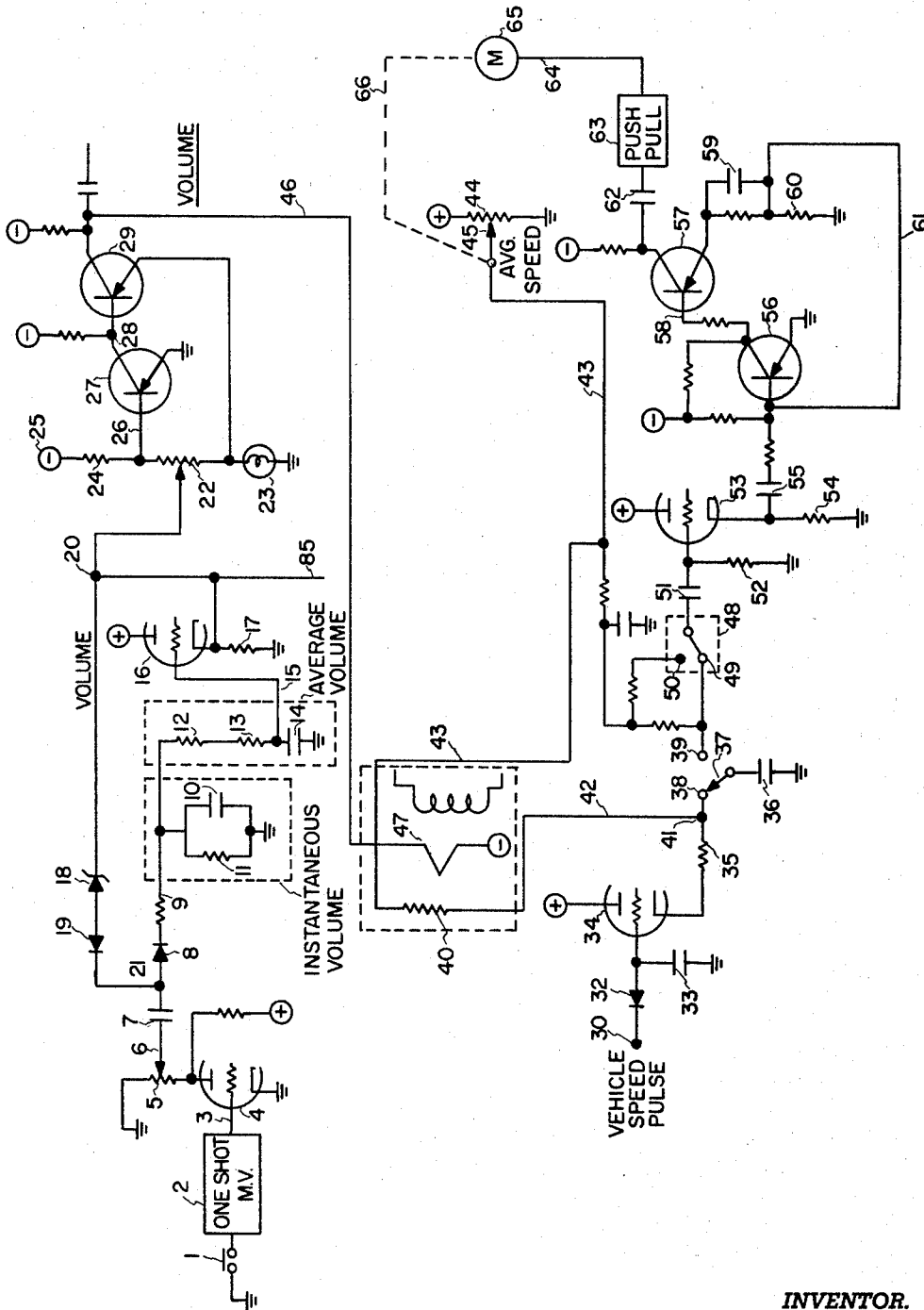


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TRAFFIC VOLUME OR SPEED COMPUTER WITH TENER
DIODE IN FEEDBACK CIRCUIT
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TRAFFIC VOLUME OR SPEED COMPUTER WITH ZENER DIODE IN FEEDBACK CIRCUIT

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ABSTRACT OF THE DISCLOSURE

Electrical apparatus for computing an average of a characteristic of traffic flow for a series of cars passing a point. One aspect involves a traffic volume computing circuit employing a condenser charged incrementally by input pulses from the passing vehicles against a relatively short time discharge so that the condenser charge provides a short term pulse rate or "instantaneous traffic volume" voltage, such voltage being applied to an RC circuit of relatively long time constant to provide an average traffic volume signal as an output, the computing circuit having a feedback circuit including a reversed biased Zener diode between such output and the pulse input to provide controlled linearity in computing the traffic volume. Another aspect involves a traffic speed computing circuit for averaging the speeds of a number of vehicles varying linearly with traffic volume, this circuit including a thermistor heated by a heater to vary its resistance to control the number of vehicles in the speed average, the heater being energized from a nonlinear degenerative feedback amplifier circuit controlled by the traffic volume signal to compensate for the nonlinearity in heating the thermistor.

This application is a division of copending application Ser. No. 137,354, filed Sept. 11, 1961 for "Traffic Density Computer," issued as Patent No. 3,239,805, on Mar. 8, 1966.

This invention relates to traffic measuring or control apparatus and more particularly relates to apparatus for measuring traffic for controlling traffic signals or other control or monitoring or indicating purposes.

This invention relates to apparatus for computing traffic volume (average number of cars passing a point per unit time) or apparatus for computing the average speed of a series of cars passing a point, each of which may be considered different aspects of apparatus for computing an average of a characteristic of traffic flow for a series of cars passing such point.

One particular aspect of this invention relates to improved circuitry for measuring the rate of traffic flow per unit of time past a point (traffic volume) for providing a traffic volume electrical output signal which varies in value linearly over a wide range of such traffic volumes. In particular, this aspect of the invention provides apparatus for sensing passage of individual vehicles, continuously determining an electrical value representing the instantaneous rate of vehicle passage per unit of time (traffic volume), continuously averaging this instantaneous traffic volume value over a base which may be time period or distance of roadway to provide an electrical value representing the average traffic volume for this base, and feeding back a portion of this averaged traffic volume signal to raise the voltage level at the input of the volume circuitry to provide an equal effect for such vehicle at any level of volume.

This improved traffic volume circuit may cooperate through improved circuitry with a speed averaging circuit and improved circuitry for in effect dividing the volume

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by the speed for computing the traffic density in vehicles per unit distance along the roadway, which is an important factor in traffic monitoring or control. The traffic density computer is the subject of the said copending application Ser. No. 137,354.

In particular in one aspect, the invention provides feedback through a cathode follower and a Zener diode connected in cascade to provide a regenerative high impedance feedback circuit with a gain of less than one (1) which has a negligible effect on the average volume storage circuit while also providing a substantially constant voltage to the instantaneous volume circuit between vehicle actuations to restore any charge bucketed by the instantaneous circuit into the averaging circuit.

The Zener diode in this feedback circuit acts as a constant voltage drop or source so that the average volume voltage fed back to the input of the instantaneous volume circuit is less than the average volume at the cathode follower by an amount equal to the Zener voltage drop and therefore less than the instantaneous volume voltage. Thus the feedback voltage raises the level of voltage at the input of the instantaneous circuit without providing any charge path for such circuit so that rapid variations (either increasing or decreasing) in instantaneous volume may occur without providing regeneration as a result of the slower averaging circuit providing the feedback.

Another aspect of the invention relates to improved circuitry for continually measuring both traffic volume and traffic speed over a base time period or distance segment while assuring that both such measurements relates to the same vehicles. In particular, this aspect of the invention provides for continually sampling passing vehicles within a time or distance sampling segment of roadway in which vehicles continually pass in and out of such segment example, determining the instantaneous and/or average traffic volume of vehicles presently included within the sampling segment, providing an average traffic speed of the vehicles presently within this segment, and insuring that both the traffic volume and speed measurements are correlated to the same vehicles.

A comparison circuit is provided for correlating the speed and volume and includes a thermistor which permits individual vehicle speed pulses to either increase or decrease the average traffic speed measurement of the vehicles within the segment linearly in proportion to the number of vehicles within the segment as represented by the traffic volume. To provide this linear relationship the invention provides a transistor feedback amplifier supplying the heater of the thermistor.

A still further aspect of the invention relates to traffic measuring apparatus which is subject to wide ranges of temperature variations and input signal values in which cascaded transistor amplifiers for such signals have degenerative feedback for the emitter of one to the base of a preceding one to provide constant gain independent of temperature and/or voltage variations for a wide range of input signals.

An object of the invention is to provide an improved traffic volume measuring circuit which is linear over a wide range of traffic volumes.

Another object is to provide an improved circuitry for measuring the average traffic speed of vehicles within a sampling segment, which has vehicles continually moving into and out of the segment, by varying the effect of a single vehicle speed pulse in modifying the average speed as a linear function of the number of vehicles presently included in such sampled segment.

Other objects are to provide improved circuitry amplifying traffic measurements and particularly such circuitry which is independent of temperature and voltage variations.

A further object is to provide improved circuitry which continually measures both the traffic volume and traffic speed of substantially the same group of vehicles within a common time or distance base representing a segment of traffic, with vehicles moving into and out of such segment.

A summary of the invention will be described as follows: Individual vehicles passing along a roadway are sensed to provide both passage and speed pulses. Such passage pulses are fed to a rate circuit which derives a voltage representing traffic volume. An instantaneous measure of such volume is average over a time period (which may be selectable) so that the average volume measurement represents the vehicles which have passed a certain segment of traffic or of roadway in which new vehicles are continually being included within the segment and old vehicles are continually being dropped from such measurement so that the average volume measurements at any one instant represents the vehicles which have passed within a previous time period. To insure that this volume measurement is accurate, feedback through a Zener diode is provided.

The individual speed pulses are stored in a condenser and are subsequently taken from that condenser and bucketed into a second condenser whose charge represents the average traffic speed. The amount of charge bucketed into the second condenser by each vehicle is controlled not only by the speed of that vehicle but also by the number of vehicles which are presently included in the sampling segment whose average speed is presently represented by the charge on this second condenser. This latter circuitry includes a thermistor which controls the amount of charge bucketed into the second condenser by the individual vehicle in proportion to the traffic volume.

Traffic density in vehicles per mile may then be derived by apparatus which effectively divides volume by speed, if desired, as set forth in said copending application Ser. No. 137,354 for example.

The above and other objects and advantages of this invention will be apparent from the following detailed disclosure and drawing of which: the drawing is a schematic diagram of a preferred form of traffic volume and speed measurement apparatus.

In reference to the drawing, the passage of an individual vehicle beyond a point along a roadway is sensed at the vehicle detector switch 1 which may be in, above or alongside the roadway in various well known forms. Monostable multivibrator 2 is operated in response to such vehicle passage to provide a negative pulse output at 3 on the grid of the normally conducting pulse amplifier 4. Accordingly amplifier 4 is cut-off thereby raising the potential at the plate and across resistor 5 in a positive direction.

The positive pulse occurring at tap 6 provides a charging path for condenser 7 (two microfarad) and condenser 10 (one microfarad) in series from the tap at 6, through condenser 7, diode 8, and 100K ohm resistor 9 and condenser 10 to ground. A greater percentage of this pulse is developed across condenser 10 than across condenser 7 because of their relative size. Successive vehicles will successively increase the charge on condenser 10 to represent a greater number of vehicles.

However, since traffic volume is the number of vehicles passing a point per unit of time, it is desirable to introduce the time factor into the measurements; accordingly resistor 11 permits a slow discharge of condenser 10 during the period between vehicle actuations so that the voltage across condenser 10 is a function not only of the number of vehicles but also of their rate and is referred to as the instantaneous traffic volume. For example, if the vehicles flowing along the roadway are closely spaced, the voltage across condenser 10 will be greater than if they are spaced farther apart.

A traffic volume averaging circuit is provided including two fifteen megohm resistors 12 and 13 and a two microfarad condenser 14. This sixty second averaging circuit

thus provides an average traffic volume voltage on line 15 which is connected to the grid of cathode follower 16. The cathode follower is ideally suited for its purpose of providing an output of the average traffic volume from line 15 since it has a high input impedance which does not substantially affect the long time constant of the averaging circuit.

Feedback is provided from the cathode resistor 17 via junction 20, through Zener diode 18 and diode 19 to junction 21 at the input of the volume circuit for a reason which will now be described.

Assume traffic volume is high; then the voltage across condensers 10 and 14 will be high.

The charging characteristics of condensers are non-linear since the charge on a condenser at any one time opposes any further charge; if the rate of flow of vehicles doubles or triples, the voltage across the condenser will not double or triple but will be substantially less. To correct this inaccuracy and thereby provide a linear measure of traffic volume, the feedback from the cathode of 16 provides a voltage at junction 21 which has a positive polarity to charge condenser 7 to this value which is additive with the vehicle input pulse at tap 6 to thereby raise the level of input voltage at junction 21. Thus as volume increases, the feedback voltage increases to raise the input voltage level so that the feedback voltage coupled with the positive passage pulse is always more positive than the charge on condenser 10 and 14 so that each passage pulse buckets a unit charge into condenser 10 independent of the volume level.

The selected Zener diode 18 in the preferred embodiment has a breakdown voltage in the reverse direction of 7.5 volts. Below this level the condenser charging circuit is linear and no feedback compensation is necessary. In normal operation the volume level would generally be greater than 7.5 volts. Therefore the diode 18 is conducting in a reverse direction and provides a 7.5 volt drop in the feedback circuit. Thus the voltage at junction 21 is 7.5 volts less than the voltage at the cathode of 16 and junction 20. The effect of this voltage drop is that the overall amplifier gain with feedback is less than one. Thus regeneration is prevented. For example, if the gain of cathode follower 16 and the feedback circuit was greater than one (1) another charge path would be provided for condenser 10 through resistor 9, diode 8, diode 19 and Zener diode 18 to the cathode of 16. Thus the charge on 10 would be increased, thereby increasing the feedback voltage to further increase the charge on the condenser in a cyclic fashion resulting in saturation of the condenser for any traffic volume.

A significant advantage of the Zener diode circuit, is that it permits a range of instantaneous volume variations without permitting regeneration. For example, if the instantaneous volume level were to decrease suddenly, the average volume voltage would remain at its previous higher level for a short period of time since it is a slower acting circuit; in such a case the feedback voltage from the cathode of 16 to junction 21 (without the Zener diode) would be greater than this new instantaneous volume and would therefore cause the instantaneous circuit to remain charged to its former level. However, by using the Zener diode the instantaneous volume voltages are permitted to vary over a range of values determined by the Zener diode before such regeneration can occur.

As will be shown subsequently a number of cars circuit including a thermistor correlates the speed measuring and volume measuring circuits. However, the thermistor is basically a non-linear device since its change in resistance is directly proportional to the heat generated in its filament but the heat generated in the filament is proportional to the square of the current through it.

Accordingly, to provide a linear correlation between speed and volume, the volume output is connected to the thermistor heater through a degenerative coupled transistor amplifier with a feedback circuit connected to provide

a gain which varies inversely with the square root of input signal volumes.

The positive volume voltage at junction 20 is connected to the tap at resistor 22 through a tungsten filament lamp 23 which has a positive temperature coefficient. Resistor 24 in series with resistor 22 and lamp 23 form a voltage divider from source 25 to ground. The voltage on line 26 is coupled to the base of PNP transistor 27 whose emitter is grounded and whose collector is connected over line 28 to a source of negative power and the base of PNP transistor 29. The collector of transistor 29 is connected over line 46 to the heater 47 of the thermistor 40. The emitter of transistor 29 is connected to the junction of resistor 22 and lamp 23.

Now assume no feedback path exists and the traffic volume voltage at junction 20 increases. Normally, this increase in the positive voltage at the base of 27 causes it to decrease in conduction so that its collector rises in a negative direction; the increase in negative potential at the base of 29 causes it to increase its conduction so that the current along line 46 increases in proportion to the volume. In this case the heat generated in the filament of 47 would be proportional to the square of the traffic volume to provide a nonlinear correlation of the speed and volume circuits. However, with the feedback path provided, as the current flow of transistor 29 increases, it provides increased heating of the filament of lamp 23; this lamp has a positive temperature coefficient of resistance and accordingly provides an increased negative voltage drop across it which is coupled to the base of 27 as degenerative feedback to increase the conduction of transistor 27, and consequently tending to decrease or oppose the increase in conduction of transistor 29.

The positive coefficient of lamp 23 is nonlinear so that for small volume voltages there is less degeneration and consequently a higher amplifier gain while for large traffic volume voltages there is more degeneration and a smaller amplifier gain. The result of such nonlinear feedback therefore provides an output voltage or current from amplifier 29 which is proportional to the square root of the input traffic volume voltage. This output voltage or current is then connected over line 46 to the heater 47 so that the heat generated at 47 is proportional to the traffic volume.

Speed determination

Individual vehicle positive voltage speed pulses are applied at input terminal 30. These pulses may have a constant width and vary in voltage in proportion to speed or may be constant voltage pulses which vary in width in proportion to speed. In either event, condenser 33 is charged through diode 32 to store a voltage representing the speed of the last car. Subsequently the charge on condenser 33 is bucketed into condenser 36 through the cathode grid circuit of follower 34, resistor 35 and terminal 38 of switch 37. Accordingly the speed signals from successive vehicles are bucketed into condenser 36 so that the voltage on condenser 36 represents the average traffic speed.

Since it is desired that the average speed measurement be of the same vehicles within the volume measurement, a thermistor 40 is connected from junction 41 over lines 42 and 43 to a tap 45 on resistor 44 in which the voltage at the tap represents average traffic speed as will be shown subsequently. For example, if the volume signal on line 46 indicates that five (5) vehicles have passed during the one minute (or some other time) period, the voltage on line 46 will heat filament 47 sufficiently to vary the resistance of thermistor 40 with respect to resistance 35 so that the speed of an individual vehicle if different from the average speed will vary the average one-fifth of this difference. If the volume voltage on line 46 indicates ten vehicles in one minute, then an individual vehicle signal at 30 has only one-tenth of an effect on the average. The above operation occurs since resistors 35 and 40 form a series voltage divider between the cathode of 34

and tap 45; thus as the volume increases the number of cars within a sampling segment increases to heat thermistor 40 and decrease its resistance so that a vehicle pulse on the grid of follower 34 will have a smaller effect on the condenser 36 voltage than otherwise.

Switch 37 is normally in its right hand position connecting condenser 36 to junction 39. However the switch is thrown to the left for an instant whenever a vehicle passes by circuitry which is not shown but which may be associated with vehicle detector 1.

A chopper 48 having inputs 49 and 50 is connected to receive the average measured traffic speed at terminal 39 from condenser 36 and the assumed average speed at its terminal 50 from line 43. The chopper alternately connects to terminals 49 and 50 at a 60 rate for example so that any difference in voltage between these two points alternately charges and discharges condenser 51 through resistor 52. If the two voltages are the same the condenser charge maintains a steady state.

Accordingly any difference in voltage is applied to the grid of cathode follower 53 and developed across cathode resistor 54 through condenser 55 to the base of PNP transistor 56. The collector of 56 connects over line 58 to the base of 57. The emitter of 57 is connected to ground through parallel resistor and condenser 59 and resistor 60. The junction of 59 and 60 is connected over line 61 to the base of 56 to provide temperature compensation. For example, if transistor 57 tends to conduct greater current flow with increase in temperature the voltage on line 61 goes more negative to increase conduction in 56 thereby so that the voltage on line 58 goes more positive to decrease conduction of 57.

The difference voltage output is fed through condenser 62 to a push pull amplifier 63 on line 64 to drive motor 65 to rotate shaft 66 to drive arm 54 to a point where the arm 45 represents the actual average traffic speed so that the output of the chopper 48 is zero and the system is balanced.

Having thus disclosed my invention from a preferred embodiment, numerous equivalent forms of my invention will be obvious to those skilled in the art upon reading the foregoing detailed disclosure. Accordingly my invention is defined in the following claims.

I claim:

1. A traffic volume computer including:

a volume determining circuit having an input for receiving vehicle passage pulses and means including an output for providing from said pulses an average pulse rate electrical signal representative of traffic volume,

means for providing individual vehicle passage pulses to said input,

and feedback means including a reverse biased Zener diode for connecting said traffic volume signal to said input so that the feedback provides a linear volume determination without regeneration.

2. A traffic volume computer including:

a volume determining circuit having an input for receiving vehicle passage pulses and means including an output for providing from said pulses an average pulse rate electrical signal of one polarity representative of traffic volume,

means for providing individual vehicle passage pulses of said one polarity to said input,

and feedback means including a reverse biased Zener diode coupling said output to said input for applying said traffic volume signal with said one polarity and with a value decreased by said Zener diode to said input so that the feedback provides a linear volume determination without providing regeneration in the forward direction of the Zener diode.

3. A traffic volume computer including:

means for sensing the passage of individual vehicles for providing individual passage pulses of one electrical polarity, representative of the individual vehicles,

means including an input and an output for receiving said passage pulses at said input for deriving from said pulses an average pulse rate electrical signal at said output having said polarity and having a value varying with the rate of passage of vehicles to be representative of traffic volume, and

feedback means having a gain of less than unity and including a reverse biased Zener diode coupling said output to said input for providing a feedback signal at said input of said one polarity and of a value less than said traffic volume signal so that the passage pulses and feedback signal are additive to increase the output signal linearly without permitting regeneration through the forward direction of the Zener diode.

4. A traffic volume computer including:
means for sensing passage of individual vehicles for providing individual pulses representative of such passage,
pulse rate measuring means including an input for receiving such pulses for determining the average rate of such passage pulses over a time period and for providing an electrical output signal representative of such an average rate, and
feedback means including a Zener diode and having a gain of $1/K$ where K is a constant determined by the Zener diode for providing a portion of said output signal to said input without permitting regeneration.

5. A traffic volume computer including:
means for deriving individual electrical pulse signals representing passage of individual vehicles,
first means having an input for receiving such pulse signals and for deriving therefrom an electrical pulse rate signal representing the rate of passage of such vehicles over a short time period,
second means for receiving such rate of passage signal for developing an average thereof over a longer time period for providing an output therefrom comprising a signal of said long average and
means including a substantial constant voltage impedance coupling said output to said input for providing a feedback signal from said output to said input with a gain of less than unity by an amount determined by said impedance so that a linear rate circuit is provided which will permit instantaneous differences between said short and long time rate determinations over a range determined by said impedance without permitting regeneration.

6. A traffic volume computer including:
means for providing individual electrical pulses of one polarity representing the passage of individual vehicles,
means including an input for receiving said pulses, a parallel condenser and resistor coupled to said input to have a charge on the condenser varied incrementally by said pulses to provide a voltage signal representing the rate of vehicle passage over a short time interval,
and a circuit including a series connected resistor and condenser coupled to the first mentioned condenser for averaging said voltage as an average rate signal over a longer time period,
a cathode follower having its grid connected for receiving said average rate signal for providing a proportionate output at its cathode,
a series connection of a diode and a Zener diode oppositely poled,
and means connecting said series diodes from said cathode to said input with said Zener diode in a reverse biased direction so that a voltage less than the average rate signal is fed back to the input as determined by the Zener diode so that the short rate voltage may decrease without regeneration occur-

ring as a result of the feedback from the longer time averaging circuit.

7. A traffic speed measuring circuit including:
first means for receiving and storing an electrical signal representing the speed of an individual vehicle,
second means for storing an electrical signal representing the average speed of a group of vehicles,
averaging circuit means including a thermistor and heater therefor, said thermistor having a nonlinear resistance characteristic in relation to electrical signal applied to its heater for modifying the average speed signal by said individual speed signal as a function of the resistance of said thermistor, said modification adjusting the signal level of said average speed signal by a part of said individual speed signal dependent on said resistance to have an average including said individual speed signal,
and means including a degenerative transistor amplifier having a nonlinear relation of output to input for heating said transistor to counteract said nonlinear characteristic to provide a linear variation in resistance for linear variation in amplifier input.

8. A traffic speed measuring circuit comprising:
first means for storing an electrical signal representing the speed of an individual vehicle,
second means for storing a further electrical signal representing the average speed of a group of vehicles,
means for measuring the rate of flow of vehicles per unit of time for a time period to provide an additional electrical signal representing traffic volume as an output,
means including a nonlinear resistance element for modifying the average speed signal by said individual speed signal as a function of the resistance of said nonlinear element, said modification adjusting the signal level of said average speed signal by a part of said individual speed signal dependent on said resistance to have an average including said individual speed signal,
and means including a degenerative transistor amplifier coupled between said output and said linear element to be responsive to said traffic volume signal for controlling the resistance of said nonlinear element to provide linear variations in said average speed signal by said individual speed signal as an inverse function of traffic volume.

9. A combination as in claim 8 in which said nonlinear element includes:
a heated thermistor, a heater therefor and means connecting said heater for energization by said amplifier so that the non-linearity of heating said thermistor is compensated by said degeneration.

10. A traffic speed computer including:
means including a first condenser for receiving and storing an electrical signal representing the speed of an individual vehicle,
means including a second condenser for storing an electrical signal representing the average speed of groups of vehicles,
means for measuring the average traffic volume of a group of vehicles within a time period to provide an average volume output signal,
means including a nonlinear element of variable resistance for modifying the signal stored in said second condenser by said signal stored in said first condenser, said modification adjusting the signal level of said average speed signal by a part of said individual speed signal dependent on said resistance to have an average including said individual speed signal,
and means including a degenerative transistor amplifier controlling said resistance of said nonlinear element in response to said traffic volume signal for providing linear variations in the signal on the sec-

ond condenser as an inverse function of changes in traffic volume.

11. Traffic speed measuring apparatus comprising:
 rate circuit means including a parallel condenser and resistor, and a Zener diode feedback circuit for receiving vehicle passage pulses and determining therefrom the average rate of vehicle passage pulses over a time period linearly over a range of traffic volumes to provide an electrical output signal representing average traffic volume;
 means including a first condenser for receiving and storing a signal representing the speed of an individual vehicle,
 means including a second condenser for storing an electrical signal representing the average speed of a group of vehicles within said time period,
 means including a nonlinear resistance element for modifying the charge on the second condenser as a function of the charge on the first condenser, said modification adjusting the signal level of said average speed signal by a part of said individual speed signal dependent on said resistance to have an average including said individual speed signal,
 first and second transistors each having emitter, base and collector,
 means connecting the base of the first transistor for control by said rate circuit output,
 means connecting the output of the collector of the first transistor to the base of the second transistor,
 means coupling the emitter of the second transistor to the base of the first transistor,
 and means coupling the collector of said second transistor to said nonlinear element for controlling the resistance of said nonlinear element so that the effect of a single vehicle speed on the average traffic speed is a linear function of the number of vehicles sensed within the time period.
12. A combination as in claim 11 in which said nonlinear element includes:
 a heated thermistor having a heater and whose resistance varies as the square of the current through its heater,
 means connecting the collector of the second transistor to said heater for heating said thermistor,
 and in which the means connecting the emitter and base include a tungsten filament lamp connected so that the degeneration of the transistor amplifier is a function of the square of the current in the second transistor.

13. A traffic flow characteristic computer for providing a substantially continuous measure of said characteristic from a series of randomly spaced vehicles passing a vehicle sensing point, and including:

- a traffic characteristic determining circuit having an input for connection to a source of voltage pulses from vehicles passing said point and representing said traffic characteristic,

an output,

and an averaging circuit comprising a short period pulse rate measuring circuit coupled to said input and a longer time period circuit coupled between said measuring circuit and said output for producing from said pulses at said input an average electrical signal at said output representing said traffic characteristic over a series of said pulses representing a series of said vehicles, said averaging circuit including

means for adjusting said average electrical signal for each received pulse for providing in said average electrical value a running average over a series of said pulses for the most recent series of vehicles passing said point over a period of time.

and feedback means for coupling said average electrical signal from said output to said input as a reference for said input voltage pulses for providing a substantially linear such adjustment of said output signal for randomly spaced input pulses over a wide range of values of said average electrical signal.

14. A traffic flow characteristic computer as in claim 13 in which said feedback means includes a nonlinear element.

15. A traffic flow characteristic computer as in claim 13 in which said feedback means includes a reversed biased Zener diode.

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