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TRAFFIC PARAMETER COMPUTER WHICH MEASURES THE RATIO
OF TRAFFIC VOLUME MEASURED AT DIFFERENT LOCATIONS
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FIG. 1

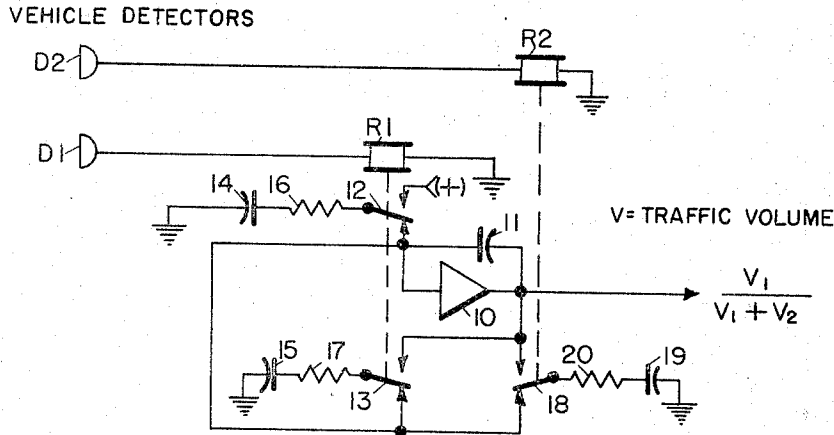
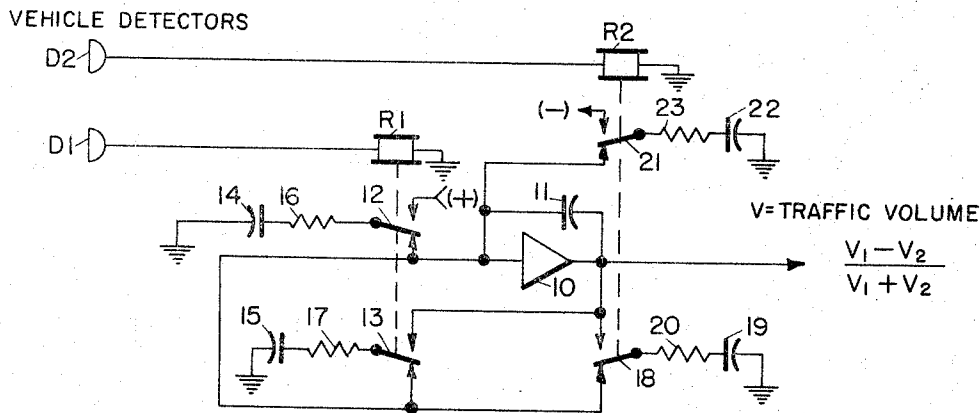


FIG. 2



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TRAFFIC PARAMETER COMPUTER WHICH MEASURES THE RATIO OF TRAFFIC VOLUME MEASURED AT DIFFERENT LOCATIONS

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ABSTRACT OF THE DISCLOSURE

The disclosure relates to apparatus for measuring the ratio of traffic volume measured at different locations. A signal accumulating means such as an operational amplifier receives a predetermined, uniform increment of signal in response to each detection of a vehicle by a vehicle detector at one location. In addition, an amount of signal dependent upon the magnitude of signal in the accumulating means is subtracted from the accumulating means in response to each vehicle detected at another of the locations. The magnitude of signals stored in the accumulating means is then representative of the ratio of traffic volume at the two locations.

Numerous instances arise when it is desirable to provide a voltage analog of the ratio of traffic volume at a given location to total traffic volume at a plurality of locations. For example, it may be desirable to provide a voltage analog of the ratio of traffic moving along a particular lane of a multi-lane highway to total traffic along the highway moving in the same direction. In such instance, separate vehicle detectors may be positioned to sense traffic moving in each of the lanes in the selected direction. Outputs of each of the separate vehicle detectors may then be applied to the computer of the instant invention, which thereupon provides an output voltage analog of the percentage of total-traffic moving in a particular direction along the highway which is utilizing a particular lane of the highway. Obviously, such measurements are not restricted to traffic moving in a single direction, since traffic moving in both directions may also be monitored, and traffic utilizing a single lane in either direction may then be expressed as a percentage of total traffic utilizing the entire highway, through use of the computer comprising the instant invention.

The invention is also useful for providing a voltage analog of the ratio of traffic volume in a particular section of a highway to traffic volume in that section plus other sections of the highway. The computer may also be used for measuring the percentage of total highway traffic volume entering or leaving at a particular access road for the highway. This would involve placement of vehicle detectors along the highway and the access road. It is obvious that many other uses for this traffic parameter also exist.

Accordingly, one object of the invention is to provide apparatus for computing the ratio of traffic volume sensed at one or more particular locations to traffic volume sensed at one or more other locations.

Another object is to provide apparatus for producing a continuously variable voltage of amplitude proportional to the ratio of traffic volume measured at a particular location to the total of traffic volume measured at that location plus other locations.

Another object is to provide a traffic parameter computer utilizing a single operational amplifier and passive components to provide a voltage analog of the ratio of traffic volume at a particular location to traffic volume at a plurality of locations.

Another object is to provide apparatus for computing

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the ratio of the difference between traffic volume sensed at two separate locations to the sum of traffic volume sensed at the two locations.

The invention contemplates novel computing means for providing a voltage analog of a traffic volume ratio comprising amplifier means having an input and an output, feedback capacitor means shunted across the input and output of the amplifier means, means coupling a pulse of fixed amplitude to the input of the amplifier means in response to each vehicle detection at locations providing numerator information for the voltage analog, and means coupling a pulse of amplitude proportioned to output voltage amplitude of the amplifier means to the input of the amplifier means in response to each vehicle detection at locations providing denominator information for the voltage analog.

The foregoing and other objects and advantages of the invention will become apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of one embodiment of the novel traffic parameter computer.

FIG. 2 is a schematic diagram of another embodiment of the novel traffic parameter computer.

Turning now to FIG. 1 there is shown an operational amplifier 10 having a feedback capacitor 11 shunted across the input and output of the amplifier. A pair of vehicle detectors D1 and D2 are respectively coupled to relays R1 and R2 of the computer. These vehicle detectors preferably comprise presence detectors such as those described in J. H. Auer, Jr. and H. C. Kendall Patent 3,042,303, granted July 3, 1962, although other types of vehicle detecting means may be used satisfactorily with the computer and it is by no means necessary that the detector be of the presence type.

The heels of a pair of contacts 12 and 13 associated with the relay R1 are coupled to a pair of capacitors 14 and 15, respectively through respective resistors 16 and 17. Similarly, the heel of a contact 18 associated with relay R2 is coupled to a capacitor 19 through a resistor 20. Front contact 12 of relay R1 is coupled to a source of positive voltage. Back contacts 12, 13 and 18 are each separately coupled to the input of amplifier 10. Front contacts 13 and 18 are each separately coupled to the output of amplifier 10.

In operation, each time a vehicle is sensed by detector D1, capacitor 14 acquires a positive charge through resistor 16. When the vehicle is no longer sensed by detector D1, relay R1 deenergizes, coupling a positive charge stored on capacitor 14 to the input of amplifier 10. Resistor 16 is sufficiently small to permit capacitor 14 to charge to a voltage amplitude substantially that of the positive voltage source during the interval in which a vehicle is sensed by detector D1, regardless of speed of the vehicle, and similarly is sufficiently small to permit substantially full discharge of capacitor 14 during the interval in which relay R1 is deenergized, regardless of how closely each vehicle follows the other in the stream of traffic being sensed. Hence, each time relay R1 is deenergized, a fixed increment of charge is discharged from capacitor 14 to capacitor 11.

In similar fashion, when relay R1 is energized, capacitor 15 acquires a negative charge from the output voltage of amplifier 10. Again, it should be noted that resistor 17 is sufficiently small to permit capacitor 15 to charge to a voltage equal to that stored across capacitor 11 during the interval in which relay R1 is energized, even when a fast-moving vehicle is sensed by detector D1.

When relay R1 deenergizes, capacitor 15 discharges, providing a voltage pulse to the input of amplifier 10. This pulse tends to decrease the voltage amplitude across

capacitor 11, since the polarity of voltage now provided from capacitor 15 is of opposite polarity to the voltage stored on capacitor 11. However, it should also be noted that when relay R1 deenergizes, capacitor 14 provides a charge to the input of amplifier 10 of polarity opposite to that provided to the input of amplifier 10 from capacitor 15.

In a fashion similar to that by which front contact 13 of relay R1 permits charging of capacitor 15 from capacitor 11 and back contact 13 permits capacitor 15 to discharge to the input of amplifier 10, front contact 18 of relay R2 permits capacitor 19 to acquire a charge from feedback capacitor 11 during the interval in which a vehicle is sensed by detector D2, and back contact 18 permits capacitor 19 to discharge to the input of amplifier 10 during intervals in which no vehicle is sensed by detector D2. Again, it should be noted that resistor 20 is sufficiently small to permit capacitor 19 to charge to substantially the amplitude of voltage stored across capacitor 11 when relay R2 is energized and to permit capacitor 19 to substantially fully discharge to the input of amplifier 10 when relay R2 is deenergized.

That the foregoing parameter computer provides an output voltage analog of the ratio of traffic volume sensed by detector D1 to traffic volume sensed by detectors D1 plus D2 may be shown in the following manner:

Let

Q_1 =charge on capacitor 14

Q_2 =charge on capacitor 15

Q_3 =charge on capacitor 19

C_1 =capacitance of capacitor 14

C_2 =capacitance of capacitor 15

C_3 =capacitance of capacitor 19

E =positive reference voltage amplitude

E_0 =output voltage amplitude of amplifier 10

V_1 =traffic volume sensed by detector D1

V_2 =traffic volume sensed by detector D2

T =a time interval during which vehicle detections are made

n_1 =number of vehicles detected by detector D1 during time T

n_2 =number of vehicle detected by detector D2 during time T

When a vehicle is sensed by detector D1 capacitor 14 charges according to the equation

$$Q_1 = C_1 E$$

and capacitor 15 charges according to the equation

$$Q_2 = C_2 E_0$$

Similarly, when a vehicle is detected by detector D2, capacitor 19 charges according to the equation

$$Q_3 = C_3 E_0$$

During time T, charges Q_1 , Q_2 and Q_3 are each multiplied by the number of vehicles sensed in that time by the respective detector producing the charge. Hence

$$(1) \quad Q_1 T = n_1 C_1 E$$

$$(2) \quad Q_2 T = n_1 C_2 E_0$$

and

$$(3) \quad Q_3 T = n_2 C_3 E_0$$

Since

$$V_1 = \frac{n_1}{T}$$

and

$$V_2 = \frac{n_2}{T}$$

Equations 1, 2 and 3 can be rewritten respectively as

$$(4) \quad Q_1 = V_1 C_1 E$$

$$(5) \quad Q_2 = V_1 C_2 E_0$$

and

$$(6) \quad Q_3 = V_2 C_3 E_0$$

Since capacitors 15 and 19 are both charged from output voltage E_0 of amplifier 10, total charge applied to the input of amplifier 10 at equilibrium is equal to total charge acquired at the output side of the amplifier during time T. Hence.

$$Q_1 = Q_2 + Q_3$$

or

$$V_1 C_1 E = V_1 C_2 E_0 + V_2 C_3 E_0$$

Then

$$(7) \quad E_0 = \frac{V_1 C_1 E}{V_1 C_2 + V_2 C_3}$$

By making $C_3 = C_2$, Equation 7 can be rewritten as

$$E_0 = \frac{V_1}{V_1 + V_2} \frac{C_1 E}{C_2}$$

Therefore, since C_1 , C_2 and E are constants, E_0 is directly proportional to the parameter

$$\frac{V_1}{V_1 + V_2}$$

It should be noted that in order to derive a volume ratio of

$$V_1/V_2$$

to compare for example, relative traffic volumes at two different locations, it is merely necessary to open the circuit comprising capacitor 15, resistor 17 and relay contact 13.

FIG. 2 illustrates a modification of the circuit of FIG. 1, wherein the output voltage analog produced by the computer represents the ratio of the difference between traffic volume sensed by detectors D1 and D2 to the sum of traffic volume sensed by detectors D1 and D2. This is accomplished by utilization of an additional contact 21 on relay R2, the heel of which is coupled to a capacitor 22 through a resistor 23. Back contact 21 is coupled to the input of operational amplifier 10, while front contact 21 is coupled to a source of negative voltage, preferably of amplitude equal to that of the positive voltage source.

Operation of the circuit comprising contact 21, resistor 23 and capacitor 22 is substantially identical to operation of the circuit comprising contact 12, resistor 16 and capacitor 14, with the exception that capacitor 22 acquires a negative charge, while capacitor 14 acquires a positive charge. Thus, when a vehicle is sensed by detector D2, energizing relay R2, capacitor 22 acquires a negative voltage through front contact 21 in series with resistor 23. The amplitude of the acquired negative voltage is substantially that of the negative voltage source, since resistor 23 is sufficiently small to permit capacitor 22 to charge to an amplitude substantially that of the negative voltage source during the interval in which a fast-moving vehicle is sensed by detector D2. When detector D2 no longer senses a vehicle, capacitor 22 discharges to the input of amplifier 10 through back contact 21 in series with resistor 23, coupling a negative input voltage to amplifier 10. Moreover, capacitor 19 discharges to the input of amplifier 10 through a back contact 18 in series with resistor 20, tending to decrease the magnitude of voltage stored on capacitor 11, regardless of polarity. This is so since the polarity of charge acquired by capacitor 19 depends upon the polarity of voltage stored on capacitor 11. Similarly, when relay R1 deenergizes after detector D1 has sensed a vehicle, the polarity of charge coupled from capacitor 15 to the input of amplifier 10

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is also such as to decrease the magnitude of voltage stored on capacitor 11.

If capacitors 14 and 22 are of the same value, a larger number of vehicle detections by detector D2 as compared to D1 produces a positive voltage from the computer as opposed to a negative voltage produced therefrom when the number of vehicles sensed by detector D1 exceeds the number sensed by detector D2. Again, it should be noted that resistor 23 is sufficiently small to permit capacitor 22 to substantially fully discharge to the input of amplifier 10 during the interval in which no vehicle is detected by detector D2, regardless of spacing maintained between vehicles in the traffic stream.

That output voltage from the computer of FIG. 2 represents the ratio of the difference between traffic volume sensed by detectors D1 and D2 to the sum of traffic volume sensed by detectors D1 and D2 may be shown in the following manner:

Let

C_4 =capacitance of capacitor 22

Q_4 =charge on capacitor 22

$-E$ =negative reference voltage amplitude

When a vehicle is detected by detector D2, capacitor 22 charges according to the equation

$$Q_4 = C_4 E$$

During time T, charge Q_4 is multiplied by the number of vehicles sensed in that time by the detector producing the charge.

Hence

$$(8) \quad Q_4 T = -n_2 C_4 E$$

which can be rewritten as

$$(9) \quad Q_4 = V_2 C_4 E$$

Since capacitors 15 and 19 are both charged from output voltage E_0 of amplifier 10, total charge applied to the input of amplifier 10 at equilibrium is equal to total charge removed from the amplifier during time T. Hence

$$Q_1 + Q_4 = Q_2 + Q_3$$

or

$$V_1 C_1 E - V_2 C_4 E = V_1 C_2 E_0 + V_2 C_3 E_0$$

Then

$$(10) \quad E_0 = \frac{V_1 C_1 E}{V_1 C_2} - \frac{V_2 C_4 E}{V_2 C_3}$$

By making $C_3 = C_2$ and $C_4 = C_1$, Equation 10 can be rewritten as

$$E_0 = \frac{V_1 - V_2}{V_1 + V_2} \frac{C_1 E}{C_2}$$

Therefore, since C_1 , C_2 and E are constants, E_0 is directly proportional to the parameter

$$\frac{V_1 - V_2}{V_1 + V_2}$$

It should be noted that the computer of FIG. 2 provides an output voltage which may be either positive or negative, depending upon the relative magnitudes of traffic volume sensed by detectors D1 and D2, while output voltage produced by the computer of FIG. 1 is always of negative polarity. As a result, when traffic volume sensed by detector D1 is equal to traffic volume sensed by detector D2, output voltage produced by the computer of FIG. 1 is one-half of its maximum amplitude, while output voltage produced by the computer of FIG. 2 is zero. Hence, relative traffic volume information may be introduced into a single polarity or dual polarity circuit, depending upon selection of a parameter computer in accordance with FIGS. 1 or 2.

It should be noted that by opening the series circuit

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comprising capacitor 19, resistor 20 and relay contact 18 in FIG. 2, the parameter

$$(11) \quad \frac{V_1 - V_2}{V_1}$$

is derived. Alternatively, by opening the series circuit comprising capacitor 15, resistor 17 and relay contact 18 in FIG. 2, the parameter

$$(12) \quad \frac{V_1 - V_2}{V_2}$$

is derived. Moreover, the sign of V_1 in the numerator of Equations 11 and 12 may be reversed by coupling front contact 12 to a source of negative voltage, while the sign of V_2 in the numerator of Equations 11 and 12 may be reversed by coupling front contact 21 to a source of positive voltage.

Thus, there has been shown apparatus for computing the ratio of traffic volume at one or more locations, traffic volume at one or more other locations and for computing the ratio of the difference between traffic volume sensed at two separate locations to the sum of traffic volume sensed at the two locations. The system requires a single operational amplifier, with passive components supplying the remaining necessary circuit elements. The system is rugged, stable and requires minimal amounts of power for operation.

Although but several embodiments of the present invention have been described, it is to be specifically understood that these forms are selected to facilitate in disclosure of the invention rather than to limit the number of forms which it may assume; various modifications and adaptations may be applied to the specific forms shown to meet requirements of practice, without in any manner departing from the spirit or scope of the invention.

What I claim is:

1. A traffic parameter computer for providing a voltage analog of the ratio of traffic volumes at different locations, comprising, detecting means situated at each of said locations, an amplifier having an input and an output, a capacitor shunted between the input and output of said amplifier, first means responsive to one of said vehicle detector means for coupling a pulse of a predetermined amount of said energy to the input of said amplifier in response to each vehicle detected at a first of said locations, and second means responsive to the other of said vehicle detectors for coupling a pulse of energy having a magnitude proportional to the output of said amplifier from the output of said amplifier to the input of said amplifier in response to each vehicle detected at another of said locations, whereby the output of said amplifier is representative of the ratio of the traffic volumes at said first and second locations.

2. A traffic parameter computer comprising vehicle detector means monitoring traffic at each of at least two locations, an amplifier having an input and an output, a capacitor shunted between the input and output of said amplifier means responsive to said vehicle detector means for one of said locations for coupling a positive pulse of predetermined energy content and of predetermined polarity to the input of said amplifier in response to each detected vehicle monitored at said one location, means responsive to said vehicle detector means for the other of said two locations for coupling a negative pulse having an energy content proportional to the output of said amplifier and a polarity the same as that of the output of said amplifier to the input of said amplifier in response to each detected vehicle at the other monitoring location, and means transferring an increment of signal of a magnitude proportional to the output of said amplifier from the output of the amplifier to the input of the amplifier in response to each vehicle detected.

3. Apparatus for measuring the ratio of traffic volume as a first location to the traffic volume at a second loca-

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tion comprising, first and second vehicle detectors at said first and second locations respectively, signal accumulating means, first means controlled by said first vehicle detector for adding to said signal accumulating means a predetermined uniform increment of signal for each vehicle detected by said first vehicle detector, second means controlled by said second vehicle detector means for subtracting from said signal accumulating means a decrement of signal representative of the then-existing value of the signal stored in said signal accumulating means in response to each vehicle detected by said second vehicle detector, whereby the magnitude of signal stored in said signal accumulating means is representative of the ratio of traffic volumes at said first and second locations.

4. The apparatus of claim 3 which further includes third means controlled by said second vehicle detector for subtracting from the signal in said signal accumulating means the same predetermined uniform decrement of signal for each vehicle detected by said second vehicle detector as is added by said first means for each vehicle detected by said first vehicle detector, whereby the signal stored in said accumulating means is representative of the ratio of the difference in traffic volumes at said first and second locations to the sum of the traffic volumes at said first and second locations.

5. The apparatus of claim 3 in which said signal accumulating means comprises an operational amplifier.

6. The apparatus of claim 3 in which said first means

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comprises, a capacitor, means for charging said capacitor to a predetermined uniform amplitude of voltage, and means controlled by said vehicle detector for transferring the charge in said capacitor to said signal accumulating means upon each detection of a vehicle by said first vehicle detector.

7. The apparatus of claim 4 in which said signal accumulating means comprises an operational amplifier.

8. The apparatus of claim 4 in which each of said first and third means comprises, a capacitor, means for charging said capacitor to a predetermined uniform amplitude of voltage which is of opposite polarity for the respective first and third means, and means controlled by the associated vehicle detector for transferring the charge in the corresponding capacitor to said signal accumulating means upon each detection of a vehicle by the respective vehicle detector.

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