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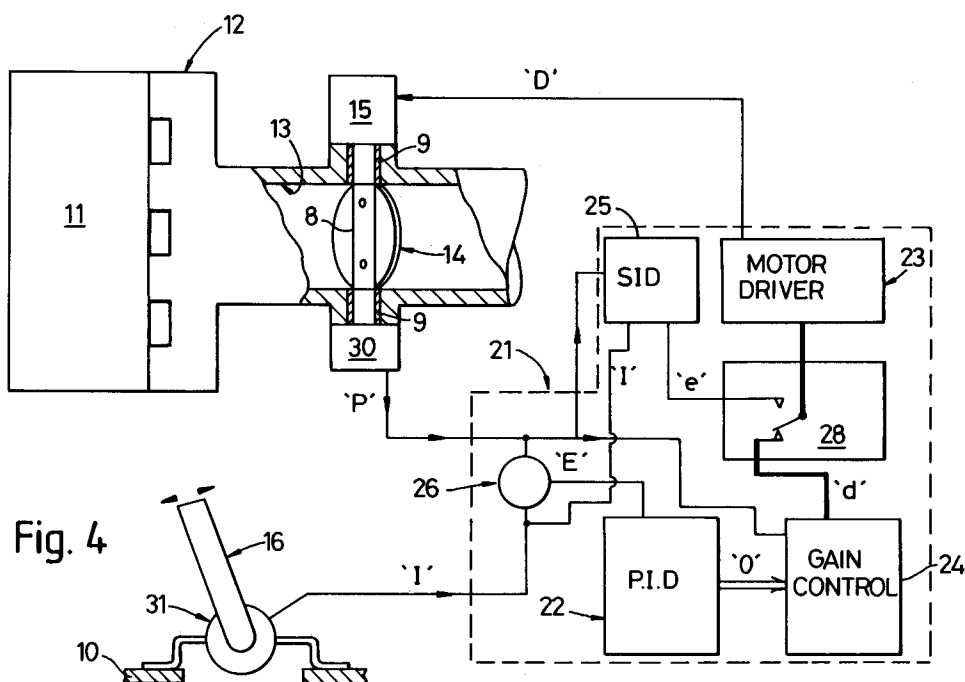
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Cowley, Oxford OX4 5NL(GB)(54) **A throttle valve control system for an engine of a vehicle.**

(57) A throttle valve control system for an engine of a vehicle is disclosed of the type having a rotatable throttle valve controlled by an electronic control means. The control means (21) being operable to increase the effort supplied to the throttle valve (14) when the throttle valve (14) approaches its closed position in order to reduce the effect of stiction and friction on the control system response. The increase in effort is obtained by increasing momentarily the system gain or providing a step input of predetermined magnitude.



This invention relates to a throttle valve control system and in particular to an electronic throttle valve control system for the internal combustion engine of a motor vehicle.

It is known for example from US Patent No. 4,831,985 to provide an electronic throttle control system for a vehicle of the kind having a throttle body and a rotary throttle valve mounted within the throttle body to control the delivery of fuel and/or air to the engine of the vehicle.

The system including means to sense the actual position of the throttle valve and provide a signal indicative thereof, means to provide a signal indicative of a required throttle valve position and means to compare said signals indicative of actual and required throttle valve position and to provide a controlling signal to a throttle valve actuator means to adjust the throttle valve position accordingly.

It is a problem with such a prior art throttle control system that at low throttle valve openings due to the differential pressure generated by the throttling effect of the throttle valve the friction and stiction associated with the throttle valve is increased as shown in Figure 1 which leads to the control system response becoming inadequate and results in hunting of the actuator means.

It is an object of this invention to improve the control system response at low throttle valve openings.

According to the invention there is provided a throttle valve control system for an engine of a vehicle having a throttle valve rotatably mounted in an inlet passage of the engine, the control system comprising a throttle valve sensing means to provide a signal indicative of the rotational position of the throttle valve, an input means to provide a signal indicative of a desired throttle valve rotational position, a control means having comparator means to compare the signals received from the sensing means and the input means and a controller means to process the error signal from the comparator means and provide a control signal to an actuator means to vary the angular position of the throttle valve between a closed position and an open position in response to said control signal received from the control means wherein when the signal received from the sensing means indicates that the throttle valve is within a predetermined range measured from the closed position and the error signal resulting from the comparison of the signals from the sensing means and the input means indicates that a change in throttle valve opening is required then the control signal sent to the actuator is greater than would normally be sent to the actuator for such an error signal.

This has the advantage that the control signal sent to the actuator means is increased at low throttle openings to compensate for the increased stiction and friction.

The control means may include a proportional control means.

The control means may include an integral control means.

Preferably the control means is a three term proportional, integral and derivative controller.

Advantageously, the gain of the system may be increased by a factor of up to 3 times its normal value when the throttle valve is within a predetermined range of 0 to 10 degrees from the throttle valve closed position.

Preferably, the control means gain is constant above said predetermined range and is increased linearly as the throttle valve is closed within said predetermined range.

The control signal D to the actuator means may be equal to

$$D = K \left(k_1 E + k_2 \int E dt + k_3 \frac{dE}{dt} \right)$$

Where

D = control signal to actuator means

E = Difference between the sensing means and input means signals

K = Overall system gain

K₁, K₂, K₃ = Control means constants

The control means may be a central processing unit (CPU) having at least one read only memory location (ROM) and one random access memory location (RAM), the system gain being stored digitally in the or one of the read only memory locations in the form of a look up table.

The greater than normal control signal may be in the form of a predetermined control signal to the actuator means, the comparator means being temporarily bypassed.

In which case, the control means may be a central processing unit having at least one read only memory location (ROM) and at least one random access memory location (RAM) the predetermined control signal being stored digitally in the or one of the read only memory locations.

The input means may be a driver operable input means in the form of a potentiometer attached to an accelerator pedal of the vehicle.

Alternatively, the input means could be an idle speed control unit.

The input means may be switchable between the potentiometer and the idle speed control unit.

The control system may be operable such that when the throttle valve is open in a first range less than 2 degrees from its closed position then the comparator means is temporarily bypassed and a predetermined control signal is sent to the actuator means and when the throttle valve is open in a second range between 2 and 10 degrees the control signal sent to the actuator means is proportionally greater for the same error signal than when the throttle valve is open in a third range more than 10 degrees from its closed position.

In such a control system, the control means may be a central processing unit having at least two read only memories locations (ROMs) and at least one random access memory location, one of the read only memory locations being used to store the predetermined control signal and another of the read only memory locations being used to store a system look up table used to increase the control signal in said second range.

The actuator means may be an electric motor.

The invention will now be described by way of example with reference to the accompanying drawing of which:-

Figure 1 is a graph of friction and stiction against throttle valve opening for a rotary throttle valve;

Figure 2 is a graph of system gain against percentage throttle opening for a control system according to a first aspect of a first embodiment of the invention;

Figure 3 is a graph of throttle valve position against time showing the response obtained from a prior art control system and the response obtained from a control system according to the first aspect of the first embodiment of the invention;

Figure 4 is a schematic diagram of a throttle valve control system according to the first embodiment of the invention;

Figure 5 is a schematic diagram of a throttle valve control system according to a second embodiment of the invention;

Figure 6a is a graph of accelerator pedal position against time for a prior art throttle valve control system;

Figure 6b is a graph of the signal sent to a motor driver against time for a prior art throttle valve control system;

Figure 6c is a graph of motor current against time for a prior art throttle valve control system;

Figure 6d is a graph of throttle valve position against time for a prior art throttle valve control system.

Figure 7a is a graph of accelerator pedal position against time for a throttle valve control system according to a second aspect of the first embodiment of the invention;

Figure 7b is a graph of the signal sent to a motor driver against time for a throttle valve control system according to the second aspect of the first embodiment of the invention;

Figure 7c is a graph of motor current against time for a throttle valve control system according to the second aspect of the first embodiment of the invention;

Figure 7d is a graph of throttle valve position against time for a throttle valve control system according to the second aspect of the first embodiment of the invention.

With particular reference to Figure 4 there is shown an internal combustion engine 11 of a motor vehicle (not shown), the engine 11 having an inlet manifold 12 defining an inlet tract 13 in which is rotatably mounted a disc throttle valve 14.

The disc throttle valve 14 is rotatable through approximately 90 degrees from a closed position where it obscures the inlet tract 13 to an open position where it provides little restriction to the flow of fluid through the inlet tract 13. For convenience the throttle valve opening is measured from the closed position in terms of degrees of rotation or percentage open, therefor 10 percent open is approximately equal to a rotation of 9 degrees from the closed position.

The throttle valve 14 is rotated by an actuator means in the form of an electric motor 15 connected to a spindle 8 of the throttle valve 14, the spindle 8 being supported by two plain bearings 9.

At the other end of the spindle 8 to the electric motor 15 there is connected a throttle valve sensing means in the form of a rotary potentiometer 30.

A control means 21 is connected to the motor 15, potentiometer 30 and also to an input means in the form of a position sensor 31 connected to an accelerator pedal 16 or the motor vehicle. The accelerator pedal 16 is rotationally connected to part of the body 10 of the motor vehicle by pivot means (not shown).

The control means 21 comprise a proportional, integral and derivative controller (P.I.D.) 22, a motor driver power amplifying device 23, a gain control device 24, a step input device 25, a comparator 26 and changeover switching means 28.

The control means 21 is essentially a central processing unit having a number of random access

memory locations (RAMs) and read only memory locations (ROMs) associated therewith to form a microcomputer.

The comparator 26 is arranged to receive a signal 'P' from the potentiometer 30 indicative of throttle valve 14 position and a signal 'I' from the position sensor 31 and perform the calculation $E = (I - P)$ where:-
 5 E is a signal indicative of the difference between a desired throttle valve position as indicated by the signal 'I' and 'P' is a signal indicative of actual throttle valve position.

In accordance with a first aspect of the invention the signal 'E' passes to the P.I.D. controller 22 which operates according to the general transfer function

$$10 \quad \text{Output signal 'O'} = k_1 E + k_2 \int E dt + k_3 \frac{dE}{dt}$$

The output signal 'O' being supplied to the gain control device 24.

15 The gain control device 24 includes a read only memory (ROM) in which is stored a look up table of gain 'K' against throttle position 'P' a part of which is shown in graphical form in Figure 2.

The gain control device 24 receives a signal indicative of actual throttle valve position which is used to address the correct part of the look up table. The gain control device 24 take the signal 'O' and factors it by the gain 'k' from the look up table so that a control signal 'd' is sent to the motor driver 23 via the switching
 20 means 28.

Therefore 'd' = k * O or

$$25 \quad \bar{d} = k \left(k_1 E + k_2 \int E dt + k_3 \frac{dE}{dt} \right)$$

where

$E = I - P$

30 k_1, k_2 and k_3 are system constants

k = Instantaneous Gain

The motor driver 23 changes the signal 'd' received from the gain control 24 into a driving current 'D' which is sent to the motor 15.

The graph of Figure 2 shows relative system gain where 1.0 = Normal Gain and a maximum relative gain of 3.0 is used for a throttle position sensed to be at or near the closed position, the actual signal ratio between 'O' and 'D' could be any suitable value. For example K could be 50 for throttle openings of 10 degrees and above which would mean a maximum circuit gain of 150.

When the signal 'P' indicates that the throttle valve 14 is open less than 2 degrees and the error signal 'E' is positive then according to a second aspect of the invention the control means 21 operates the
 40 changeover switch 28 engaging the step input device 25 and bypassing the comparator 26.

The step input device 25 produces a predetermined control signal 'e' which is stored in a read only memory in digital form to the motor driver 23.

The predetermined control signal 'e' is several times greater than the error signal 'E' which would be present due to such a small throttle valve opening and is of magnitude sufficient to provide a control signal
 45 'D' to the motor 15 less than but near to the signal level required to overcome the stiction associated with the control valve A.

The operation of the throttle control system can best be understood with reference to Figures 3, 6 and 7.

Considering first Figure 3 and assuming that at time equals 0.0 the accelerator pedal 16 is moved
 50 instantly to a position indicating a required throttle valve position of 2.5% open.

In the case of a prior art throttle control system the throttle valve 14 will tend to hunt because the integrator part of the P.I.D. controller will integrate the small error signal 'E' until the drive 'D' to the motor 15 is sufficient to break the stiction present. The throttle valve 14 will then overshoot the desired position and will remain open too much until the integrator has ramped down sufficient to allow the motor 15 to urge
 55 the throttle valve 14 closed.

In the case of the control means 21 according to the invention the amount of overshoot and frequency response of the throttle valve system is increased by the increase in system gain introduced by the gain control device 24 within a predetermined range of 0 to 10 degrees from the closed position.

The control signal D sent to the motor 15 for small throttle valve openings is greater due to the effect of the gain control device 24 than it would normally be, causing the integrator part of the P.I.D. controller 22 to ramp up and down more quickly.

The fact that at low throttle valve openings the friction on the spindle 8 is increased due to the increased loading from the throttle valve 14 prevents the throttle valve control system from becoming unstable even though the system gain is up to three times that normally usable for the control system to perform satisfactorily.

At very low throttle valve openings of less than 2 degrees the system response is further improved by the bypassing of the comparator 26 and engagement of the step input device 25 as will be understood with reference to Figures 6 and 7. Figures 6a - d show the response of a prior art throttle control system without a step input device or gain control. In Figure 6a is shown the driver applying a demand for a small throttle opening at zero time by means of the accelerator pedal due to the slow speed at which the integrator part of the P.I.D. controller operates there is no movement of the throttle valve as shown in Figure 6d and so the driver at time T1 increases the demand for throttle opening which causes the motor to suddenly overcome the stiction associated with the throttle valve 14 and rapidly open the throttle valve 14 overshooting the desired throttle opening.

In Figures 7a - d is shown the response to a driver demanding a small throttle opening in a control system having a step input device 25 as part of the control means.

The step input device 25 sensing a small throttle opening and a small accelerator pedal 16 demand operates the switch 28 to allow a step input of magnitude 'e' to the motor driver 23.

As soon as the position of the accelerator pedal 16 is sensed to have moved a predetermined amount and the signal 'd' exceeds the signal 'e' then the step input device 25 is disabled by means of the switch 28 allowing the normal error signal 'd' to reach the motor driver 23.

The effect of the step input device 25 is to send a short pulse of power to the motor 15 of sufficient magnitude to overcome stiction.

Figure 7d shows the response to a step input from the accelerator pedal 16 as shown in Figure 7a.

Comparing Figures 6d and 7d the improvement to system response over a prior art throttle valve control system can be clearly seen.

Referring now to Figure 5 there is shown a second embodiment of the invention which is similar in many respects to the first embodiment just described.

Figure 5 shows an internal combustion engine 111 of a motor vehicle (not shown), the engine 111 having an inlet manifold 112 defining an inlet tract 113 in which is rotatably mounted a disc throttle valve 114.

The disc throttle valve 114 is rotatable through approximately 90 degrees from a closed position, where it obscures the inlet tract 113, to an open position where it provides little restriction to the flow of fluid through the inlet tract.

For convenience the throttle valve opening is measured from the closed position in terms of degrees of rotation or percentage open.

The throttle valve 114 is rotated by an actuator means in the form of an electric motor 115 connected to a spindle 108 of the throttle valve 114, the spindle 108 being supported by two plain bearings 109.

At the other end of the spindle 108 to the motor 115 there is connected a throttle valve sensing means in the form of a rotary potentiometer 130.

A control means 121 is connected to the motor 115, potentiometer 130 and also to an input means in the form of a position sensor 131 connected to an accelerator pedal 116 of the motor vehicle or alternatively to an engine control unit 117 of the motor vehicle.

A changeover switch in the form of an accelerator switch 127 connected to the accelerator pedal 116 by means not shown is provided to select the respective input means required.

The accelerator pedal 116 is rotationally connected to part of the body 110 of the motor vehicle by pivot means (not shown).

The control means 121 comprises of a three term proportional, integral and derivative controller (P.I.D.) 122, a motor driver power amplifying device 123, a gain control device 124 and a comparator 126.

The control means 121 is essentially a central processing unit having a number of random access memories and read only memories associated therewith to form a microcomputer.

The comparator 126 is arranged to receive a signal 'P' from the potentiometer 130 indicative of throttle valve position and a signal 'I' from the position sensor 131 and to perform the calculation

$E = (I - P)$, or $E = (I_2 - P)$, where:-

E is a signal indicative of the difference between a desired throttle valve position as indicated by the signal 'I' or I_2 depending upon the position of the throttle switch 127; and 'P' is a signal indicative of actual throttle

valve position.

The signal E passes from the comparator 126 into the P.I.D. controller 122 which operates according to the general transfer function

$$\text{Output signal 'O'} = k_1 E + k_2 \int E dt + k_3 \frac{dE}{dt}$$

The output signal O being supplied to the gain control device 124. The gain control device 124 includes a read only memory in which is stored a look up table of gain K against throttle position P.

The operation of the gain control device 124 is such that the control signal 'd' sent to the motor driver is equal to K x O or in other words

$$d = K k_1 e + k_2 \int E dt + k_3 \frac{dE}{dt},$$

where E = (I - P) or

(I₂ - P) depending upon switch 127 position.

k₁, k₂ and k₃ are system constants

K = Instantaneous Gain

The signal P is supplied to the gain control device 124 to determine the actual gain required from the look up table. If the signal P indicates that the throttle valve position is less than 10 degrees open then the value of gain K will be increased by an amount depending upon its value stored in the look up table. The control signal d is therefore proportionally greater for throttle valve 14 openings of less than 10 degrees than it would be for throttle valve openings of greater than 10 degrees open.

The motor driver 123 receives the signal 'd' and converts it into an output current signal 'D' of correct polarity.

Under normal driving conditions the accelerator switch 127 is in the position shown in Figure 5 but when the driver removes his foot completely from the accelerator pedal 116 the accelerator switch 127 is moved into the opposite position such that the comparator 126 now receives the signal I₂ from the electronic control unit 117 instead of the signal I from the position sensor 131 connected to the accelerator pedal 116.

The engine control unit 117 now acts as an idle control device receiving an indication of actual engine speed from a speed transducer 129 and adjusting the signal I₂ to maintain a substantially constant predetermined engine idle speed.

Therefore if the driver removes his foot from the accelerator pedal 16 when the actual engine speed is above the predetermined idle speed the signal I₂ will be such as to cause the control means to send a signal 'D' urging the throttle valve 114 closed.

As soon as a driver of the motor vehicle moves the accelerator pedal 116 the accelerator switch 127 is operated to reconnect the output I from the position sensor 131 to the comparator 126. The control means 121 now acts as a closed loop throttle valve control system via the motor 115 and the sensing means 130, any movement of the accelerator pedal 116 will be mimicked by the throttle valve 114.

Claims

1. A throttle valve control system for an engine (11, 111) of a vehicle having a throttle valve (14, 114) rotatably mounted in an inlet passage (13, 113) of the engine, the control system comprising a throttle valve sensing means (30, 130) to provide a signal indicative of the rotational position of the throttle valve (14, 114), an input means (31, 131) to provide a signal indicative of a desired throttle valve rotational position, a control means (21, 121) having comparator means (26, 126) to compare the signals received from the sensing means (30, 130) and the input means (31, 131) and a controller means (22, 23, 24, 122, 123, 124) to process the error signal (E) from the comparator means (26, 126) and provide a control signal (D) to an actuator means (15, 115) to vary the angular position of the throttle valve (14, 114) between a closed position and an open position in response to said control signal (D) received from the control means (21, 121) characterised in that when the signal received from the sensing means (30, 130) indicates that the throttle valve (14, 114) is within a predetermined range measured from the closed position and the error signal (E) resulting from the comparison of the

signals from the sensing means (3-, 130) and the input means (31, 131) indicates that a change in throttle valve opening is required then the control signal (D) sent to the actuator (15, 115) is greater than would normally be sent to the actuator (15, 115) for such an error signal (E).

- 5 2. A control system as claimed in Claim 1 in which the system gain is increased by a factor of up to 3 times its normal value when the throttle valve is within said predetermined range of 0 to 10 degrees from the throttle valve closed position.
- 10 3. A control system as claimed in Claim 1 or 2 in which the system gain is constant above said predetermined range and is increased linearly as the throttle valve (14, 114) is closed within said predetermined range.
- 15 4. A control system as claimed in Claim 1 in which the control signal D to the actuator means is equal to
Where

$$D = \text{control signal to actuator means}$$

$$E = \text{Difference between the sensing means and input means signals}$$

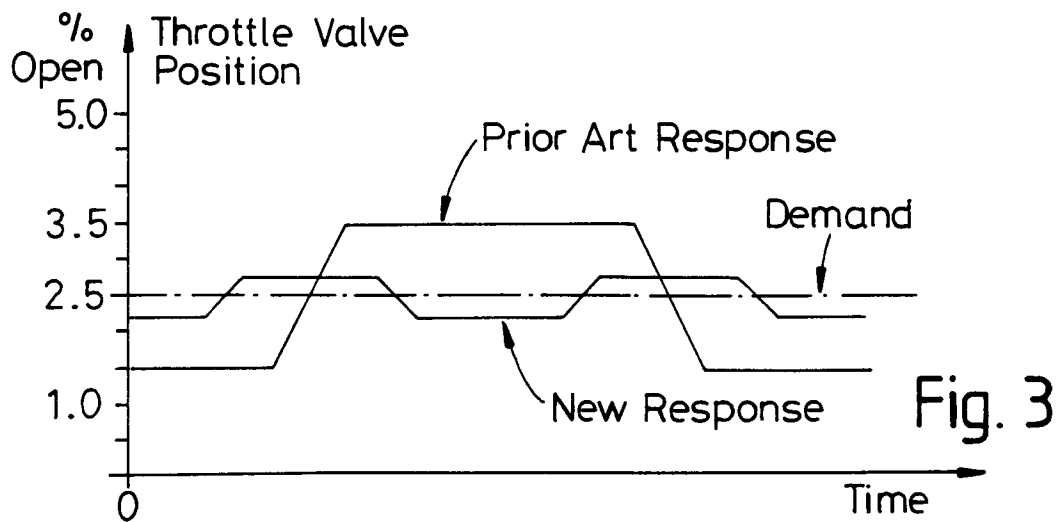
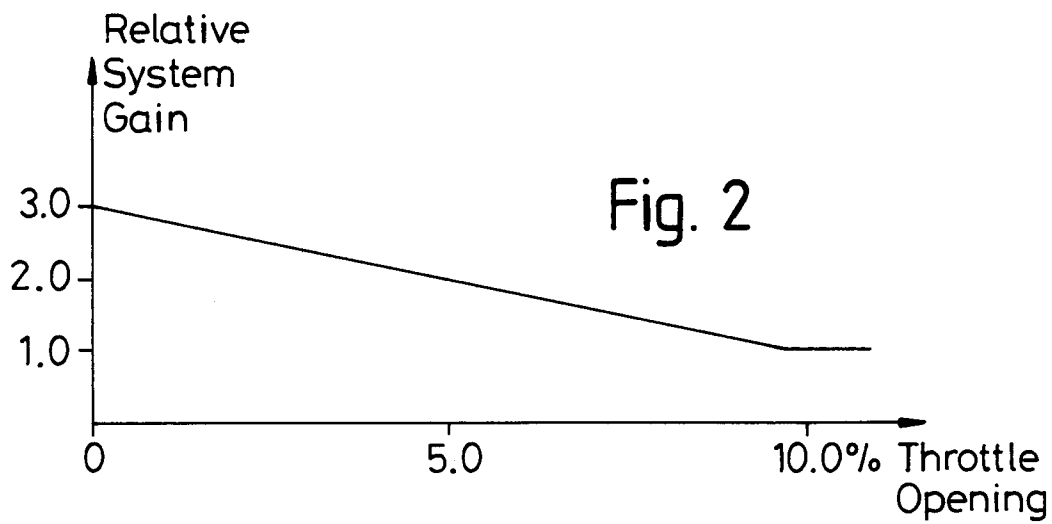
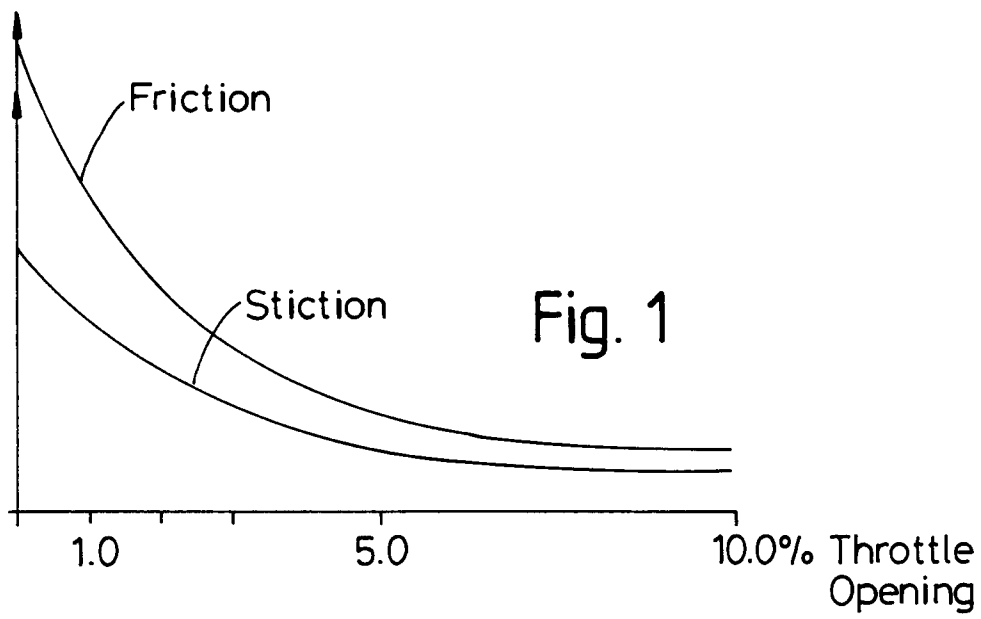
$$K = \text{Overall system gain}$$

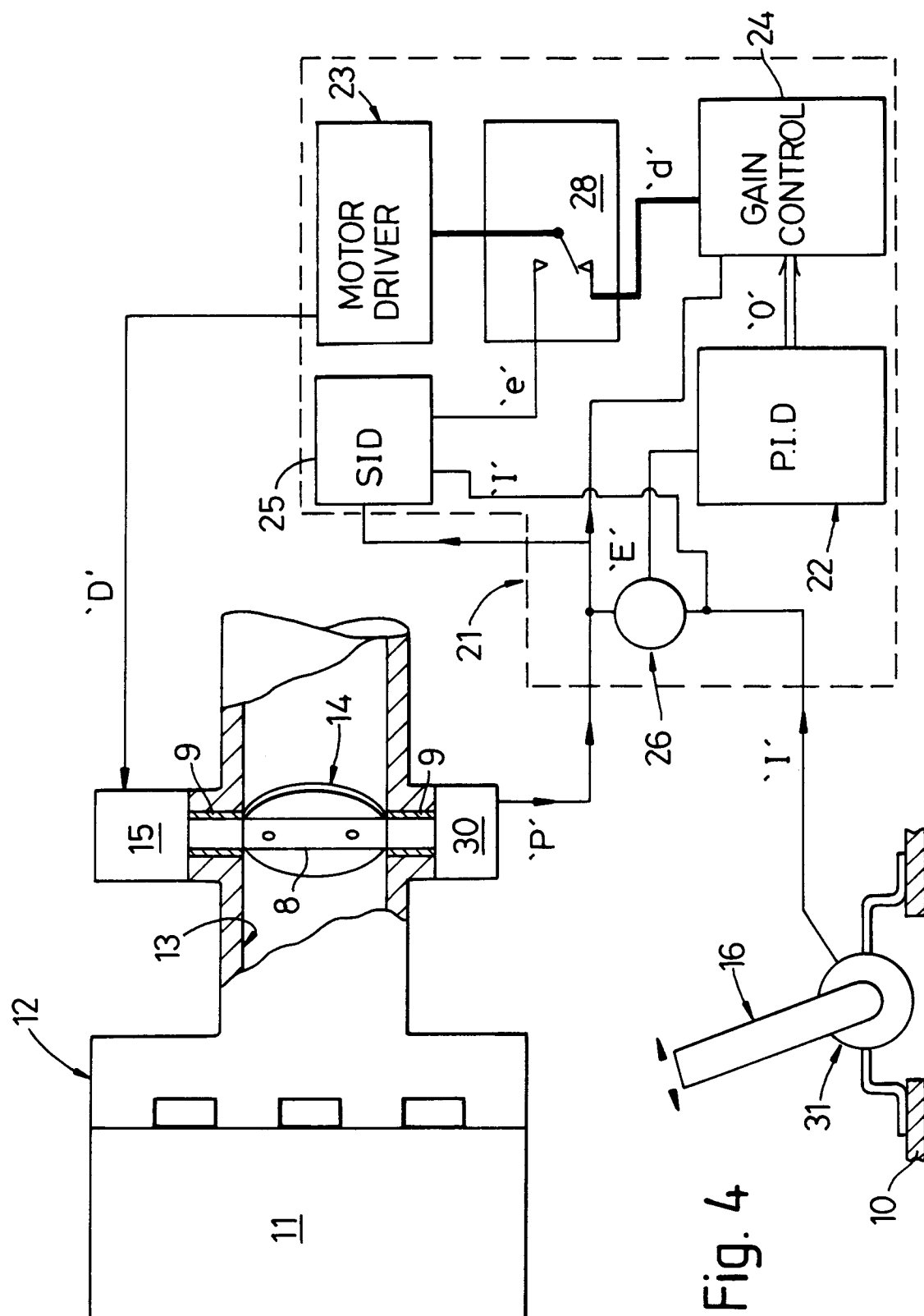
$$k_1, k_2, k_3 = \text{Control means constants}$$
- 20 5. A control system as claimed in any preceding claim in which the control means (21, 121) is a central processing unit (CPU) having at least one read only memory location (ROM) and at least one random access memory location (RAM) and in which the system gain is stored digitally in the or one of the read only memory locations in the form of a look up table.
- 25 6. A control system as claimed in Claim 1 in which the greater than normal control signal is in the form of a predetermined control signal to the actuator means (15), the comparator means (26) being temporarily bypassed.
- 30 7. A control system as claimed in any preceding claim in which the input means is a driver operable input means in the form of a potentiometer (31, 131) attached to an accelerator pedal (16, 116) of the vehicle.
- 35 8. A control system as claimed in any of Claims 1 to 6 in which the input means is an engine idle speed control unit (117).
- 40 9. A control system as claimed in any of Claims 1 to 6 in which the input means is switchable between a potentiometer (131) attached to an accelerator pedal (116) and an engine idle speed control unit (117).
- 45 10. A control system as claimed in Claim 1 in which when the throttle valve (14, 114) is open in a first range less than 2 degrees from its closed position then the comparator means (26) is temporarily bypassed and a predetermined control signal is sent to the actuator means (15) and when the throttle valve is open in a second range between 2 degrees and 10 degrees the control signal sent to the actuator means is proportionally greater for the same error signal than when the throttle valve is open in a third range more than 10 degrees from its closed position.

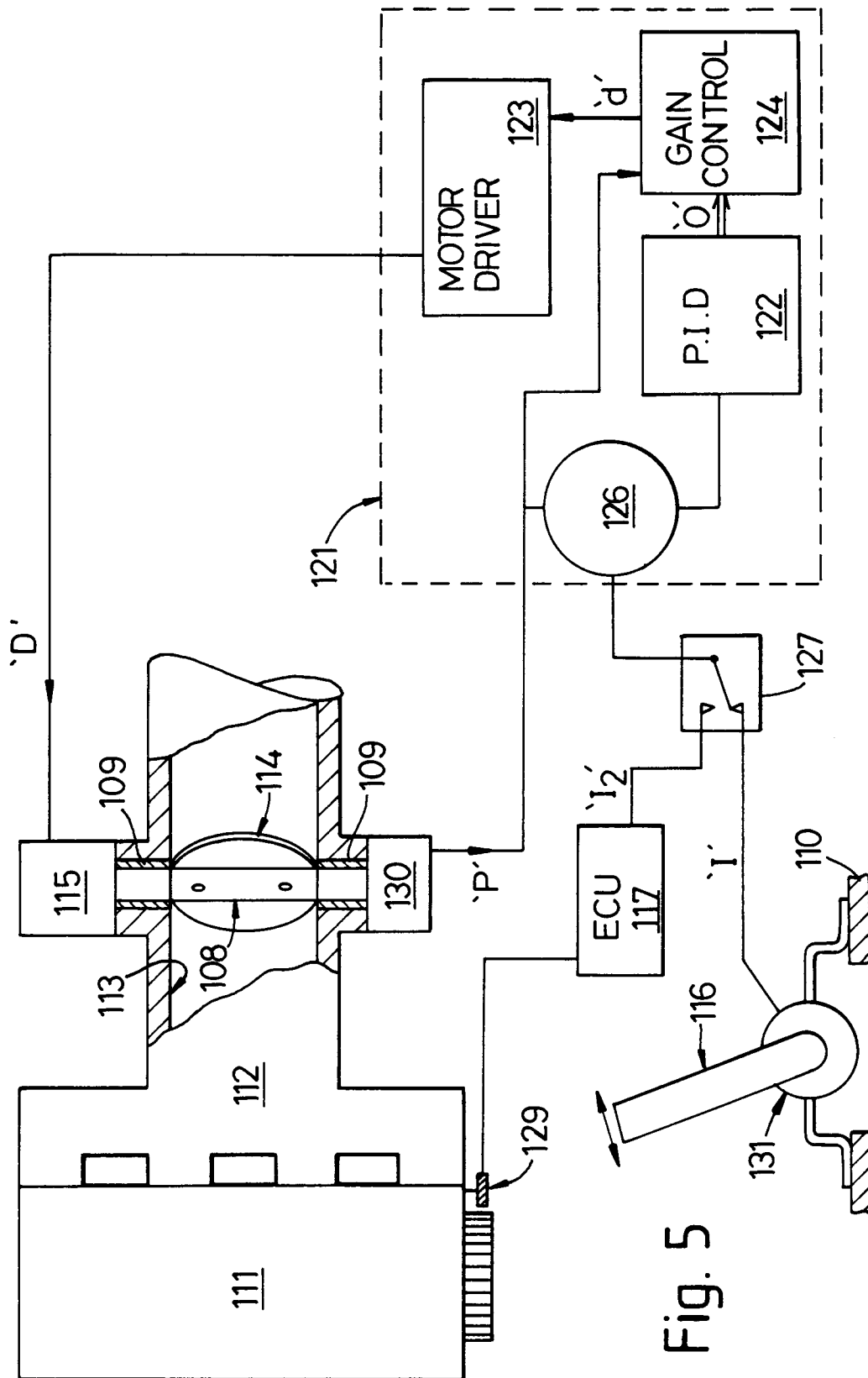
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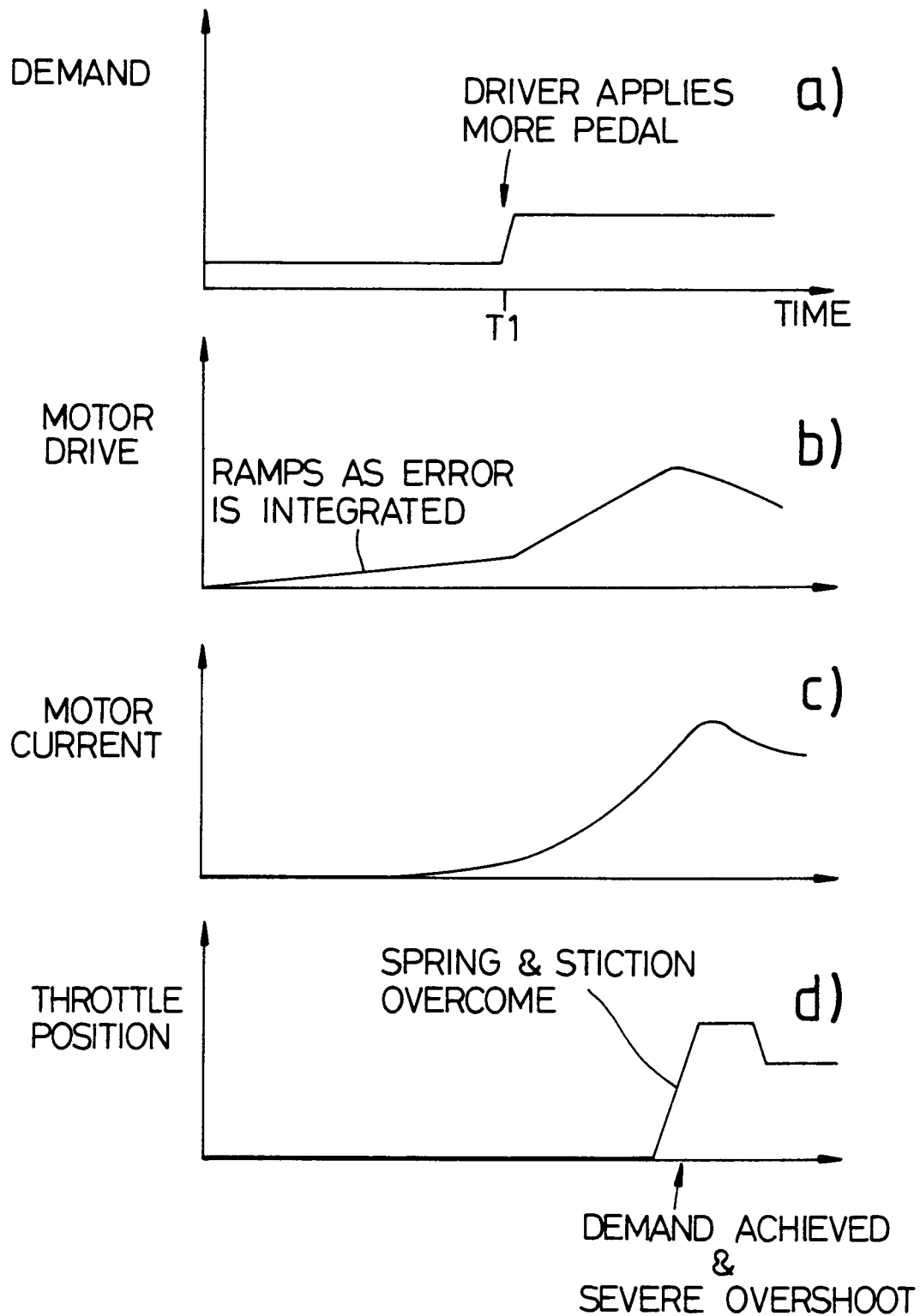
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Fig. 6 PRIOR ART

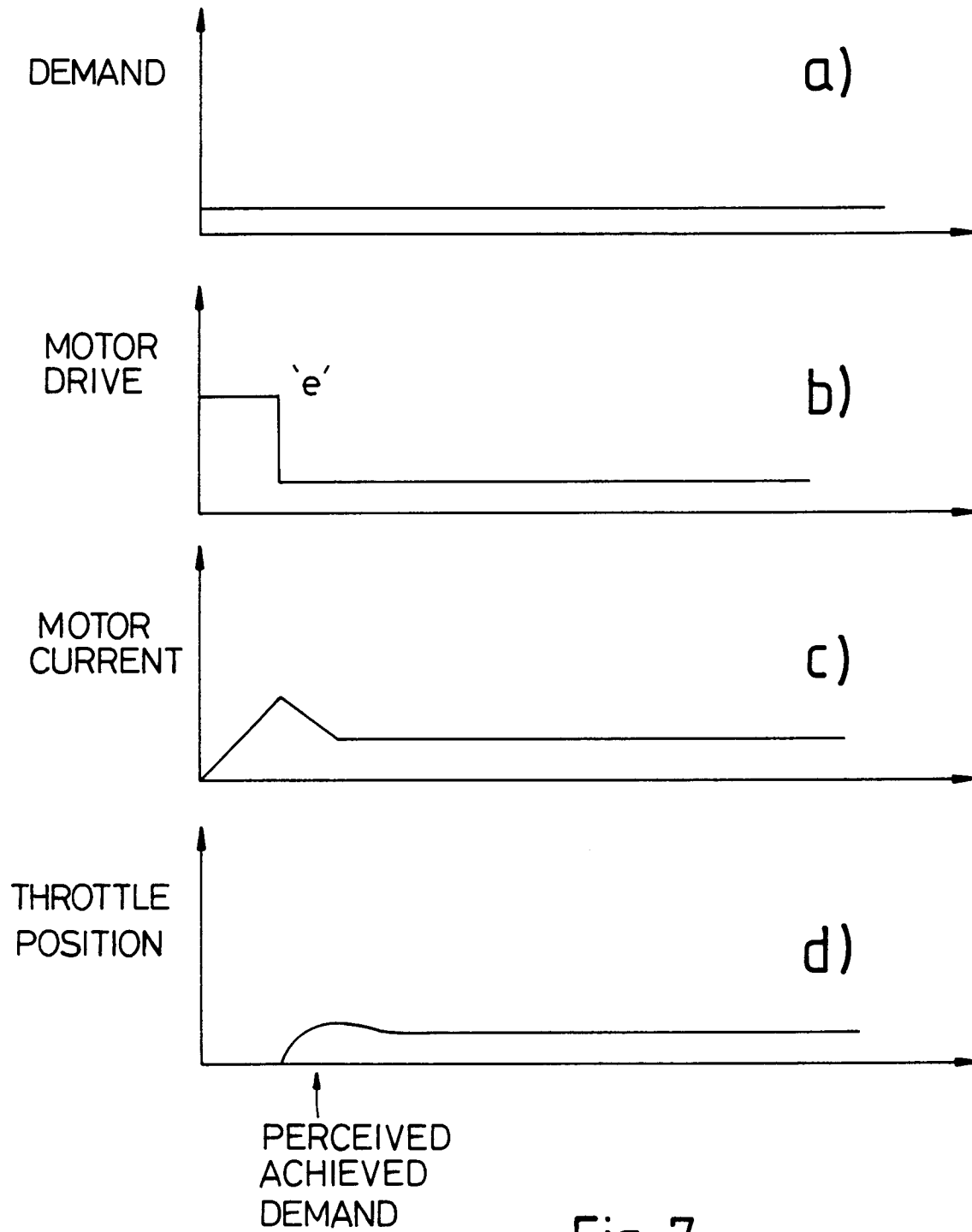


Fig. 7