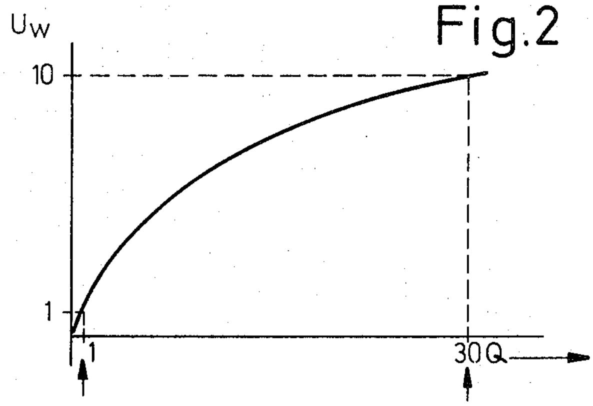
Fig.2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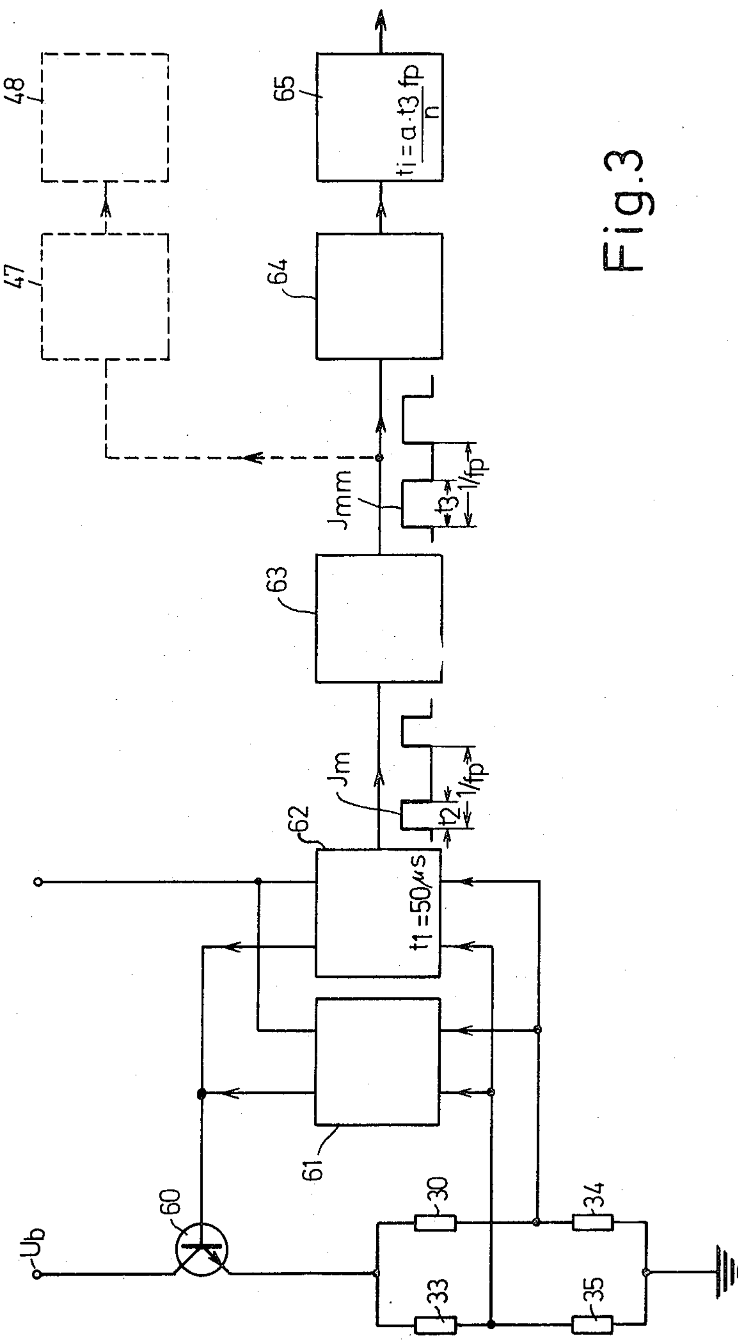
48
47
65
$t_i = \frac{a \cdot t_3 \cdot f_p}{n}$
64
63
Jmm
t3
1/fp
62
Jm
t2
1/fp
t1 = 50µs
61
60
Ub
30
33
34
35

Fig.3

FUEL INJECTION ARRANGEMENT

BACKGROUND OF THE INVENTION

The invention relates to arrangements for controlling fuel injection in internal combustion engines.

More particularly the invention relates to electronic fuel-injection control arrangements of the type which determine the amount of fuel to be injected either per unit time or per combustion cycle per cylinder.

Still more particularly the invention relates to such electronic control arrangements as control fuel-injection as a function of the amount of air flowing into the intake passage of the engine.

An arrangement of this type is already known for controlling the injection of fuel into each of the engine cylinders via the respective injection valves. That arrangement includes a temperature-dependent resistor positioned in the air-intake passage of the engine. The temperature-dependent resistor is heated by a separate heating coil located in the immediate vicinity of the temperature-dependent resistor. The heating coil serves to transfer heat to the temperature-dependent resistor at a constant rate. Because the temperature-dependent resistor is located in the air-intake passage of the engine it will be subjected to the cooling effect of air inflow, and such cooling effect will increase with increasing air flow and decrease with decreasing air flow, resulting in a corresponding variation of the conductivity of the resistor. This resistance variation is exploited for the purpose of controlling the length of time for which the fuel-injection valves are opened, and thus for controlling the quantity of fuel injected into the respective cylinders. To this end, the prior art employs the temperature-dependent resistor as one arm of a bridge circuit. The voltage across the bridge diagonal varies as a function of the air intake flow, and thus constitutes an electrical signal indicative of such flow. This bridge-diagonal voltage is used in the prior art to control the astable period of a multivibrator determining the length of time for which the respective injection valves are opened.

One disadvantage of this prior-art arrangement is that inaccuracies in the electrical indication of the air inflow result from variations in the voltage supply providing current for the heating coil. Greater accuracy can be achieved if the temperature-dependent resistor is heated not by a separate heating means, but instead by the actual current flowing through it, particularly when an electronic control arrangement is used for maintaining the current at such a value as to result in a practically constant temperature of the temperature-dependent resistor when the air inflow is zero. With such an approach, the magnitude of the heating current will itself provide an indication of the time average of the air inflow rate.

This method of monitoring air flow, by monitoring the current necessary to maintain a temperature-dependent resistor at a constant temperature despite the cooling effect of air flow, is very well suited for fuel-injection systems. In actual practice, the constant-temperature method provides very short response times, for instance about **10** msec or less, so that variations in the magnitude of the regulated heating current very closely follow the variations in the actual air inflow rate. With this constant-temperature method, the temperature-dependent resistor is employed as one of the four resistance arms of a resistance bridge, the other three resistors being substantially independent of temperature and located outside the air inflow passage. The bridge has two diagonals. The voltage across one of the diagonals is used as the input signal for the current control means, and the output of the current control means is a voltage applied directly across the other of the bridge diagonals, so that the output of the current control means provides a variable supply of heating current to the temperature-dependent resistor. The greater the rate of air inflow, the greater the bridge imbalance, the greater input signal to the current control means, the greater the output voltage, and the greater the heating current through the temperature-dependent resistor.

This prior-art arrangment suffers from two considerable disadvantages. It is necessary when the motor is at a standstill for the measuring bridge to be balanced, and therefore the current control means must provide enough current even at standstill to maintain the temperature-dependent resistor at the predetermined constant temperature. In constrast, when the air inflow rate is maximum, which occurs upon full load conditions and/or at high speeds, the magnitude of the heating current necessary to maintain the temperature-dependent resistor at the predetermined temperature is double or triple that which is necessary when the air inflow rate is zero. The actual information concerning the air inflow rate is not represented by the magnitude of the heating current, but rather by its deviation from the base value needed to maintain the predetermined temperature in the absence of air flow, and thus it is desired to suppress the informationless base current, by means of a differentiating stage, for example. However, formation of the time derivative of the heating current is not mathematically equivalent to the deviation of the heating current from its base value, so that inaccuracies result in the electrical measuring signal, and these inaccuracies can be very considerable.

A second disadvantage of the prior-art arrangements results from the mathematical relationship between the heat-power N_H dissipated in the temperature-dependent resistor and the time-average of the air inflow rate Q, this relationship being $N_H = Q^{1/2}$. Moreover, this non-linearity is further compounded by reason of the non-linear relationship between the dissipated heat energy and the magnitude of the heating current. Specifically, the input signal for the current control means is usually the voltage U_S developed across that bridge diagonal defined by the junction of the temperature-dependent resistor and the resistor directly in series therewith. Thus, the numerical proportionality between the monitoring voltage U_S, proportional to the heating current magnitude, and the air inflow rate is $U_S \sim Q^{1/4}$. This extreme non-linearity, by a power of 4, means that even when the air inflow rate Q varies considerably, the monitoring voltage U_S will vary to a far lesser degree. For example, the ratio of minimum to maximum air inflow rate for the range of normal engine operation may be about 1:35, while the ratio of corresponding minimum to maximum monitoring voltage will be as little as 1:2.5, which imposes very great limitations upon the accuracy realizable with such an air-flow monitoring arrangement.

SUMMARY OF THE INVENTION

It is the general object of the present invention to provide an airflow monitoring arrangement for use in fuel-injection arrangements which is not possessed of the disadvantages enumerated above.

This object, and others which will become more understandable below, can be met, according to the invention, by providing a temperature-dependent resistor in the air-intake passage. Control means is provided, and furnishes to said resistor a heating current having a first current component sufficient to maintain the resistor at a predetermined temperature in the absence of air flow in said passage, and a second current component superimposed upon but distinguishable from said first component and equal to zero in the absence of air flow and varying sufficiently in response to the cooling effect of air flow to maintain the temperature-dependent resistor at the predetermined temperature. Timing means generates fuel-injection pulses whose pulse-duration is a function of the second current component.

It is contemplated, for example, to provide a heating current composed of a first D.C. component and a second, periodic component which varies as a function of the air inflow rate, and which is equal to zero in the absence of air flow. The second or periodic component may be a simple sinusoid whose amplitude varies in accordance with the air flow, or it may be a train of rectangular pulses whose frequency and/or pulse-duration varies with air flow. Other possibilities will be self-evident. For example, it would be possible to provide a heating current having first and second sinusoidal components of greatly different frequencies, the amplitude of the first sinusoidal component being constant, and the amplitude of the second sinusoidal component varying with the air inflow rate. Likewise, the first current component might be sinusoidal, whereas the second component might be a steady D.C. current whose steady magnitude varies as a function of air inflow. Other variations are possible, so long as the two components of the heating current are readily distinguishable.

In a preferred embodiment of the invention, the second current component consists of a train of heating pulses whose frequency f_p is automatically controlled by the heating-current control means and serves as an indication of the air inflow rate. It is particularly simple and advantageous if the pulse duration t_i of these heating pulses be constant.

When the second current component is a train of heating pulses, as just described, experience has shown it to be particularly advantageous for the pulse-duration of the heating pulses to be about 10 microseconds, and for the frequency f_p of the pulse train to range from about 1 kHz— preferably about 2 kHz—at idling to about 20 kHz—preferably about 12 kHz—at full load and at high speeds of the engine.

In a preferred embodiment, modulating means is provided for creating an additional train of pulses having a frequency f_p identical to the frequency of the train of heating pulses, but having a pulse-duration proportional to the frequency f_p. Experience has shown it to be very advantageous for the modulating means to generate a pulse train having a pulse-duration of about 10 microseconds and a frequency of about 2 kHz at idling, and a pulse-duration of about 60 microseconds and a frequency of about 12 kHz at full load and/or high speeds of the engine.

The auxiliary train of duration-modulated and frequency-modulated pulses must be transformed into signals corresponding directly to the amount of fuel to be injected, either on a per-unit-time basis or on the basis of the amount per cylinder per combustion cycle, or on another desired basis, and most often representing directly the length of time for which individual fuel-injection valves are to be opened. Because the generated pulses are in fact both frequency-modulated, the transformation is simple and direct. The train of pulses can simply be integrated, during a predetermined fraction of the crankshaft rotation cycle. For instance, an integrating capacitor can be connected to a constant-current source via a switch controlled by the train of frequency-modulated and duration-modulated pulses. The pulse train is applied to and gates the switch for a predetermined fraction of the crankshaft rotation cycle, and the voltage to which the capacitor charges will be directly proportional to the air inflow rate, in contrast to the prior-art arrangements where the flow-indicating signal was proportional only to the fourth-root of the air inflow rate. Now if the charged capacitor is caused to discharge through a constant-current source, i.e., effecting a constant-current discharge of the capacitor, then the total time from the start of the discharge until the reaching of zero voltage will be proportional to the air inflow rate. Means responsive to the existence of charge on the integrating capacitor can be provided, in order to furnish a valve-opening signal for the entire time of the discharge, and it will be appreciated that the duration of such valve-opening signal will be proportional to the air inflow rate. By employing the expedient of modulating both the frequency and pulse duration of the train of gating pulses, excellent accuracy can be obtained, even when the ratio of the minimum to maximum valve-opening times is as great as 1:36.

It has already been mentioned that the heating current through the temperature-dependent resistor includes a first current component and a second current component, and that the second current component is zero when the air inflow is zero. Under such conditions, the first current component must be sufficient to maintain the temperature-dependent resistor at the predetermined temperature. However, if the first current component (whether A.C., D.C. or whatever) is fixed, it may not be possible to maintain the predetermined temperature, for instance in the case of extremes of ambient temperatures. Accordingly, in a preferred form of the invention, means is provided for automatically controlling the first current component in such a sense as to maintain the predetermined temperature, when the airflow rate and therefore the second current component are zero. Such an automatic adjustment can advantageously occur upon turning off the engine ignition system, and the control arrangement together with the measuring bridge can be connected to the engine starter battery for a time interval whose length is such as to effect the adjustment.

If the first current component is a constant-value D.C. component and the second current component is an A.C. component of variable amplitude, then it is advantageous if the second A.C. current component be supplied by a controllable current source furnishing frequencies between 10 kHz and 100 kHz and controlled by a difference amplifier connected across one of the bridge diagonals. With this arrangement, as with the heating pulse arrangement, a great improvement in sensitivity is effected. When the air inflow rate varies between values having a ratio of 1:30, the monitoring voltage will vary in a fairly wide range between values having a ratio of about 1:10. The possibility for greater precision in the fuel-injection control is thereby created.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a combined circuit diagram and schematic mechanical representation of one embodiment of the invention;

FIG. 2 is a graph indicating the relationship between the magnitude of the second current component U_w and the air inflow rate; and

FIG. 3 is a circuit diagram of another embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The fuel-injection arrangement of FIG. 1 is intended for use in a four-cylinder four-stroke combustion engine 10 and includes as essential components four electromagnetically operated injection valves 11, four fuel conduits 13 conveying fuel to the respective injection valves 11 from a distributor 12, an electromotor-driven fuel pump 15, and a pressure regulator 16 which serves to maintain the fuel pressure at a constant value of about 2.0 atm. The arrangment further includes an electronic control arrangement, to be described in detail. The electronic control arrangement cooperates with signaling means 18 coupled to the camshaft 17, and the control arrangement is activated twice per camshaft revolution and each time furnishes a valve-opening pulse S for the injection valves 11. The duration of the valve-opening pulse, indicated by t_i in FIG. 1, determines the length of time for which the injection valve is opened, and because of the constant-pressure conditions, also the quantity of fuel injected. The magnetic windings 19 of the injection valves are each connected in series to a respective coupling resistor 20, and by way of these resistors 20 to a common amplifying and power stage, which contains at least the illustrated amplifying transistor 22. The emitter-collector path of the transistor 22 is connected in series with the coupling resistors 20, and thereby with the magnetic windings 29, which each have one terminal connected to ground.

When employing a combustion engine of the type in question, and particularly an engine provided with a discrete ignition system, it is important that the ratio of the injected fuel to the quantity of air sucked into the cylinder during the piston intake stroke, be stoichiometric, so that the injected fuel can be completely combusted. At the same time, for the sake of efficiency, it is important that no excess of air be mixed with the fuel.

In order to realize the desired stoichiometric ratio of fuel to air, a temperature-dependent resistor 30 is located in the air-intake passage 25 of the engine, downstream of the air filter 26 but upstream of the pedal-controlled throttle valve 28. The total current flowing through temperature-dependent resistor 30 is designated J_h in FIG. 1. Resistor 30 consists of a coil of thin platinum wire having a temperature coefficient alpha of 0.0039/° C. On the one hand, resistor 30 is heated by its own current J_h and, on the other hand, cooled by contact with the stream of inflowing air, symbolically indicated by arrow 32 in FIG. 1. The greater the air inflow rate, the greater is the cooling effect upon temperature-dependent resistor 30. In order to stabilize the arrangement and render it independent of battery-voltage variations, such as result from loading, the temperature-dependent resistor 30 is employed as one of the four resistance branches of a bridge, the other three resistances being formed by resistors 33, 34 and 35 located outside the air-intake passage 25. The resistor 33 in particular serves in the ultimate compensation of resistance variations of resistor 30, and advantageously is made of the same material as temperature-dependent resistor 30.

The total heating current J_h flowing through resistor 30 is composed of a first steady-value D.C. component J_g and a second periodic component J_w, in this embodiment an A.C. sinusoid of variable amplitude. The first D.C. component J_g is manually adjustable by means of a variable resistor 36, and is so set that when the motor is at standstill, and the air inflow at zero ($Q = 0$), the temperature-dependent resistor 30 will be maintained at a temperature of about 150° C, and the voltage drop across resistor 30 will be equal to the voltage drop across resistor 33. To furnish the second A.C. current component, an A.C. current source 38 is provided, comprising for example a frequency-stabilized oscillator having a frequency between about 2 and 10 kHz and supplemented by a power amplifier. The amplitude of the A.C. sinusoid furnished by current source 38 is controlled by means of a control signal, the application to source 38 of the control signal being sumbolized by arrow 39 in FIG. 1. The amplitude of the generated A.C. current will increase with increasing bridge imbalance, and decrease with decreasing bridge imbalance. a difference amplifier 40 is connected to the junction of resistors 33 and 35 via a coupling capacitor 41, and is connected to the junction of resistors 30 and 34 via a coupling capacitor 42. Difference amplifier 40 has a very high gain, so that in response to even very small bridge imbalances amplifier 40 will furnish to controllable A.C. current source 38 a control signal sufficient to effect a precise variation in the amplitude of the furnished A.C. current. When the temperature of resistor 30 changes even slightly, the amplitude of the A.C. current component J_w will change perceivably, and to such an extent as to maintain the resistor 30 at the predetermined temperature. When the temperature of resistor 30 is actually at the predetermined temperature (of about 150° C), there will be no control signal applied to the current source 38, and the amplitude of the A.C. current component will be zero. A third coupling capacitor 43 filters out the D.C. voltage drop across bridge resistor 34, permitting only the A.C. voltage drop U_w to pass to the timing means of the circuit.

FIG. 2 is an exemplary graph of the actual relationship between the airflow monitoring voltage U_w and the airflow rate Q, in a particular embodiment of the invention. It will be seen that whereas the airflow rate varies between values having a ratio of 30:1, the airflow monitoring signal U_w varies within a satisfactorily wide range, between values having a ratio of 10:1.

The airflow signal U_w is applied to an amplifier **45**, is amplified, and then rectified by rectifier **46**, and applied to the input of integrating means **47**. Integrating means **47** integrates the airflow voltage U_w, but only for the duration of gating pulses received from the output E_1 of a pulse generator **49**. Pulse generator **49** cooperates with signaling means **18**, which as mentioned before cooperates with the engine camshaft **17**. The gating signal applied to the integrator **47** from output E_1 is such that integration from zero of the airflow voltage U_w occurs during a predetermined **90** of camshaft rotation, in the type of engine here illustrated. During the integration from zero of U_w, a non-illustrated integrating capacitor integrates a D.C. current whose magnitude corresponds to the amplitude of the A.C. current component J_w, and the voltage across the non-illustrated capacitor increases. The total voltage developed across the capacitor at the end of the charging period, constitutes an indication of the air inflow rate.

In order to produce a valve-opening pulse S whose duration is proportional to the air inflow rate, the integrating capacitor is caused to discharge with a constant current, at a suitable moment during the camshaft or crankshaft revolution. The total time of this discharge is t_i, and is proportional to the air inflow rate Q. A comparator **48** produces an output signal at the start of the discharge and continues to produce such a signal until the charge on the integrating capacitor falls to zero. This output pulse is applied to the base of power transistor **22**, which produces a corresponding amplified valve-opening pulse S, of duration t_i.

The embodiment of FIG. **3** is the same in principle, but employs markedly different circuitry.

In FIG. **3**, as before, the temperature-dependent resistor **30** is positioned in the air inflow path of the air-intake passage **25**, while the resistors **33, 34, 35** forming the measuring bridge, are located outside the air-intake passage. Actually, the other resistors, and especially resistor **33**, could be located in the air-intake passage, so as to be exposed to the same ambient temperature as resistor **33** when the airflow is zero. However, then these other resistors would have to be positioned as not to be subject to the cooling effects of air flow. For instance, resistor **33** could be a temperature-dependent resistor identical to resistor **30** and located in a recess within the internal wall of the air-intake passage, so as to be fully subject to the ambient temperature of the incoming air (which might vary considerably) while not being subject to the cooling effects of the air inflow.

The circuit of FIG. **3** is provided with first control means **61** and second control means **63**, the circuitry for which is a matter of routine implementation and does per se constitute part of the invention.

The total current furnished to bridge **30, 33, 34, 35** is furnished by transistor **60**, whose collector is connected to a point of stabilized voltage U_b. First control or adjusting means **61** is operative for adjusting the value of the first current component, which in this embodiment is a D.C. steady-value current component. Adjusting means **61** accomplishes this adjustment by receiving as input signal the voltage across the bridge diagonal when the air inflow is zero. For instance, as one possibility, when the engine is turned off, and the air inflow therefore zero, first control means **61** will be operative for about 5 seconds and will establish a current level for the first current component exactly sufficient to balance the bridge by maintaining temperature-dependent resistor **30** at the predetermined temperature (e.g., about 150° c). Provision of first control means **61** thus insures that extremes of ambient—i.e., atmospheric—temperature associated for example with summer and winter weather will not introduce any ambiguity into the system's response to the cooling effect of air flowing into the air-intake passage.

With the current level for the first current component now adjusted, the second control means **62** will serve to provide the second current component, which is the component that maintains the predetermined temperature despite the cooling effect of air inflow. In this embodiment, the second current component is a train of rectangular pulses having a fixed pulse-duration $t_1 = 50$ μs and a frequency f_p which increases and decreases in direct response to the increases and decreases of the air inflow cooling effect. The pulse frequency f_p constitutes an indication of the air inflow rate.

Second control means **62**, in addition to the 50-microsecond heating pulses, produces 10-microsecond pulses having the same frequency f_p as the heating pulses. The input signal to second control means **62** is the same as the input signal to first control means **61**, namely the imbalance voltage appearing across the bridge diagonal. Control means **62** may comprise as its principal component a monostable multivibrator, for example a Schmitt trigger, whose astable period varies as a function of the bridge imbalance. The amplitude of the heating pulses is chosen sufficiently high that at idling the frequency f_p can be about 2 kHz, and about 12 kHz at full load and/or at high engine speeds.

Each time control means **62** produces a 50-microsecond heating pulse it also produces a 10-microsecond pulse J_m whose frequency is identical to the frequency of f_p of the train of heating pulses. The 10-microsecond pulses J_m are applied to a pulse-length modulator **63** which produces a further train of pulses J_{mm} which also have a frequency equal to f_p and which furthermore have a pulse-duration t_3 proportional to the frequency f_p. Accordingly, the pulse-duration of the pulses J_{mm} increases in response to increasing air inflow. The duration of the pulses J_{mm} varies from about 10 microseconds when the engine is idling, to about 60 microseconds at full load and/or high speeds. A constant-current source **64** is provided, and is operative during the existence of a pulse J_{mm} for furnishing a constant-magnitude current to an integrating circuit **64** which includes a non-illustrated integrating capacitor. The integrating circuit is operative in this embodiment for a predetermined 180° of the crankshaft rotation cycle. The charge accumulated on the non-illustrated integrating capacitor is discharged, during the subsequent 180° of crankshaft rotation, with a constant discharge current, and the fuel-injection valve is opened for the duration of this discharge, for example by employing the comparator **48** of FIG. **1.**

As a variation of the embodiment of FIG. **3**, the current pulses J_{mm} could be applied to the integrating means **65** directly, and the constant current **64** source would accordingly be omitted.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of circuits and constructions differing from the types described above.

While the invention has been illustrated and described as embodied in fuel-injection arrangement capable of matching the quantity of injected fuel to the quantity of combustion air, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended

1. In an arrangement for controlling fuel injection in an internal combustion engine as a function of air flow into the air-intake passage of the engine, the combination comprising a temperature-dependent resistor positioned in the air-intake passage; control means for furnishing to said resistor a current having a first current component sufficient to maintain said resistor at a predetermined temperature in the absence of air flow in said passage, and a second current component superimposed upon but distinguishable from said first component and equal to zero in the absence of air flow and varying sufficiently in response to the cooling effect of air flow to maintain said resistor at said temperature; and timing means for generating fuel-injection pulses whose pulse duration is a function of said second current component.

2. An arrangement as defined in claim **1**, wherein at least one of said components is periodic.

3. An arrangment as defined in claim **1**, wherein said second component is periodic.

4. An arrangement as defined in claim **1**, wherein at least one of said components is a D.C. component.

5. An arrangement as defined in claim **1**, wherein said first component is a D.C. component of fixed value.

6. An arrangement as defined in claim **1**, wherein at least one of said components is an A.C. component.

7. An arrangement as defined in claim **1**, wherein said second component is an A.C. component of variable amplitude.

8. An arrangement as defined in claim **1**, wherein said first component is a D.C. component of substantially fixed value, and wherein said second component is a periodic component.

9. An arrangement as defined in claim **1**, wherein said control means comprises means for generating a train of current pulses constituting said second current component and having a frequency which varies as a function of the difference between the actual resistance value of said resistor and the resistance value corresponding to said temperature.

10. An arrangement as defined in claim **9**, wherein the duration of said current pulses is fixed.

11. An arrangement as defined in claim **9**, wherein said frequency is about 1 kHz in response to airflow cooling conditions corresponding to idling engine speeds and about 20 kHz in response to airflow cooling conditions corresponding to full-load and high engine speeds.

12. An arrangement as defined in claim **10**, wherein said duration of said pulses is about 10 micrsoseconds.

13. An arrangement as defined in claim **9**, wherein said control means further includes pulse-width modulating means for generating a train of monitoring pulses whose frequency and pulse-duration are proportional to the frequency of said train of current pulses.

14. An arrangement as defined in claim **13**, wherein said monitoring pulses range in duration between about 10 and about 60 microseconds and range in frequency between about 2 and about 12 kHz.

15. An arrangement as defined in claim **13**, wherein said control means further includes integrating means operative during a predetermined fraction of a crankshaft revolution for generating an integral signal substantially proportional to the time integral of said train of monitoring pulses.

16. An arrangement as defined in claim **15**, wherein the duration of the fuel injection is substantially proportional to the magnitude of said integral signal.

17. An arrangement as defined in claim **16**, wherein said integrating means includes an integrating capacitor and wherein said integral signal is the voltage across said capacitor, and wherein said control means further includes constant-current discharge means for discharging said capacitor with a constant discharge current so that the time of discharge is proportional to said integral signal.

18. An arrangement as defined in claim **1**, wherein said first current component is adjustable, and wherein said control means includes adjusting means for automatically so adjusting said first current component as to maintain said temperature-dependent resistor at said predetermined temperature when said second current component is zero.

19. An arrangement as defined in claim **18**, wherein said adjusting means is operative for effecting adjustment of said first current component during a time period subsequent to turning off the engine ignition system, whereby the adjustment of the first component can be made in the absence of air flow and with said second current component equal to zero.

20. An arrangement as defined in claim **1**, wherein said control means includes three further resistors forming with said temperature-dependent resistor a resistance bridge having two diagonals, a difference amplifier having two inputs connected across one of said diagonals and having a blocking capacitor connected at each input to said difference amplifier, and controllable A.C. current source means having an input connected to the output of said difference amplifier and operative for applying to said resistance bridge an A.C. current which varies in amplitude as a function of the signal at the output of said difference amplifier.

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