

- | | | |
|------|-----------|---|
| [72] | Inventor | Bernard G. Radin
Oak Park, Mich. |
| [21] | Appl. No. | 781,183 |
| [22] | Filed | Dec. 4, 1968 |
| [45] | Patented | Jan. 19, 1971 |
| [73] | Assignee | Ford Motor Company
Dearborn, Mich.
a corporation of Delaware |

- [54] POSITION TO VOLTAGE TRANSDUCER AND
SPEED CONTROL SYSTEM UTILIZING SAME
10 Claims, 9 Drawing Figs.**
- [52] U.S. Cl. 180/105,
180/108; 123/102**
- [51] Int. Cl. B60k 31/00**
- [50] Field of Search 180/105 — 110;
123/102, 103**

References Cited

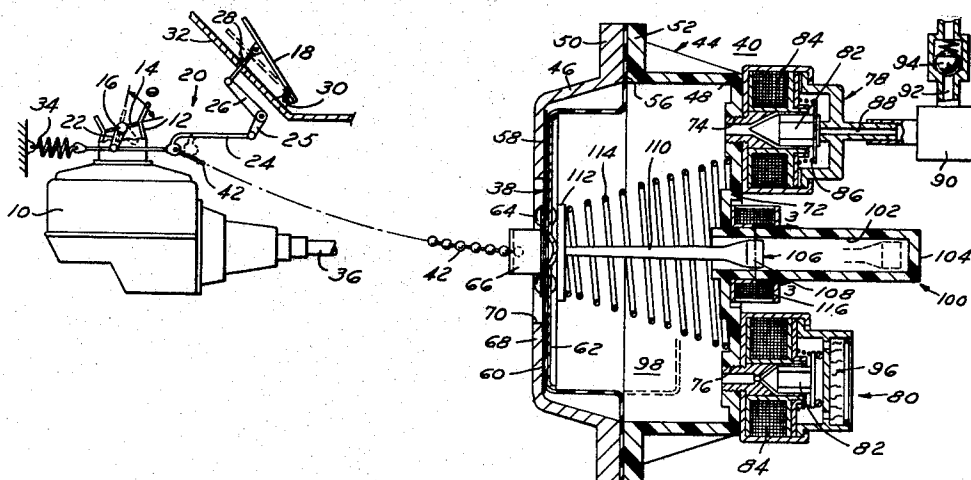
UNITED STATES PATENTS

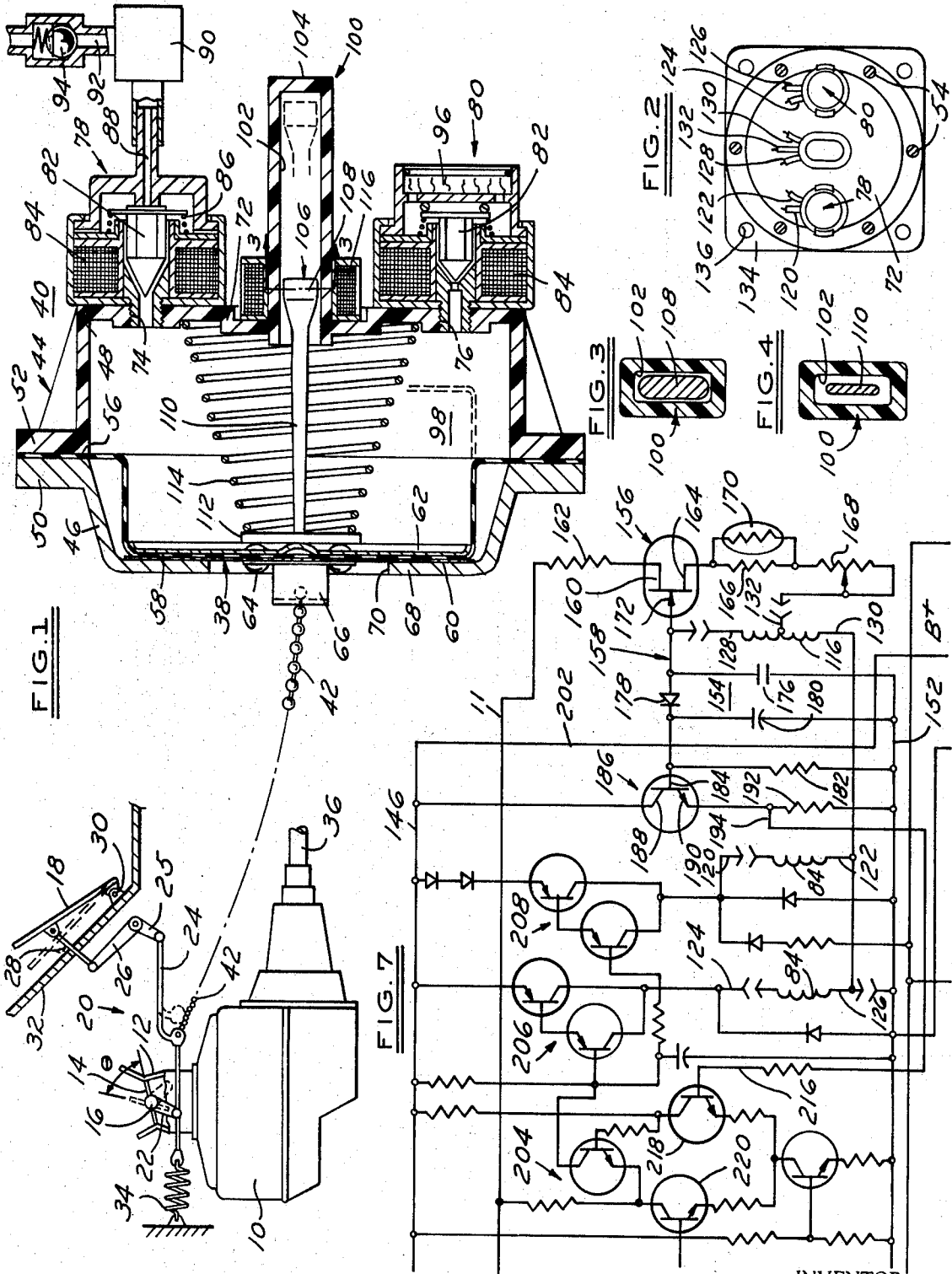
- | | | | |
|-----------|---------|----------------------|----------|
| 2,841,745 | 7/1958 | Shields | 246/182X |
| 3,062,312 | 11/1962 | Dietrich et al. | 180/109 |
| 3,195,672 | 7/1965 | Brennan | 180/105 |
| 3,332,406 | 7/1967 | Perry et al. | 180/108 |
| 3,405,779 | 10/1968 | Johnston | 180/109 |

Primary Examiner—Kenneth H. Betts

Attorneys—John R. Faulkner and Keith L. Zerschling

ABSTRACT: This disclosure relates to a position sensor and, more particularly, to a position to voltage transducer in which an oscillator is employed having a high input impedance active device, for example, a field effect transistor, coupled to a tank circuit including a center tapped winding or coil. This coil has an opening for the reception of a metallic means, preferably constructed of a ferromagnetic material, attached to a movable mechanical device, the position of which is desired to be sensed. The oscillator produces an alternating voltage output and this output is varied, for example, in a linear fashion, as a function of the positioning of the metallic means within the center tapped winding or coil. The output of the oscillator is then rectified, filtered and applied, preferably through an amplifier, to a position indicating meter. This position sensor or position to voltage transducer is particularly suitable for use in an automobile speed control device of the electronic type for producing a feedback signal as a function of the position of a controller means, for example, a throttle of an internal combustion engine in an automotive vehicle. The position of the throttle or controller means may be controlled by a servo motor in the form of a vacuum motor or actuator. The coil mentioned above is positioned on the exterior of the vacuum motor and the movable means takes the form of the diaphragm of the vacuum motor which controls the position of the controller or throttle. The metallic means, preferably constructed of ferromagnetic material, is affixed to this diaphragm. As a result, an output signal is developed from the oscillator which has a magnitude that is a function of the position of the controller or throttle with the minimum amplitude occurring when the throttle or controller is in the idle position and the maximum output occurring when the controller or throttle is at its wide open or full throttle position.





INVENTOR.
 BERNARD G. RADIN
 BY
 John R. Faulkner
 Keith L. Zerschling
 ATTORNEYS

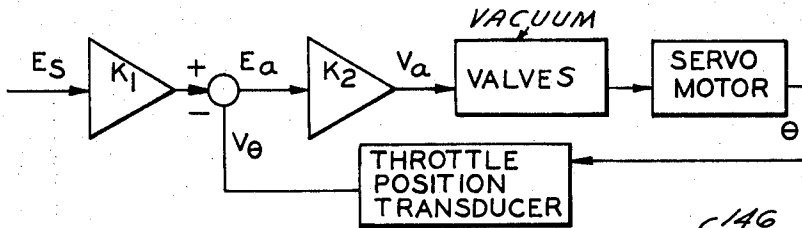


FIG. 6

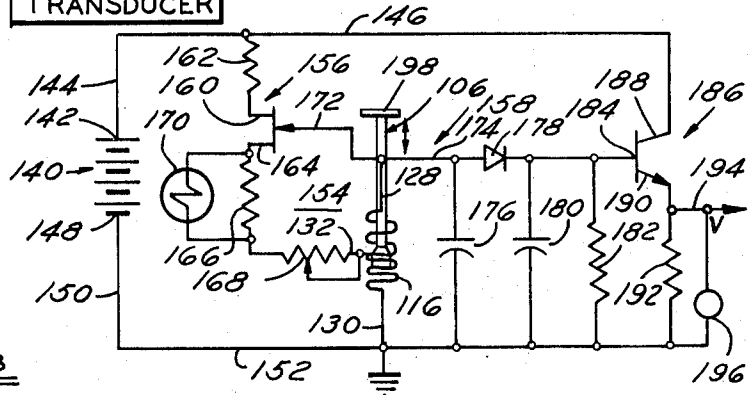
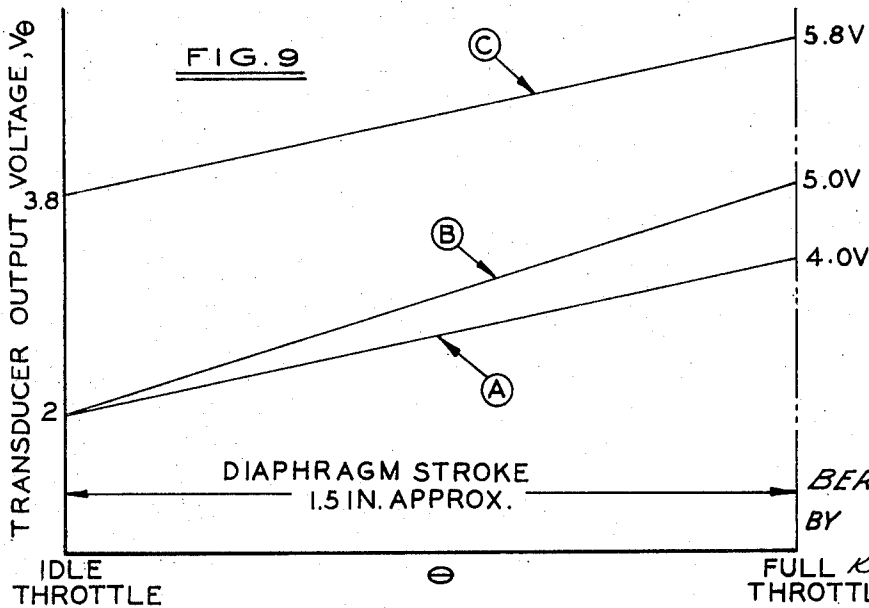
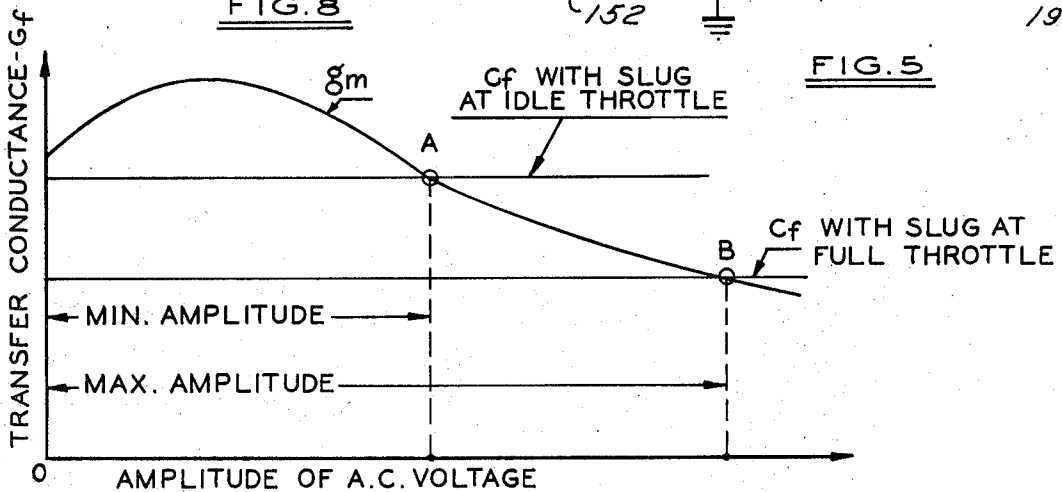


FIG. 5



INVENTOR
BERNARD G. RADIN
BY *John R. Faulkner*
Keith L. Zerschling
ATTORNEYS

POSITION TO VOLTAGE TRANSDUCER AND SPEED CONTROL SYSTEM UTILIZING SAME

BACKGROUND OF THE INVENTION

There have been numerous position sensors proposed in the prior art for producing an output voltage which is a function of the position of a movable mechanical device. The present invention is directed, in part, to such a position sensor in which the position of a mechanical movable means is transduced to a voltage which may appear on a readout device calibrated in terms of the position of the movable means. This invention overcomes a number of problems in the prior art, for example, there are not contacts involved in the invention which may wear, corrode, and be subject to contamination in the ambient in which the position sensor operates.

The position sensor of the present invention is of the oscillator type employing an active device having an extremely high input impedance, for example, a field effect transistor, and also employs a tank circuit having an inductive element, for example, a coil with an opening positioned therein. This inductive element together with a capacitive element forms the tank circuit, and the output of the oscillator is varied by the movement of a metallic means, preferably constructed of ferromagnetic material, positioned within the opening in the inductive element or coil and affixed to the movable means.

The amplitude of oscillation of the oscillator is varied by the movement of the metallic means within the opening in the inductive element or coil and as a greater amount of the metallic means is inductively coupled to the inductive element or coil the greater will be the losses in the tank circuit. The use of the high input impedance active device prevents loading of the inductive element and provides a highly accurate output voltage that produces larger changes in voltage with respect to an incremental change in the position of the movable means than occurs in prior art devices.

This position sensor, in the form of a position to voltage transducer may be used, as a portion of an electronic speed control system in which the movable means is a part of a power actuator, for example, the diaphragm of a vacuum actuator or motor which is attached to the controller or throttle for an internal combustion engine of an automobile automotive vehicle. This position to voltage transducer produces an output voltage transducer which is a function of a position of the controller or throttle in the speed control system. This voltage is used as a feedback signal that is combined with a speed error signal to provide an actuating signal for actuating the valves of the vacuum motor or actuator. This action provides a very steady operation of the system without undue oscillations or hunting. The position to voltage transducer when used in a speed control system is very advantageous since it has no moving contacts and, therefore, can operate very well in a high temperature contaminated environment that is found in the engine compartment of an automotive vehicle.

SUMMARY OF THE INVENTION

This invention relates to a position sensor and, more particularly, to a position to voltage transducer that may be employed in a speed control system of the electronic type of an automotive vehicle. It supplies a feedback voltage having a magnitude which is a function of the position of the controller or throttle of the internal combustion engine of the vehicle.

The position sensor, or position to voltage transducer, comprises an oscillator having an active element and a tank circuit. The active element preferably has a very high input impedance relative to the impedance of the tank circuit. A field effect transistor is admirably suited for use as this active element since it has an input impedance in the order of 10^7 ohms. The tank circuit includes a center tapped inductive element or coil having an opening positioned therein. This opening receives a metallic means or slug which is affixed to a movable means. As the metallic means or slug is inserted within the

opening, the loading seen by the tank circuit increases in such a fashion as to produce an alternating voltage output which varies in amplitude with the position of the movable means and the position of the metallic means. This output is then rectified, filtered and applied to a readout mechanism, preferably through an amplifier.

The inductive element may be of the center tapped type with two end terminals and an intermediate terminal, and the active device has an input means comprised of a control electrode and a common electrode, and an output means comprised of an output electrode and said common electrode. The intermediate terminal may be connected to the common electrode of the active device, for example, the source terminal of a field effect transistor. One of the end terminals of the inductive element is connected to the control electrode of the active device, for example, the gate terminal of the field effect transistor. A source of electrical energy has one terminal connected to the output electrode of the source of electrical energy, for example, the drain electrode of the field effect transistor. The other terminal of the source of electrical energy is connected to the other end terminal of the inductive element. Proper temperature compensating may also be provided through the use of a thermistor.

The movable means may be moved between a first extreme position and a second extreme position. When the movable means is in the first extreme position with respect to the inductive coil, a small percentage of the metallic means is inserted in the opening in the inductive element or coil, and, therefore, a small percentage of it is inductively coupled to the inductive element or coil and will appear as a small load resistance across the inductive element. At this position the amplitude of the oscillations produced by the oscillator is at a maximum value. As the movable means is moved toward the other extreme position a greater percentage of the metallic means is inserted within the opening in the inductive element or coil and a greater percentage of it is inductively coupled to the coil. As a result, a greater effective resistance appears across the inductive element or coil and the output voltage of the oscillator is reduced. The output voltage of the oscillator is reduced to its minimum value when the movable means and the ferromagnetic means reaches the other extreme position. A unilateral conducting device in the form of a diode is coupled to the tank circuit and the control or gate electrode of the active element or field effect transistor for rectifying this output voltage. This output voltage may then be filtered by a conventional capacitor and resistor arrangement. It may then be amplified by a standard current amplifier of the solid state type, for example, a transistor, and this voltage may then be applied to a meter which may be calibrated in terms of the position of the movable means.

The above described position sensor, or position to voltage transducer, may form a part of an electronic speed control system for an automotive vehicle. The movable means in this case is the movable portion of a servo motor, for example, a diaphragm of a vacuum motor that is coupled to a controller or throttle of an internal combustion engine. The inductive element or coil with the opening therein is mounted on the servo motor and the metallic means or slug is attached to the diaphragm for movement in a direction of movement of the diaphragm. In a speed control system the metallic means is constructed of ferromagnetic material since this material provides a greater change in voltage per increment of movement than do other metallic materials. When the controller or throttle is in the idle position the maximum amount of the ferromagnetic material is positioned within the opening in the inductive element or coil thereby providing a maximum reflected resistance across the inductive element or coil which results in a minimum voltage output signal. As the controller or throttle is moved toward the wide open or full throttle position less and less of the ferromagnetic material is positioned within the opening in the inductive element or coil and is coupled thereto. This provides an increasing alternating voltage output from the oscillator. The rectified and amplified output

from the oscillator is then combined with a speed error signal from another portion of the electronic speed control system for producing an actuating error signal which actuates the vacuum valves of the servo motor, preferably a vacuum motor or actuator.

The ferromagnetic material is shaped to provide the above mentioned output voltage characteristics and when the controller is in the idle position a maximum volume of the ferromagnetic material is positioned within the opening in the inductive element or coil and is, therefore, coupled to the coil. As the controller or throttle is moved toward the full or wide open throttle position, as the result of the operation of the vacuum motor, the diaphragm moves the ferromagnetic material so that less of it is coupled to the conductive element or coil.

Eddy currents are induced in the ferromagnetic material thereby effectively coupling a resistive load to the tank circuit, as stated above. This effective load resistance varies with the displacement of the ferromagnetic material thereby providing the above described position to voltage characteristics.

The use of a very high input impedance active element, for example, a field effect transistor, in the oscillator provides high output voltage variations with respect to the variation and position of the movable means or diaphragm of the vacuum motor. This results from the fact that the internal impedance of the generator, which is in the form of the active device, changes very little with the changes in the effective valve of the resistive load brought about by the changes in volume of ferromagnetic material coupled to the inductive element or coil.

An object of the invention is the provision of a position sensor, or position to voltage transducer, which is reliable, accurate and has a long operating life.

Another object of the invention is the provision of a position sensor, or position to voltage transducer, which provides high output voltage changes with respect to changes in position to the device whose position is to be sensed.

A further object of the invention is the provision of a speed control system utilizing a reliable, accurate and durable position to voltage transducer which will produce a signal which is a function of a position of a controller or throttle of an internal combustion engine.

Another object of the invention is the provision, in a speed control system, of a feedback means which is highly accurate, reliable and durable, and provides large changes in output voltage with respect to changes in the position of a controller or throttle of an internal combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a portion of a speed control mechanism for an automotive vehicle utilizing the present invention and including a sectional view through a vacuum motor.

FIG. 2 is a top plan view of the vacuum motor shown in FIG. 1.

FIG. 3 is a partial sectional view taken along the lines 3-3 of FIG. 1.

FIG. 4 is a partial sectional view taken along the same lines as FIG. 3 but with the vacuum motor in a different position.

FIG. 5 is a circuit diagram of the position sensor or position to voltage transducer of the present invention.

FIG. 6 is a block diagram of a portion of a speed controlled system utilizing the position sensor or position to voltage transducer shown in FIG. 5.

FIG. 7 is a partial circuit diagram of a speed control mechanism utilizing the circuit shown in FIG. 5 and showing the electronic components of the block diagram of FIG. 6.

FIG. 8 is a graph of the amplitude of the alternating voltage output of the position sensor, or position to voltage transducer, of the present invention plotted against the transfer conductance of the tank circuit of the oscillator.

FIG. 9 is a graph showing the displacement of the diaphragm of the vacuum motor shown in FIG. 1, or the displacement of other movable mechanical means, plotted against the output voltage of the position sensor, or position to voltage transducer, of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings in which like reference numerals designate like parts throughout the several views thereof, there is shown in FIG. 1 a portion of a speed control mechanism for an automotive vehicle that utilizes the present invention. In this FIG. 1 an internal combustion engine 10 is shown having an air intake means 12 which may be part of a carburetor mounted on the internal combustion engine 10. The carburetor has a movable controller means 14 which may be in the form of a carburetor throttle plate pivotally mounted for rotation about a pivot 16. The controller means or throttle plate 14 may be conventionally connected to an accelerator pedal 18 through a conventional linkage system 20 comprising arm 22, link 24, link 25, link 26 and link 28. The accelerator pedal may be pivotally mounted at 30 to the floor board 32 of the vehicle.

The controller means or throttle plate 14 is biased to its closed position by means of a tension spring 34 having one end thereof affixed to the link 24. When the accelerator pedal 18 is depressed, the controller means or throttle plate 14 will be rotated counterclockwise, as shown in FIG. 1, toward its open position through the linkage means 20 to provide more air and fuel for the internal combustion engine 10 and thus increase its speed. A drive shaft 36 from the internal combustion engine 10 may be connected to the driving wheels of the automotive vehicle through a conventional transmission and driveline. The link 24 and hence the controller means 14 or carburetor throttle is also connected to a diaphragm 38 of a vacuum motor or power actuator 40 through a suitable chain-type connector 42.

The vacuum motor or power actuator 40 comprises a housing 44 having a first cup-shaped portion 46 and a second cup-shaped portion 48. The cup-shaped portions 46 and 48 each have radially extending flanges 50 and 52, respectively, which may be connected together by means of a plurality of bolts or screws 54. The diaphragm 38 is constructed of a flexible, elastomeric material and has its outer periphery, designated by the numeral 56, trapped and suitably affixed between the flanges 50 and 52.

The main body portion 58 of the diaphragm 38 is positioned between an outer metallic plate 60 and an inner metallic cup-shaped plate 62, with the main body portion 58 being affixed between the two plates 60 and 62 by a plurality of rivets 64. The rivets 64 are also employed to affix the main body portion 58 of the diaphragm 38 to the hooklike connecting member 66 that receives one end of the chainlike connecting member 42. This diaphragm construction described above is conventional, and further description is considered unnecessary.

The cup-shaped portion 46 of the housing 44 may be constructed of any suitable material, and it includes an end wall 68 having a central aperture 70 positioned therein so that atmospheric pressure may be applied to the side of the diaphragm 38 that is positioned against the outer plate 60.

The other cup-shaped portion 48 of the housing 44 is constructed of an insulating material for example, plastic; and it has an end wall 72 positioned in generally spaced parallel relationship with respect to the end wall 68 of the cup-shaped portion 46 of the housing 44. This end wall 72 has a pair of spaced threaded bores 74 and 76 that receive a normally closed vacuum valve 78 and a normally open atmospheric valve 80, respectively. The vacuum valve 78 and the atmospheric valve 80 are conventional in construction and will be described only to the extent necessary for an understanding of the invention. Each of these valves includes a ferromagnetic shuttle or valve member 82 each of which is controlled by means of separate solenoid or winding 84.

The shuttle or valve member 82 of the vacuum valve 78 is spring biased by a spring 86 into a position to cover the end of conduit 88. The valve member or shuttle 82 is fluted so that fluid may flow through the valve when the winding 84 is actuated and the valve member or shuttle 82 is moved to the left as shown in FIG. 2 to uncover the conduit 88. The conduit 88 is connected to a vacuum accumulator 90 which may be suitably connected through a conduit 92 and a check valve 94 to the intake manifold of the internal combustion engine 10. On the other hand, the atmospheric valve 80 is normally open, as shown, so that atmospheric pressure may force air through a filter 96 into chamber 98 that is formed by the cup-shaped portion 48 of the housing 44 and the diaphragm 38. The filter 96 removes dirt, oil vapors and other contaminants that are normally present in the engine compartment of an automotive vehicle. It is readily apparent from an inspection of the atmospheric valve 80 that when it is in the position shown in FIG. 1, air may flow into the chamber 98 through the passages shown. When the solenoid or winding 84 is energized, the shuttle or valve member 82 will move to the left, as shown in FIG. 1, thereby restricting the flow of air into the chamber 98 and may, if moved fully to the left as shown in FIG. 1, cut off communication of the chamber 98 with the atmosphere.

The end wall 72 of the cup-shaped portion 48 of housing 44 has a protuberance 100 communicating with the chamber 98 and essentially forming part of it. This protuberance 100 has an axially extending opening 102 positioned therein and a closing end wall 104. The axially extending opening 102 extends at substantially right angles to the end wall 72.

A means 106 in the form of a metallic slug, preferably constructed of a ferromagnetic material, extends into the opening 102. This means 106 has an enlarged end portion 108, a central, generally tapered portion 110 and a radially extending flange 112 positioned opposite the end 108. A helical compression spring 114 has one end positioned against the end wall 72 and the other end positioned against the radially extending flange 112 of the means 106. The radially extending flange 112 is positioned against inner cup-shaped plate 62 so that the compression spring 114 forces outer plate 60 into engagement with end wall 68 of cup-shaped portion 46. As a result, the diaphragm 38 and the means 106 will be positioned as shown in FIG. 1 when the speed control mechanism is inoperative.

An inductive element in the form of a coil or winding 116 is positioned about the protuberance 100 and against the end wall 72 of the cup-shaped housing member 48. Thus, when the diaphragm 38 is positioned as shown in FIG. 1 with the plate 60 in engagement with the end wall 68, the enlarged end portion 108 of the movable means 106 is positioned with the central opening in coil or winding 116.

As shown in FIG. 2 the winding 84 of the vacuum valve 78 has terminating leads 120 and 122 and the winding 84 of the atmosphere valve 80 has terminating leads 124 and 126. Additionally, the coil or winding 116 has terminating leads 128 and 130 as well as a center tap lead 132. Additionally, the housing 44 and, more particularly, the cup-shaped housing portion 48 may have an outwardly extending mounting flange 134 with a plurality of apertures 136 positioned therein for mounting the vacuum motor 40 on any suitable mounting plate in an automotive vehicle.

The cup-shaped portion 48 of the housing 44 is constructed of the insulating plastic material in order to magnetically and electrically isolate or insulate the means 106 and the winding or coil 116 from the housing 44. In FIG. 1 as shown, the controller means or throttle 16 is shown in solid lines in its idle or closed position. Similarly, the diaphragm 38 and the means 106 is shown when the controller means or throttle 16 is in the closed or idle position. The dotted lines of FIG. 1 show the controller means or throttle 16 in its wide open or full throttle position as well as showing certain portions of the linkage 20 and the accelerator pedal 18 in the fully open or full throttle position. The dotted lines also show the position of the diaphragm 38 and the means 106 when the controller 16 or throttle is in its wide open or full throttle position. Obviously,

these components may occupy any position intermediate these two extreme positions or limiting positions. In this respect FIG. 3 is a partial sectional view through the protuberance 100 with the enlarged portion 108 of the means 106 positioned within the opening in winding or coil 116. On the other hand, FIG. 4 is a partial sectional view taken along the same lines and showing in cross section the generally tapered portion 110 of the means 106 positioned within the opening in the coil or winding 116 when the diaphragm 38 and the means 106 are in their dotted line positions.

Referring now to FIG. 5, there is shown the position sensor or position to voltage transducer of the present invention which may be readily used with the speed control system, including the vacuum motor, shown in FIGS. 1 through 4. A source of direct current electrical energy 140 has a positive terminal 142 connected through lead 144 to line 146. The negative terminal 148 is connected through lead 150 to line 152. The position sensor or position to voltage transducer comprises an oscillator 154 having a solid state active element 156 and a tank circuit 158. The solid state active element 156 is of the form that has a very high input impedance; for example, a field effect transistor. An output electrode 160 in the form of a drain electrode of the field effect transistor is connected to line 146 through a resistor 162. A common electrode 164 in the form of the source electrode of the field effect transistor is connected to lead 132 of the inductive element 116 in the tank circuit 158. This inductive element 116 is shown in the form of the winding or coil as described in relation to FIGS. 1 through 4. A resistor 166 and a variable compensating resistor 168 are connected in circuit between the common or source electrode 164 and the lead 132, and a temperature compensating thermistor 170 is connected in parallel with the resistor 166. The control electrode 172 of the solid state active element 156, which maybe the gate electrode when the solid state active element is a field effect transistor, is connected to a lead 174.

The lead 128 of the inductive element 116, in the form of the coil or winding, is connected to this lead 174, while the other lead in the lead 130 of the inductive element 116 is connected to line 152. A capacitor 176 is connected across the inductive element 116 and to the lead 174 at one terminal and to the line 152 at the other terminal. These two elements, that is, the inductive element 116 and the capacitor 176 form the resonant tank circuit 158 of the oscillator 154. It is apparent that the output of the oscillator 154 appears across the tank circuit on the lead 174 and is an alternating voltage.

This alternating voltage from the oscillator 154 is rectified by a unilateral conducting device in the form of a diode 178. The rectified voltage is filtered by a capacitor 180 and a resistor 182 connected in parallel between lead 174 and line 152. This rectified and filtered voltage has a magnitude of for DC level proportional to the amplitude of the alternating voltage produced by the oscillator and is applied to the base 184 of a solid state current amplifier in the form of a transistor 186. This transistor 186 has its collector 188 connected to line 146 and its emitter 190 connected through resistor 192 to line 152. An output lead 194 is connected intermediate the emitter 190 and the resistor 192. A meter 196 is connected across the resistor 192 and between the output lead 194 and the line 152.

In FIG. 5 a mechanically movable means 198 shown by the block may be moved between the two extreme positions in the direction shown by the arrow. The means 106 in the form of a metallic or ferromagnetic slug is connected to the movable means 198 and is positioned within the inductive element or coil 116. The relationship of these elements may be as shown in FIG. 1 with the movable means 198 being the diaphragm 38 which is in engagement with the radially extending flange 112 of the means 106.

The position sensor or position to voltage transducer shown in FIG. 5 may be incorporated in a speed control system shown partially in the block diagram in FIG. 6 and is denoted in this block diagram as a throttle position transducer which in effect produces a voltage $V\theta$ on the lead 194. The voltage $V\theta$

is a function of the angular position of the controller or throttle 14 and of the linear position of the diaphragm 38 of the vacuum motor 40 which in the block diagram is denoted as the servo motor. Thus as the controller or throttle 14 moves from the solid line position shown in FIG. 1 toward its dotted line position shown in dotted lines in FIG. 1, the angle θ will increase and the voltage $V\theta$, which in this case is a feedback voltage, will also increase. This action will be explained in greater detail subsequently.

In the block diagram shown in FIG. 6, a speed error signal E_s is fed to an amplifier K1 and this amplified speed error signal is fed to a differential amplifier which is shown in the block diagram in the form of a summer. The amplified speed error signal is compared with the feedback signal $V\theta$ to result in an actuating error signal E_a . This actuating error signal is amplified by the amplifier K2 to result in an amplified actuating signal V_a . This amplified actuating signal V_a is fed, as will be explained more fully in relation to FIG. 7, to the windings 84 of the vacuum valve 78 and the atmospheric valve 80 to actuate them in proportion to the signal, and these values control the position of the diaphragm 38 of the vacuum motor 40 which in the block diagram is shown as a servomotor. This system is very stable in operation and is substantially free of oscillating and hunting.

Referring now to FIG. 7 there is shown a partial circuit diagram of an electronic circuit for a speed control system which is essentially the circuit diagram of the electrical components of the block diagram shown in FIG. 6 and the includes the circuit components shown in FIG. 5 of the position sensor or position to voltage transducer. In this circuit diagram the elements shown in FIG. 5 carry the same numerals and the source of electrical energy 140 is represented by the line B+. Thus in this circuit the line 146 may be energized from the source of electrical energy B+ through lead 202 and certain control switches of the speed control system fully described in copending Application Ser. No. 798,672, filed Feb. 12, 1969, in the names of Elliot Josephson and Zbigniew J. Jania and assigned to the assignee of this invention. The line 146 also supplies operating voltages for the various electrical components shown in FIG. 7 which include a differential amplifier 204, that serves as the summer and amplifier K2 shown in FIG. 6, a first Darlington amplifier 206 and a second Darlington amplifier 208.

The output of the differential amplifier 204 is connected to the input of the two Darlington amplifiers are connected in series with the winding 84 of the atmospheric valve 80 and the winding 84 of the vacuum valve 78, respectively. As stated previously, the oscillator 154 produces an output voltage which is rectified by diode 178 and then filtered. This voltage is then applied to the base of the transistor 186 which amplifies this voltage. The output ($V\theta$) of the amplifier 186 is fed through leads 194 and 216 to the base of transistor 218 forming a portion of the differential amplifier 204. The speed error signal E_s is amplified by amplifier K1 shown in FIG. 6 and is applied to the input of transistor 220 forming another portion of the differential amplifier 204. The output of the amplifier or transistor 186 applied to the input of transistor 218 is the voltage $V\theta$ which is proportional to the displacement of the main body portion 58 of the diaphragm 38 away from the wall 68 of the cup-shaped housing member 46. This is accomplished through the use of the means 106 comprising the metallic slug, preferably of a ferromagnetic material which changes the inductance of the winding 116 and the effective resistive load across it as a function of the displacement of the main body portion 58 of the diaphragm 38 from the wall 68 of the cup-shaped housing portion 46.

In operation if the speed error signal applied to transistor 220 and the signal applied from the output of the oscillator 154 to transistor 218 of the differential amplifier 204 indicates that the vehicle is operating at a speed lower than the desired speed, the winding 84 of the vacuum valve 78 will be energized more fully thereby opening the vacuum valve and the winding 84 of the atmosphere valve 80 will be energized

more fully thereby closing this atmosphere valve. As a result, an increased vacuum is produced in the chamber 98 and atmospheric pressure applied through the aperture 70 in the end wall 68 of cup-shaped housing portion 46 will move the main body portion 58 of diaphragm 38 and the means 106 to the right as shown in FIG. 1 against the bias of the spring 114. This causes the means 106 in the form of the metallic slug to be inserted further within the opening 102 of the protuberance 100 and causes an increased force to be applied through chain member 42 to link 24 of the accelerator linkage 20 thereby rotating the controller member or throttle plate 14 more fully counterclockwise and opening it more fully. This will increase the speed of internal combustion engine 10 and the vehicle until balanced conditions are reached. At the same time the movement of the means 106 with respect to the coil 116 contained in the oscillator will cause a change of inductance in the winding 116 and hence its inductive reactance and a change in the effective resistance appearing across it. The further the movable member 106 is moved to the right and is inserted in the opening 102 in the protuberance 100, the greater will be the output voltage of the oscillator 154. This increased voltage from the oscillator 154 will be applied through transistor-amplifier 186 to transistor 218 of differential amplifier 204 thereby causing an output signal to Darlington amplifiers 206 and 208 which will balance the system.

If the speed of the vehicle increases above a desired speed, the opposite situation will take place with the atmospheric valve 80 moving to an open position and the vacuum valve 78 moving to a closed position. This results in an increased pressure in the chamber 98 moving the main body portion 58 of diaphragm 38 to the left as shown in FIG. 1 thereby causing spring 34 attached to the link 24 of the throttle linkage 20 to rotate controller member or throttle plate 14 toward its closed position. This reduces the speed of internal combustion engine 10 and the speed of the vehicle. When this happens, the means 106, in the form of the metallic, preferably ferromagnetic slug, will move to the left as shown in FIG. 1. This results in the decreased output from the oscillator 154 and a decreased voltage applied to the transistor 218 through amplifying transistor 186. Consequently, this voltage in combination with any change of voltage applied to the input of transistor 220 will, through the differential amplifier 204 and the Darlington amplifiers 206 and 208, bring the system back into balance so that the vehicle will then travel at the desired speed.

It can be appreciated that with the circuits shown in FIGS. 5 and 7 and with the mechanism shown in FIGS. 1 through 4, the movement of the means 106 varies the amplitude of the output voltage of the oscillator 154. When the vacuum motor 40 is in the solid line position shown in FIG. 1, the controller or throttle 14 is in the solid line position, and the means 106 is also positioned in the solid line position. In this position, the large end 108 of the means 106 is positioned within the opening in the winding 116 formed by the protuberance 100. This corresponds to the position of the movable means 198 shown in FIG. 5. As the main body portion 58 of the diaphragm 38 in FIG. 1 moves to the right thereby opening the controller or throttle 14 and increasing the angle θ as shown, the means 106 moves to the right as shown in FIG. 1 so that less and less of the metal, preferably ferromagnetic material, is coupled to the magnetic field produced in the winding or inductive element 116. This increases the amplitude of the alternating voltage output of the oscillator 154. Similarly, as the movable means 198 and the means 106 is moved downwardly in FIG. 5 less and less of the metal or iron in the means 106 is coupled to the coil 116 and, therefore, the output voltage from the oscillator 154 will increase.

This phenomenon is caused primarily by two effects: (1) changes in the self and mutual inductances of the two halves of the inductive element or winding 116 and (2) a change in the effective resistive load effectively coupled to the tank circuit brought about by eddy currents induced in the metal, preferably ferromagnetic, of the means 106. The greater the volume of metal or ferromagnetic material coupled with the

winding or coil 116, the greater will be this effective resistive load coupled across the tank circuit. Referring now to FIG. 8 there is shown a plot of the amplitude of the AC voltage of the oscillator against a term denoted transfer conductance- G_f . The term G_f or transfer conductance is expressed by the equation:

$$G_f = \frac{rLC_1}{(L_1 + M)(L_2 + M) - r_1r_2LC_1}$$

where $L = L_1 + L_2 + 2M$

L_1 = inductance of 1/2 of winding 116

L_2 = inductance of 1/2 of winding 116

r_1 = resistance of 1/2 of winding 116

r_2 = resistance of 1/2 of winding 116

M = mutual inductance of the two halves of the winding or coil 116

r = total load (ohms) coupled to tank circuit 158

It will be noted that gm is plotted in FIG. 8 and this is the transconductance of field effect transistor 156. When gm equals the transfer conductance, minimum amplitude alternating oscillations occur having the amplitude as shown. This occurs when the parts are in the position as shown in the solid lines in FIG. 1 with the large portion 108 of the means 106 positioned within the opening in the winding 116 and with the means 198 shown as positioned in FIG. 5. The term r which is a total load coupled to the tank circuit includes the resistive load effectively coupled to the tank circuit due to the eddy currents induced in the means 106. The greater the amount of metal or ferromagnetic material coupled with the magnetic field of the winding 116, the greater will be this effective resistive load and, therefore, G_f will rise.

It has been determined that the frequency of the oscillations of the oscillator 154 varies within a small frequency range as the means 106 is moved within the coil or winding 116. The primary effect of movement of the means 106, therefore, is to change the resistance r effectively coupled to the tank circuit which is brought about by eddy current losses induced in the metal or ferromagnetic material that is magnetically coupled to the coil or winding 116 and by hysteresis losses in this material. Thus the greater the volume of material magnetically coupled to the coil or winding 116, the smaller will be the amplitude of oscillations. As the volume of material coupled to the winding 116 decreases with the movement of the diaphragm 38 and means 106 to the right as brought out in FIGS. 1, 3 and 4 and the downward movement of the movable means 198 and means 106 shown in FIG. 5, the greater will be the amplitude of the oscillations since the transfer conductance G_f will decrease as a function of the above equation.

FIG. 9 shows the transducer output voltage, $V\theta$, which appears on lead 194 as a function of the diaphragm stroke or the value of the angle θ shown in FIG. 1 which is the angle of movement of the controller or throttle 14. FIG. 9 shows different slopes and different variations brought about by various shapes of the means 106 positioned within the coil or winding 116. The voltage $V\theta$ is a function of the diaphragm stroke or displacement angle θ . The function may be described as a curve having at all points a positive slope and is such that it lies anywhere between the lines A and C. Moreover, in a speed control system, it may be desirable that the slope of the curve anywhere between the two end points be not less than that of line A and no greater than that of line B.

It may be desirable to provide a voltage output $V\theta$ from the position sensor or position to voltage transducer which is proportional to the displacement or movement of the means 106 so that the voltage $V\theta$ varies linearly with the displacement of moveable means 106. The means 106, however, may be shaped to provide for various curves that meet the criteria mentioned above and discussed in connection with FIG. 9.

As will be readily apparent to those skilled in the art, the means 106, preferably constructed of ferromagnetic material, may be shaped to produce oscillations of maximum amplitude when the movable mechanical means 198 is in the position

shown in FIG. 5 and the diaphragm 38 is in the solid line position shown in FIG. 1. This means may also be shaped to produce oscillations of decreasing amplitude as the means 198 is moved downwardly in FIG. 5 or as the diaphragm 38 is moved to the right as shown in FIG. 1. To accomplish this purpose, it is merely necessary to have a small volume of the material coupling the inductive element or winding 116 when the mechanically movable means 198 is in the position shown in FIG. 5 or the diaphragm 38 in FIG. 1 as is shown in the solid line position. In this case, FIG. 4 would show a cross section of the means 106 when the diaphragm 38 is positioned in the solid line position as shown in FIG. 1 and the enlarged portion 108 would be located intermediate the two ends of the means 106 and would have a large volume of material coupled to the coil 116 when the diaphragm 38 is in the dotted line position. With this configuration, FIG. 3 would show the cross section of means 106 when the diaphragm is in the dotted line position as shown in FIG. 1.

With the above described configuration of the means 106, the circuit diagram of FIG. 5 would remain the same except that the meter 196 would be calibrated to compensate for the polarity change of the output signal from the amplifier 186. With respect to the speed control circuit diagram shown in FIG. 7, a unity gain polarity reversing amplifier would have its input circuit connected to the lead 194 and its output circuit connected to the base of transistor 218. Thus the signal on the base of transistor 218 would increase as the diaphragm 38 of the vacuum motor or actuator 40 is moved from the solid to the dotted line positions and as the angle θ increases as shown in FIG. 1.

The present invention thus provides a very reliable, durable and accurate position sensor, or position to voltage transducer, that produces high differences in voltage due to displacement or movement of a means, the position of which is to be sensed. Moreover, this invention provides an accurate, inexpensive, reliable position to voltage transducer in combination with certain components of an automotive vehicle to provide a feedback signal for an electronic system that provides speed control for an automobile vehicle.

I claim:

1. In an automotive vehicle having an internal combustion engine, a throttle means for controlling the speed of the engine and an actuator coupled to said throttle means for moving said throttle means from an idle position to a full throttle position, a throttle position transducer comprising an oscillator producing an alternating voltage, means coupled to the actuator for varying the amplitude of the alternating voltage as a function of the position of the throttle means as the throttle means is moved from an idle position toward a full throttle position, and means coupled to the oscillator for producing a unidirectional voltage having a magnitude proportional to the amplitude of the alternating voltage.

2. The combination of claim 1 in which said oscillator comprises an active device and a tank circuit coupled to said active device, said tank circuit including an inductive element, and said means coupled to said actuator for varying the amplitude of the alternating voltage includes means for varying the value of the effective resistance coupled across said inductive element.

3. The combination of claim 2 in which said inductive element comprises a coil having a central opening positioned therein, and said means coupled to said actuator for varying the value of the effective resistance coupled across said inductive element comprises a ferromagnetic mass positioned within and movable within said opening.

4. The combination of claim 3 in which said active element has an input means and an output means, said input means comprises a control electrode and a common electrode, said output means comprises an output electrode and said common electrode, said coil has a terminal at one end, a terminal at the other end and an intermediate terminal, the terminal at one of said ends being connected to said control electrode, and the intermediate terminal connected to said common

electrode, a source of electrical energy having one terminal connected to said output electrode and the other terminal connected to the terminal at the other of said ends of said coil.

5. The combination of claim 4 in which a capacitor is connected across the two terminals at the end of said coil to form in combination with said coil the tank circuit of said oscillator.

6. The combination of claim 5 in which said means for producing a unidirectional voltage having a magnitude proportional to the amplitude of the alternating voltage comprises a unilateral conductive means coupled to said control electrode and to said terminal at said one of said ends of said coil.

7. The combination of claim 3 in which said active device is a solid state device having a very high input impedance compared to said tank circuit.

8. The combination of claim 3 in which said active device is a field effect transistor, said control electrode is the gate electrode, said output electrode is the drain electrode and said common electrode is the source electrode of said field effect transistor.

9. In a speed control system for an automotive vehicle the combination comprising a movable controller for controlling

the speed of the vehicle as a function of the position of the controller, an actuator means coupled to said controller for controlling the position of said controller, and means coupled to said actuator for producing a voltage having a magnitude proportional to the position of said controller moves to increase the speed of the vehicle, said means comprising an oscillator producing an alternating voltage, means coupled to said oscillator and said actuator for varying the magnitude of the alternating voltage proportional to the position of said actuator, and rectifying means coupled to said oscillator for producing a unidirectional voltage from the alternating voltage.

10. The combination of claim 9 in which said oscillator comprises an inductive element having a central aperture, and said means coupled to said oscillator and said actuator comprises a ferromagnetic means positioned within said central aperture and having a varying cross-sectional area whereby a decreasing volume of said ferromagnetic means is coupled to said inductive element as said actuator means moves said controller means to increase the speed of the vehicle.

25

30

35

40

45

50

55

60

65

70

75