

Sept. 15, 1970

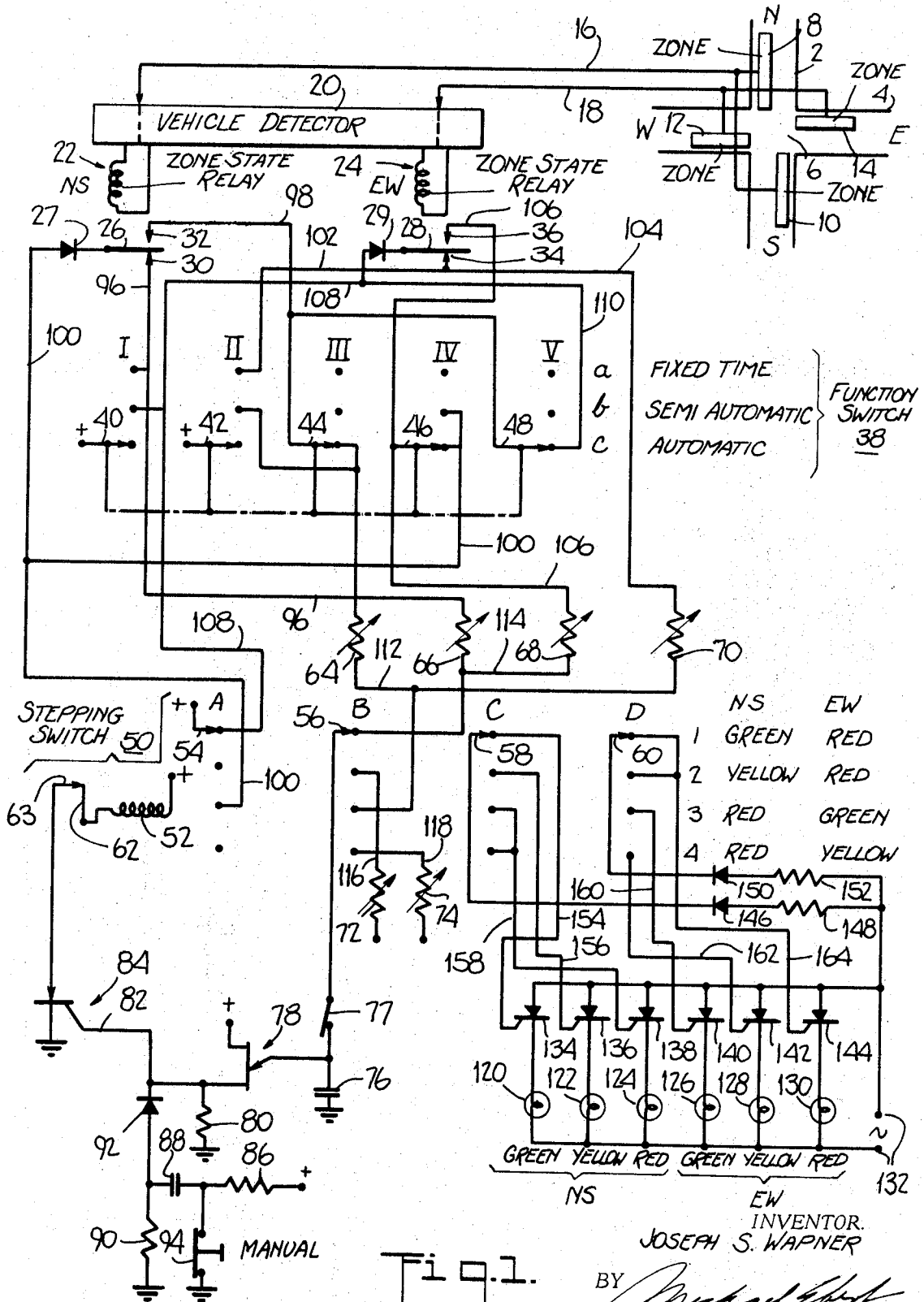
J. S. WAPNER

3,529,285

TRAFFIC CONTROL SYSTEM

Filed May 11, 1967

3 Sheets-Sheet 1



	NS	EW
1	GREEN	RED
2	YELLOW	RED
3	RED	GREEN
4	RED	YELLOW

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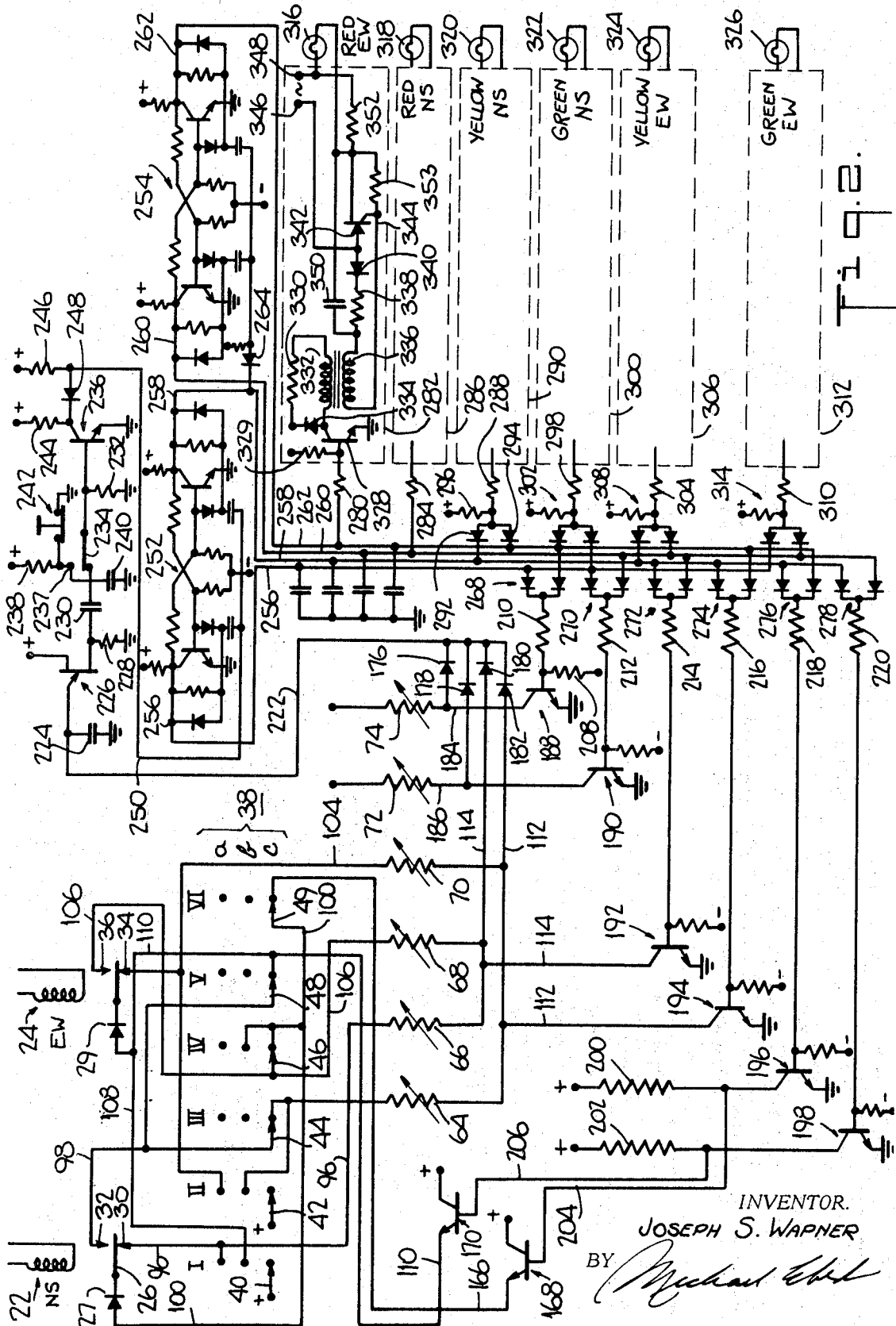
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TRAFFIC CONTROL SYSTEM

Filed May 11, 1967

3 Sheets-Sheet 2



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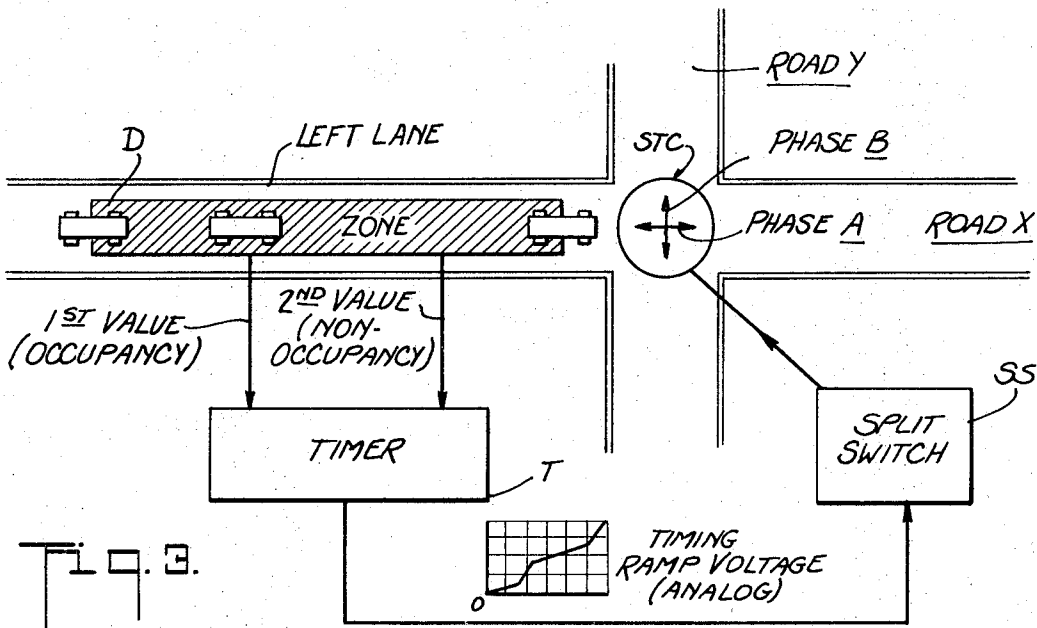


Fig. 3.

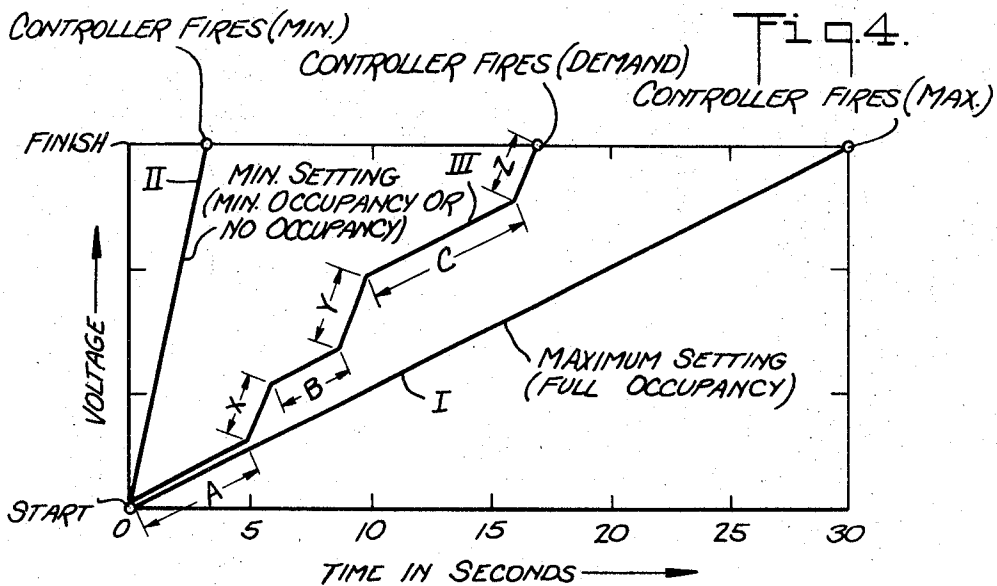


Fig. 4.

- A = OCCUPANCY BETWEEN 0 AND 5 SECONDS
- B = ADDITIONAL OCCUPANCY BETWEEN 6 AND 9 SECS.
- C = ADDITIONAL OCCUPANCY BETWEEN 10 AND 16 SECONDS
- X = NO OCCUPANCY
- Y = NO OCCUPANCY
- Z = NO OCCUPANCY

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3,529,285

TRAFFIC CONTROL SYSTEM

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Continuation-in-part of application Ser. No. 359,831, Apr. 15, 1964. This application May 11, 1967, Ser. No. 637,783

Int. Cl. G08g 1/08

U.S. Cl. 340—37

7 Claims

ABSTRACT OF THE DISCLOSURE

A system adapted to regulate the flow of traffic at an intersection of two roads, and including a traffic controller which in one phase of operation gives the right of way only on traffic in one of the roads, and in another phase of operation gives the right of way only to traffic in the other road. The operation of the controller is governed by a timer which produces a timing interval which depends on traffic conditions, the traffic controller being caused to switch phase at the end of this interval.

RELATED APPLICATION

This application is a continuation-in-part of the pending application bearing the same title, Ser. No. 359,831, filed Apr. 15, 1964, now abandoned.

This invention relates generally to traffic control systems, and more particularly to an analog computer for operating a traffic signal controller and adapted to maintain an optimum degree of flow efficiency at an intersection under fluctuating vehicular traffic conditions.

The flow of traffic at an intersection of two roadways is generally governed by a signal controller whose operating cycle has two phases which shall hereafter be designated phase A and phase B. In phase A, a "go" or green signal is accorded to traffic in the first road (X) and a "stop" or red signal is given to traffic in the second road (Y), whereas in the alternative phase B, the signals are reversed. The point of phase transfer in the operating cycle is usually referred to as the split. In some instances, the controller may include a "warning" or yellow signal which when a split occurs is presented for a predetermined interval before the "go" or "stop" signal is given.

In either phase of operation, the signal controller necessarily imposes a delay on the flow of traffic in one of the two intersecting roads. Since the purpose of any traffic controller system is to minimize delay and thereby keep traffic moving, the basic problem one is confronted with in the operation of a signal controller is when to effect the phase split in the operating cycle. For example, if the flow of traffic on road X is heavy while that on road Y is very light, it is obviously desirable to hold the signal controller in phase A and to transfer to phase B only when a vehicle appears on road Y, and to revert to phase B as soon as this vehicle clears through the intersection. But when the traffic intensity on both roads is heavy, then the split must be manipulated to take this condition into account in order to promote flow efficiency. Obviously a traffic controller which alternately switched from phase A to phase B periodically without regard to actual traffic conditions would militate against the efficient flow of traffic.

If on the other hand the traffic pattern at a given intersection in the course of a day were more or less predictable, it might be possible to program the operation of a signal controller to minimize delay at all times, so that the controller would function in one manner to take care of peak traffic in the course of the day, and would function in other ways when other predictable patterns

are encountered. However, while traffic peaks may generally be anticipated at given intersections, the actual pattern of traffic is so variable in the course of any day that a programmed controller falls far short of attaining the desired objective.

It is for this reason that computers have been developed to measure prevailing traffic parameters and to actuate the signal controller as a function of actual rather than estimated parameters. In traffic engineering the three main parameters which are usually measured for this purpose are speed, density and volume. Traffic density is a measurement of the number of vehicles occupying a unit length of roadway at a given moment. Traffic speed is the speed of vehicles flowing upon the roadway, while traffic volume is the number of vehicles passing a given point during a specified time period.

In computers of the type heretofore devised for automatic actuation of a signal controller, the computer is designed to measure one or more of the parameters of density, speed and volume by means of digital techniques. In density measurement, the number of vehicles entering a given space is recorded and the number departing from the same space is recorded in order to arrive at a count representing the number within the space. In volume measurement, the number of vehicles passing a given point per hour is counted. In speed measurement, the time it takes for a vehicle to travel between two spaced points is determined.

The nature of vehicles is such that they do not lend themselves to treatment as digits. Hence computers for traffic control whose operation is digital are incapable of effecting optimum control under fluctuating traffic conditions. If all vehicles were of the same size and if they travelled at the same speed, they could readily be handled as digits for purposes of computation. But this is not actually the case and by counting the number of vehicles passing a given point, the count attained during a prescribed interval does not reveal the true nature of traffic. For instance, twenty trailer trucks successively passing a point during a given interval will give a low count, whereas during the same interval many more small cars could have passed, yet the trailer trucks constitute a much heavier traffic condition.

In view of the foregoing it is the principal object of this invention to provide a system including a computer affording an analog of actual traffic conditions, which analog value governs the operation of a signal controller to effect a split therein in a manner promoting optimum flow efficiency in a fluctuating traffic pattern.

More specifically, it is an object of the invention to provide a traffic control system of the above type wherein the presence or absence of vehicles within an elongated zone in a lane in advance of an intersection is detected to produce occupancy and non-occupancy values which determine the duration of a timing interval, whereby said interval constitutes an analog of actual traffic flow, the signal controller being caused to split at the conclusion of the interval.

A further object of the present invention is to provide in system which is flexible in operation so that at different times or for different traffic problems it may operate in different modes. Using basically the same elements, switching is provided to secure a fully automatic system, a semiautomatic system, a fixed time cycle system, or a system involving manual control under special circumstances when that is required. The system also may be readily adjusted to secure optimum operation during any predetermined part of a day or under special circumstances involving unusual traffic congestion.

Briefly stated, these objects are accomplished in a system provided with a signal traffic controller positioned at an intersection, a detector being disposed within a zone

in a lane in advance of the intersection whose length is sufficient to include a plurality of vehicles, the detector acting to sense the presence of any vehicle or a portion thereof within said zone or the absence of all vehicles therefrom to produce a first value representing the state of zone occupancy and a second value representing the state of zone non-occupancy, the detector being coupled to a timer which runs from a start point to a finish point at a rate which in response to said first value is slow and which in response to said second value is fast whereby the resultant timing interval has a duration which is an analog of the actual traffic conditions detected in said zone, the controller being caused to split when said finish point is reached to cause a change of phase delaying traffic flow in said lane.

For a better understanding of the invention as well as further objects thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of one embodiment of the invention involving a combination of electromechanical and electronic elements;

FIG. 2 is a schematic diagram of a system which is wholly electronic and involves no electromagnetic elements except simple and reliable relays;

FIG. 3 shows in block diagram the essential elements of the analog system in generalized form; and

FIG. 4 is a graph representing the operation of the timer.

Referring first to FIG. 1, there is illustrated the simplest and usual type of intersection of two streets or roads 2 and 4 which will be hereinafter respectively referred to as a north-south, NS highway and an east-west, EW highway having the intersection 6. As will become evident as the description proceeds, the apparatus which will be described may be readily extended to more elaborate configurations of intersections merely by increase of the steps involved in a complete cycle of operation. Thus the invention may be extended to the control of traffic at intersections of three or more highways, special intersections involving dead ends of one or more highways, intersections at which certain right turns or the like may be permitted safely either at all times or during certain times when cross traffic is also permitted, or the like. The basic system may be readily modified either by adjustments or by extensions for these situations. For simplicity the description will be first confined to the simple intersection shown.

One of the aspects of the control system is that for each approach to the intersection it does not merely detect vehicles at a particular point; rather, it detects and responds to vehicles which are present within an extended length of each approach. At 8, 10, 12 and 14 there are indicated the lengths or areas of the approaches to the intersection within which vehicles are detected. These lengths or zones may be of different extents in accordance with average travelling conditions of vehicles on the respective highways. For example, assuming that the highway 2 carries relative high speed traffic and the highway 4 is a secondary one on which traffic is generally slower, or should be for safety, the zones 8 and 10 may be substantially longer than the zones 12 and 14. These zones may have lengths ranging upwardly from 35 feet under most conditions, the most suitable length being determined from traffic studies. The fact that the length will generally be fixed is not detrimental to the flexibility of the system since the timing devices in the system may be adjusted to secure good compensation for varying conditions.

In accordance with the invention, the basic aspect is that any vehicle within the zones 8, 10, 12 and 14 should be detected. The invention is not concerned with the particular detecting means used, detectors or pickup devices of applicable type being well known. Typically, for example, the detection areas are delimited by conductive loops energized by high frequency currents and sub-

jected to inductance variations due to the metal of the vehicle. The loops for a single highway may be connected in series or in parallel, and such connections to a responsive device are indicated at 16 and 18, these effectively providing respective signals for the NS and EW highways to a device 20 which may be called the vehicle detector. The device 20 may, for example, be of a well known type in which a high fixed frequency current is produced feeding the loops delimiting the detection areas and in which means is provided sensitive to phase shift giving rise to output currents which correspond to the presence of vehicles in the respective areas. These outputs are indicated as providing currents to the windings of respective zone state relays 22 and 24. The former relays will be energized when any vehicle or a portion thereof is within the detection zones 8 or 10; while the relay 24 will be energized when any vehicle or a portion thereof is within the zones 12 or 14. Similar operations of relays individual to the intersecting highways may be produced by other detecting arrangements, radar, capacitive, super-sonic, or the like. Many such devices are well known and for the purposes of the present invention any may be used provided it is suitable to detect the presence of vehicles in predetermined areas. Even multiple treadle systems may be used such as will respond to the entering and leaving of the areas by vehicles.

The relay 22 is provided with a movable contact 26 normally closed with a fixed contact 30 and adapted to disengage this contact and close with a fixed contact 32 when the relay is energized. The relay 24 has a corresponding movable contact 28 and the respective normally closed and normally open contacts 34 and 36. A further element of the system is a function switch 38 having five contact banks I, II, III, IV and V, and three alternative positions, *a*, *b* and *c*. The movable contacts 40, 42, 44, 46 and 48 of the respective banks are ganged on a common shaft. The positions *a*, *b* and *c* are indicated by the descriptive legends "Fixed Time," "Semi-Automatic," and "Automatic." The significance of these terms may be more conveniently described as follows:

"Fixed Time" indicates the selection of operation in a fixed time cycle with predetermined intervals corresponding to the usual traffic signal system which is clock controlled. In the present system such operation is secured by utilization of RC arrangements.

"Semi-Automatic" implies an operation which, though vehicle controlled as will be described hereafter, gives preferential treatment to one highway, the control light for which is normally green so that high speed traffic thereon will ordinarily be maintained except as required by the presence of one or more vehicles on a minor cross road.

"Automatic" refers to a selected operation in which the type of preference just mentioned is not given, though some preference for the most desirable maintenance of traffic flow is involved in timing as will become evident hereafter.

The major control element of the system is a stepping switch indicated at 50 which comprises the conventional operating solenoid 52 effecting through ratchet operation the stepping of movable contacts 54, 56, 58 and 60 of four banks A, B, C and D, the movable contacts engaging (functionally) fixed contacts arranged in four positions 1, 2, 3 and 4. This stepping switch may be of conventional type in which the energizing winding 52 tensions a spring when energized, the spring then operating a pawl to produce a step when the winding is de-energized. The stepping switch is rotary so that after contact is made at 4 the next step makes contact at 1. Such stepping switches are generally provided with more than four contacts, but may be wired in conventional fashion to produce the repeated cycling in four steps as here required. It may be here noted that such a switch may have its wiring readily changed to produce six or some other number of steps as may be required, for example, in the case of a triple intersection by extension of what is being here described.

For convenience of reference, legends are provided at the right of the switch indicating the traffic light conditions existing for control of the NS and EW highways by its various positions, the green, yellow and red illuminated lights being indicated.

As usual, the stepping switch is provided with an interrupter involving the movable contact 62 engaged with the fixed contact 63 when the winding 52 is energized, the contact being opened when the winding is energized.

Further elements of the system are the adjustable resistors 64, 66, 68 and 70 which may be independently adjusted to provide proper timing as will be more fully described hereafter. Another pair of adjustable resistors is indicated at 72 and 74, these being settable for adjustment of the duration of yellow lights.

The various adjustable resistors which have been described control currents for the charging of a capacitor 76. Time intervals are established by such charging which occurs at variable rates depending upon the settings of the resistors and which, alone or in combination, are involved in the charging. Normal leakage of the capacitor 76 through the emitter of a unijunction transistor 78 may take care of spurious conditions which may occur to restore the system to normal; or, if desired for more rapid discharge, the capacitor 76 may be shunted by a suitable bleed resistor.

The potential buildup at the ungrounded terminal of the capacitor 76 is utilized to fire the unijunction transistor 78, the emitter of which is connected to the ungrounded capacitor terminal. One of the bases of the unijunction transistor is connected to a positive supply terminal. As will appear in the further description, a number of these positive supply terminals are indicated in the daigram. It will be understood that they are actually the same terminal and have been indicated separately only to simplify the diagram. The positive terminal of a voltage supply is connected to these terminals, the supply being conventional and not shown since it may be provided from the alternating power supply line through the usual rectifier and filter system. The negative terminal of the supply is grounded. The control system may be operated at a low direct voltage such as 15 to 25 volts with low currents flowing through the mechanical contacts so that these are not subject to being damaged by burning.

The second base of the unijunction transistor is connected to ground through the load resistor 80 and is connected at 82 to the gate terminal of a silicon controlled rectifier 84. The cathode of this rectifier is connected to ground while its anode is connected to the contact 63. The combination of the unijunction transistor and the silicon controlled rectifier provides a sufficient heavy current surge to energize the winding 52. The unijunction transistor provides ample current to the gate terminal of the rectifier while drawing only a minute current through its emitter as the capacitor 76 charges. The operation of the arrangement just described is as follows:

When the capacitor 76 becomes charged to a critical potential, the unijunction transistor 78 is fired and in turn fires the silicon controlled rectifier. The surge of current energizes the winding 52 tensioning the stepping switch spring and opening the contact at 62, 63. This removes the supply of current to the silicon controlled rectifier and since the capacitor 76 immediately discharges when firing of the unijunction transistor occurs, all of the parts are restored to their quiescent state. When the winding 52 is thus de-energized, a step of the switch occurs.

At this point manual control may be conveniently described. The positive supply terminal is connected through resistor 86 and capacitor 88 to the junction between resistor 90 and diode 92 polarized as indicated. The cathode of this diode runs to the connection 82. The lower terminal of the resistor 90 is grounded. The junction between resistor 86 and capacitor 88 is normally grounded through the manual pushbutton switch 94. The last assembly has no effect on the operation previously de-

scribed resulting from charging of capacitor 76. But if the switch 94 is momentarily opened, a positive pulse is applied through capacitor 88 and diode 92 to the gate terminal of the rectifier 84 to fire it and produce a step of the switch as previously described. This provides for manual stepping of the switch by a traffic officer if he takes over control of the intersection. The stepping may be as rapid as he desires. To make manual operation entirely independent of vehicle control a normally closed switch 77 may be opened to prevent charging of capacitor 76.

Interconnection of the various elements may now be described.

The normally closed contact 30 of relay 22 is connected at 96 to the fixed contact in position *a* of bank I of the function switch and to the upper terminal of adjustable resistor 66. The normally open contact 32 of relay 22 is connected at 98 to the movable contact 44 of bank III and also to movable contact 48 of bank V of the function switch. The movable contact 26 of relay 22 is connected through diode 27 and connection 100 to the fixed contact in position 3 of bank A of the stepping switch 50 and to the fixed contact in positions *b* and *c* of bank IV of the function switch.

The fixed contact 34 of relay 24 is connected at 102 to the fixed contact in position *a* of bank II of the function switch, and at 104 to the upper terminal of the variable resistor 70. The fixed contact 36 of relay 24 is connected at 106 to the movable contact 46 of bank IV of the function switch and to the upper terminal of the variable resistor 68. The movable contact 23 of relay 24 is connected through diode 29 and line 108 to the fixed contact in position *b* of bank I of the function switch and to the fixed contact in position I of bank A of the stepping switch 50. It is also connected through the diode and line 110 to the fixed contact in position *c* of bank V of the function switch.

The movable contacts 40 and 42 are connected to the positive supply terminal, as is also the movable contact 54 of bank A of the stepping switch.

The lower terminals of resistors 64 and 70 are connected together at 112 and to the fixed contact in position 3 of bank B of the stepping switch.

The lower terminals of resistors 66 and 68 are connected together at 114 and to the fixed contact in position 1 of bank B of the stepping switch. The movable contact 56 of this bank B is connected to the ungrounded terminal of capacitor 76 through the normally closed switch 77.

The resistors 72 and 74 have their lower terminals connected to the positive supply terminal and their upper terminals are connected respectively at 116 and 118 to the fixed contacts in positions 2 and 4 of bank B of the stepping switch.

The last two banks C and D of the stepping switch control the signal lights 120, 122, 124, 126, 128 and 130 at the intersection. The first three of these control the traffic on the NS highway 2, while the last three control that on the EW highway 4. One terminal of each of these lamps is connected to one side of the alternating current power line indicated at 132. The individual lamps are connected through the silicon controlled rectifiers 134, 136, 138, 140, 142 and 144, respectively, to the other side of the line. To the last side of the line the movable contact 58 is connected through the diode 146 and resistor 148, while the movable contact 60 is similarly connected through the diode 150 and the resistor 152. The gate terminals of the rectifiers are respectively connected to the fixed contacts of the banks C and D through the lines 154, 156, 158, 160, 162 and 164, respectively. As will be evident, the connections are so arranged as to produce for the successive positions of the stepping switch the control light indications shown at the right of the stepping switch.

While sufficiently heavy contacts of the stepping switch could control the respective lamp currents directly, it is desirable, to avoid overloading and consequent damage and to make use of a conventional small size stepping switch, to utilize the switch to control the silicon controlled rectifiers which are capable of handling what may be quite heavy currents particularly at intersections where the single lamps illustrated are duplicated in parallel. At important or dangerous intersections multiple lamps are thus used. The resistors 148 and 152 limit the control currents to suitable values and the diodes 146 and 150 prevent reverse current flows. In the arrangement illustrated half-cycle energization of the lamps is provided, and the operation of the rectifiers is conventional and need not be described in detail. It will be evident that the lamp current control switching arrangement may be extended in obvious fashion to the control of more elaborate intersections and may include provisions for the showing of red signals on both intersections simultaneously to permit pedestrian crossing, or the like. This, of course, involves corresponding control of the steps of the stepping switch, but such extensions will be obvious, involving what are, in effect, multiple step controls of the type provided for the showing of yellow lights.

There will now be described the aspects of control of the stepping switch in the automatic operation established by the positioning of the function switch 38 with its movable contacts in position c. It will be noted that this position involves the movable contacts 40 and 42 in ineffective positions so they may be disregarded in what follows.

First, there may be considered what occurs when the stepping switch is in position 1 (showing green for the NS highway), assuming no traffic on either highway so that both relays 22 and 24 are de-energized.

For any stepping to occur, the capacitor 76 must be charging to reach a firing potential for the unijunction transistor 78, and the circuit may be best considered by following it backwardly from the upper terminal of capacitor 76 to consider whether or not charging current flows thereto. If the circuit is thus traced for the condition described, i.e., both relays de-energized, it will be found that no path leads from the capacitor to a positive supply terminal, and accordingly there is no charging so that the condition remains fixed. The same situation will be found to be true if the stepping switch is in position 3. In other words, in the absence of any traffic the system remains in the condition finally assumed after a preceding operation under vehicular control, such stable positions being 1 and 3.

At this point it will be convenient to consider the situation which will exist if the stepping switch is in position 2. This position presents a yellow signal to the NS highway and a red signal to the EW highway. In this position it will be seen that tracing a circuit from the upper terminal of capacitor 76 connections run through movable contact 56 of bank B, connection 116 and resistor 72 to the positive supply terminal. Charging therefore occurs at a rate determined by the setting of resistor 72. The result is the ultimate production of a step of the switch 50 to position 3. It will be noted that the connections just described are completely independent of the conditions of the relays 22 and 24, and hence whenever position 2 of the stepping switch is attained there will be initiated a step to position 3 irrespective of any other conditions in the control system. In similar fashion when position 4 is attained there will be a step to position 1 under control of the setting of resistor 74. The resistors 72 and 74 accordingly determine the duration of yellow signals. By reason of independent settability, the yellow signals for the respective highways may be caused to persist for different times; it is usually desirable to have a long yellow signal exhibited on a high speed highway to give ample warning of an impending transition to red so as to avoid the necessity for sudden stops, whereas shorter yellow signals may be provided on lower speed highways to

minimize delays in traffic flow. It will now be evident that what has just been described for the timing of yellow signals may be extended to the timing of "walk" signals when desired, there being provided additional steps of a stepping switch which from the standpoint of operation are controlled in the fashion just described. A yellow signal, for example, may be followed by a red signal on both highways with simultaneous exhibition of a signal indicating that pedestrians may cross the intersection. In general the pedestrian signal may be of a fixed duration.

Next to be considered is the condition which exists when a particular highway has a green signal and traffic continues on this highway without the appearance of a vehicle in a detection zone on the other highway. Under these conditions the green signal should continue without interruption until a change is required by a vehicle on the other highway. The situation may be considered by assuming that the stepping switch is in position 1 giving clearance to the NS highway. Under these conditions traffic on the NS highway may continuously or intermittently energize the relay 22. The condition for relay 22 de-energized has already been considered. If relay 22 is energized, relay 24 being de-energized, tracing of the circuit backwardly from the capacitor 76 will reveal that no path is connected to a positive supply terminal for charging. One connection, however, may be especially noted: going backwardly through contact 56, connection 114, resistor 68, line 106, contact 46, and line 100, we arrive at diode 27. It will be found that because of the energized condition of relay 22 a positive potential does appear at the movable contact 26 which is closed against 32. But the diode 27 is disposed to block charging flow so that the path just described is effectively open. The minute leakage current through the diode 27 will be so small as to flow off through the emitter of unijunction transistor 78 and, accordingly, no effective charging of capacitor 76 takes place.

The result is that in the absence of the appearance of a vehicle on the EW highway the green signal will be maintained for the NS highway.

Considering the symmetry of the circuit, it will be evident that similar conditions exist if the stepping switch is in position 3 and traffic is solely on the EW highway. In this last case the diode 29 performs the same blocking function as the diode 27 previously described.

The next condition which may be considered may be that assuming the stepping switch in position 1, exhibiting a green signal on the NS highway with traffic continuously within one or both of the NS detection zones but with a vehicle entering one of the EW detection zones. When this last occurs both relays are energized.

If connections are now traced backwardly from capacitor 76, it will be found that no connection to a positive supply terminal exists through the resistor 66. However, a connection to a positive supply terminal through resistor 68 does exist which may be traced as follows: from capacitor 76 through contact 56 to connection 114, thence through resistor 68, to connection 106, through the closed contact at 36, 28, through diode 29, and line 108 and through contact 54 to the positive supply terminal. Considering these connections, the diode 29 is disposed for forward flow of charging current. No other paths to a positive supply terminal exist, and consequently the capacitor 76 is charging solely through resistor 68. Under the assumption of a heavy traffic flow on highway NS, the resistor 68 may be assumed adjusted to provide a relatively high time constant to permit disposal of the NS traffic. But, though the delay may be relatively long, a step will ultimately occur to position 2 and then, as described, to position 3 to stop the NS traffic and give a green light to the EW vehicle or vehicles.

The situation thus presented is highly desirable: a maximum flow of traffic on the NS highway is permitted and, in particular, a situation is presented which will

clear through the intersection a group of vehicles which may initially have been stopped in one of the NS detection zones, for example, 8. If a number of vehicles are stopped in this zone, for example, by reason of the leading one having been stopped, and perhaps making a left turn, the long delay may be set to afford time for successive vehicles to get under way and clear the intersection before movement on the EW highway starts. As is well known, if a number of vehicles are stopped, as each moves there is a substantial time delay for the next to get under way, usually a matter of several seconds. A group of vehicles thus stopped should be permitted to clear the intersection following movement of the first.

However, once the detection zones of the NS highway are free of vehicles, movement on the EW highway should promptly occur. This is effected as follows:

Under this last condition the relay 22 will be de-energized while relay 24 will be energized. Tracing the circuit back from the capacitor 76, there will be found to exist the connection to the positive supply terminal through resistor 68 as before. But there will now also be found to exist a second charging circuit through resistor 66 as follows: through contact 56 to connection 114, through resistor 66 and connection 96, through the now closed contacts 30 and 26, through diode 27, through connection 100, through contact 4, and to line 106 and thence as before to the positive supply terminal. The result is that the capacitor 76 is then being charged through both resistors 66 and 68 in parallel to provide a more rapid charging. In fact, resistor 66 may be adjusted to have a much lower resistance value than resistor 68. If during this charging another vehicle passes through a detection zone of highway NS, the charging through resistor 66 may be interrupted, but whenever no such vehicle appears, the charging rate is speeded up. The time for the transition to position 2 is therefore a minimum if no vehicles appear in the detection zone in highway NS, and the delay is maximum if vehicles are continuously in those detection zones. For intermediate conditions the transition is speeded up in favor of the establishment of EW traffic flow.

As will be clear from the symmetry of the circuit, similar conditions exist in the transition from position 3 of the stepping switch with, of course, reversal of the highways considered. In this last case, resistors 64 and 70 are involved rather than resistors 66 and 68. Since all four of these resistors are separately adjustable, maximum and minimum times may be set to suit what are normal traffic conditions. If, during the course of the day, traffic flow conditions change, an officer may readily change the settings of the resistors, including resistors 72 and 74, to suit new conditions. For example, it may well occur that usually the NS highway carries heavy traffic and the EW highway may have relatively light traffic. But if a plant is located on the EW highway and at a particular hour a large number of employees are leaving the plant, preferential treatment may be given to the EW traffic to dispose of it most expeditiously.

The system also takes care of certain transient conditions. Note that the relays 22 and 24 are closed only when a vehicle is in a corresponding detection zone. Suppose that a vehicle proceeding north on the NS highway makes a right turn at the intersection to proceed east, and swinging widely moves momentarily into the detection zone 14. This would, of course, start a timing action similar to what would occur if a vehicle moving west entered the same detection zone. But if it enters and then leaves the zone 14, the charging of capacitor 76 will be interrupted at the time of leaving, and a step of the switch 50 will not occur. The partial charge thus produced on the capacitor 76 will gradually leak away through the emitter of the transistor 78, or, as previously indicated, there may even be provided an actual leakage resistor across the capacitor 76. Even if no leakage occurred, the only result would be to produce a

somewhat shorter than normal charging time for the capacitor after another vehicle enters the detection zone 14. Similar transient conditions might also occur, for example, if a private lane existed at the position of a detection zone so that it would be entered for a short interval by a vehicle moving into the lane.

The foregoing covers the operations involved when the function switch 38 is in the automatic position *c*. There may now be considered the conditions which exist when the setting is in the semi-automatic position *b*,

The semi-automatic position of the function switch involves operation differing from the foregoing only in that after position 3 of the stepping switch is achieved there will occur automatic stepping to position 1 whether or not a vehicle appears in a detection zone of the NS highway. This means that unless a vehicle on the EW highway has enforced a different situation, the NS highway will always have a green light so that traffic thereon need not slow down except possibly just after a vehicle on the EW highway has exerted control. In other words, high speed traffic flow may exist on the NS highway except under unusual conditions.

From the standpoint of operation there need only be considered the condition in which the stepping switch is in position 3. The charging circuit may be traced from capacitor 76 through movable contact 56 to connection 112 and thence through resistor 64 and contact 42, now in position *b*, to the position supply terminal. A charging circuit is thus set up which is independent of conditions of the relays 22 and 24. The resistor 64 is that which establishes a maximum time delay in favor of traffic on the EW highway before the stepping to the fourth position.

If relay 24 is energized by one or more vehicles in the detection zone of the EW highway, charging is solely through the resistor 64. But as soon as no vehicle is in either of the detection zones 12 or 14, relay 24 is de-energized, and another charging path may be traced from connection 112 through resistor 70, through the closed contacts at 34 and 28, through diode 29 and connection 108 and then through movable contact 40 (in position *b*) to the positive supply terminal. In this case charging is through both resistors 64 and 70 in parallel and a quick stepping to position 4 and then to position 1 will take place. All of the other operations of the control are the same as described for the automatic setting of the function switch 38 and need not be repeated. The sole difference is the automatic return of the stepping switch to position 1 which is maintained except when a vehicle on the EW highway requires clearance.

Position *a* of the function switch 38 is referred to as a fixed time setting though this may or may not be strictly the case depending upon the settings of the resistors of the group 64-70. If the resistors 66 and 70 are set at values much less than the resistors 64 and 68, times will be essentially constant irrespective of detections of vehicles and the system will then function effectively the same as that conventionally controlled by a time switch. However, in this setting some preference may be given to vehicles which are in the detection zone to speed up the cycling to some extent.

Considering the function switch 38 in position *a*, and the stepping switch in position 1, a charging circuit may be traced from capacitor 76 through contact 56, connection 114, resistor 66, connection 96, and contact 40, in position *a*, to the positive supply terminal. Charging is thus effected through the resistor 66 independently of the conditions of the relays 22 and 24. However, if relay 24 is energized, another parallel circuit may be traced from connection 114 through resistor 68 and connection 106 through the closed contacts 36 and 28, through diode 29 and then through connection 108 and contact 54 to the positive supply terminal. If resistor 68 is set at a value comparable with or less than resistor 66, the presence of a vehicle in a detection zone of the EW highway will ac-

celerate the stepping to position 2 and thence automatically to position 3.

If the switch is in position 3 a similar situation exists, charging being through contact 56 and connection 112 and thence through resistor 70, connections 104 and 102, and through contact 42 to the positive supply terminal. This charging path is independent of the conditions of the relays. If relay 22 is energized, there is a further charging path through resistor 64, contact 44, connection 98, closed contacts 32 and 26, diode 27, connection 100 and contact 54 to the positive supply terminal, so that charging then is through both resistors 64 and 70 in parallel to speed up the transition to position 4 and then to position 1. This so-called fixed time adjustment may be used when there is traffic congestion on both highways. It will be evident that by adjustments of the resistors, however, the time for transition from position 1 to position 3 may be made quite different from that from position 3 to position 1.

Manual control by the momentary openings of switch 94 (switch 77 being opened) can be used to override the automatic operations.

Referring now to FIG. 2 which involves electronic control without mechanically moving parts except for the relays 22 and 24 and the use of the function-selecting switch 38 and the switches involved in manual operation, consideration of the construction and operation will be clarified by pointing out that the relay connections to and through the function switch and the variable resistor arrangement are all similar to what has already been described. The differences are basically that for the stepping switch there is substituted a two-stage counter which establishes four conditions corresponding to the four positions of the stepping switch. Output lines from the counter control the charging of a capacitor which, in FIG. 2, provides pulses for the stepping of the counter. The output lines from the counter also have matrix connections to devices including silicon controlled rectifiers for control of illumination of the signal lights.

The various parts and connections which are the same as those in FIG. 1 are designated by the same numerals to eliminate the necessity for repetition of the description. The new and different connections are the following:

A line 166 connects the fixed contact at position *c* of an additional bank VI of the function switch 38 to the emitter of a transistor 168, the collector of which is connected to the positive supply terminal. In similar fashion the connection 110 previously described is extended to the emitter of a second transistor 170 to the collector of which is connected to the positive supply terminal. These transistors are rendered conductive as will be hereafter described to provide current through the connections 166 and 110.

A set of diodes 176, 178, 180 and 182 are provided to supply independent charging currents from the several resistors to a common condenser-charging line 222. The upper terminal of resistor 74 is connected to the positive supply terminal and its lower terminal is connected at 184 to the anode of diode 176 while the upper terminal of resistor 72 is also connected to the positive supply terminal and its lower terminal is connected at 186 to the anode of diode 178. The connections 184 and 186 also run to the collectors of the respective transistors 188 and 190, the emitters of which are grounded.

The lines 114 and 112 are connected respectively to the anodes of the diodes 180 and 182 and to the collectors of transistors 192 and 194, the emitters of which are grounded.

A pair of resistors 200 and 202 have their upper terminals connected to the positive supply terminal and have their lower terminals respectively connected at 204 and 206 to the bases of the transistors 168 and 170. These terminals are also respectively connected to the collectors of transistors 196 and 198, the emitters of which are grounded.

In the case of each of the transistors 188, 190, 192, 194, 196 and 198, the bases are individually connected to a negative potential terminal, i.e., negative with respect to ground, through resistors typified at 208. (The positive terminals heretofore and hereafter referred to are also with respect to ground, a three terminal direct power supply being here used.)

The bases of the transistors just mentioned are also connected through respective resistors 210, 212, 214, 216, 218 and 220 to paired diodes described later.

The capacitor charge through the connection 222 is indicated at 224, and at this point there may be described the type of operation involved in the selective charging of this capacitor through the resistors 64, 66, 68, 70, 72 and 74. If the transistors 188, 190, 192 and 194 are conducting, the lower terminals of the resistors are effectively grounded and consequently no positive outputs are provided from their connections 184, 186, 114 and 112. But if any one of these transistors is cut off by reason of a negative base, the ground connection is effectively open so that a positive potential is applied to the anode of the corresponding diode of the group 176, 178, 180 and 182 to provide a charging current. As will appear, the control system renders selectively non-conductive these transistors which are normally conductive. The diodes block reverse current flows.

Somewhat similar considerations apply to the controls of the transistors 168 and 170. When the diodes 196 and 198 are conducting, the bases of the transistors 168 and 170 are grounded and the transistors do not pass current from the positive terminal. However, when the transistors 196 and 198 are selectively cut off by negative potentials applied to their bases, the bases of the transistors 168 and 170 become positive through the connections of resistors 200 and 202 to the positive supply terminal, and the transistors 168 and 170 accordingly supply current through their emitters.

The ungrounded terminal of capacitor 224 is connected to the emitter of the unijunction transistor 226, the upper base of which is connected to the positive supply terminal while the lower base is connected through the load resistor 228 to ground. The lower base of the unijunction transistor is connected through capacitor 230 and the normally closed switch 234 to the base of the transistor 236 which is connected through resistor 232 to ground. For manual operation the switch 234 is engaged with the upper contact 237 to the junction of resistor 238 and capacitor 240. The upper terminal of resistor 238 is connected to the positive supply terminal, while the lower terminal of capacitor 240 is grounded. A normally closed pushbutton switch 242 grounds the junction 237. For manual operation, with the switch 234 in its upper position, the push button switch 242 is opened, and its opening produces a positive pulse through resistor 238 to the base of transistor 236. In other operations, the firing of the unijunction transistor produces positive pulses through the capacitor 230 and the normally closed lower position of the switch 234 to the base of transistor 236.

The emitter of transistor 236 is grounded and its collector is connected through load resistor 244 to the positive supply terminal. It is also connected through diode 248 to the lower terminal of resistor 246 which runs to the positive supply terminal. The anode of the diode 248 is connected to the line 250. When the transistor 236 is non-conducting, the line 250 is positive; but when the transistor 236 conducts, the line 250 is effectively grounded, and when this conduction occurs a negative pulse is delivered through the line 250.

Control is effected through the counter comprising the bistable multivibrators 252 and 254 which are conventional and need not be described in detail. Counting is effected by the delivery of the negative pulses through line 250 to the first multivibrator and through delivery of negative pulses to the second multivibrator through the diode 264 from the output of the first multivibrator

appearing on line 258. Two-stage binary counting is thus effected. Four output lines 256, 258, 260 and 262 run from the multivibrator stages as shown and selective connections to these effect the control operations. As usual, four configurations exist, lines 256 and 258 always being of opposite polarity and lines 260 and 262 also being of opposite polarity. Capacitors shown in a group at 266 are connected between these respective lines to ground to suppress transients and noise.

The various resistors of the group 210 to 220 are selectively connected to the lines 256, 258, 260 and 262 through diode pairs, the pair for the connection of resistor 210 being indicated at 268. The resistor 210 is connected to the cathodes of the diodes and the lines are selectively connected to the anodes. In the case of the pair 268 the connections are to the lines 256 and 262. In the case of the diode pair 270 connected to resistor 212, the connections are to the lines 256 and 260. The diodes of the pair 272 connected to resistor 214 are connected to the lines 258 and 260. The diodes of the pair 274 connected to the resistor 216 are connected to the lines 258 and 262. The diodes of the pair 276 connected to resistor 218 are connected to the lines 258 and 262, these connections being the same as for the diodes at 274. The diodes of the pair 278 connected to resistor 220 are connected to the lines 258 and 260 corresponding to the connection of the diodes of the pair 272.

The connections just described control the corresponding transistors as follows:

If either diode of a pair at any time is connected to a positive line current flows therethrough and through the associated resistor and the resistor corresponding to 208 rendering the transistor base positive so that the transistor conducts preventing charging current from flowing from the line connected to its collector. On the other hand, if both diodes of a pair are connected to negative lines, the flow of current through the corresponding resistor of the group 210, etc., is cut off and the base of the corresponding transistor is negative, cutting off current flow through the transistor so that charging of the capacitor 224 from the line connected to its collector occurs. Proper switching accordingly results.

Control of the signal lamps is effected through units containing silicon controlled rectifiers which are delimited by dotted lines in the figure. A resistor 280 connected to line 262 provides a control signal for the unit 282 which will be later described in detail. Similarly a resistor 284 is connected to line 260 provides for control of the unit 286.

In the case of the next four units 290, 300, 306 and 312 the connections are somewhat different. In the case of the third unit 290, a resistor 288 is connected to the anodes of a pair of diodes 292 and 294, the cathodes of which are respectively connected to the lines 258 and 262. The anodes are also connected through resistor 296 to the positive supply terminal.

The next unit 300 is similarly associated with a resistor 298 connected to a diode-resistor unit 302 in which the diodes are connected to the lines 256 and 262.

Unit 306 is similarly connected through resistor 304 to the diode-resistor assembly 308, the diodes of which are connected to the lines 258 and 260. The unit 312 is connected to the resistor 310 which is in turn connected to the diode-resistor assembly 314, the diodes of which are connected to the lines 256 and 260.

The units 282, 286, 290, 300, 306 and 312 respectively supply current to the lamps 316, 318, 320, 322, 324 and 326.

Instead of individual lights multiple light may be connected in parallel for traffic control. The light 316 is red for the EW highway while light 318 is red for the NS highway. Light 320 is yellow for the NS highway and light 322 is green for the NS highway. Light 324 is yellow for the EW highway and light 326 is green for the EW highway.

Referring to the components in the unit 282, resistor 280 runs to the base of transistor 328, this base being also connected through resistor 329 to the negative supply terminal. The positive supply terminal is connected through resistor 330 and the direct terminal winding 332 of a saturable reactor to the collector of the transistor 328, the emitter of which is grounded. A diode 334 is connected between the positive supply terminal and the collector of this transistor to take care of inductive surges.

The alternating current winding 336 of the saturable reactor has one terminal connected through resistor 338 and diode 340, polarized as indicated, to the anode of a silicon controlled rectifier 342, the gate terminal of which is connected to 344 to the other terminal of the winding 336. One side of the alternating current supply line indicated at 346 is connected to the anode of the rectifier 342. The second side of this line indicated at 348 is connected through resistor 352 to the cathode of the rectifier. A resistor 353 is connected between the cathode of the rectifier and its gate terminal. The light or lights 316 are connected between the side 348 of the alternating current supply line and the cathode of the rectifier. The capacitor 350 is connected between the cathode of the rectifier and the right-hand terminal of the winding 336. When the transistor 328 is non-conducting, no appreciable current flows through the control winding 332 of the saturable reactor, and accordingly the winding 336 provides a high impedance which in association with resistor 353 results in an insufficient positive supply to the gate terminal of the silicon-controlled rectifier to fire it, and consequently the rectifier does not supply current to the light 316. On the other hand, when the transistor 328 conducts, direct current flows through the winding 332 and the winding 336 presents a low impedance resulting in a sufficiently positive supply to the gate of the rectifier to fire it during forward half cycles and thereby illuminate the light 316. The circuitry just described for the illumination of the light 316 is conventional and may, of course, be replaced by many other types of controls. More elaborate controls may be used to provide full wave excitation of the light.

As will now be evident, lighting of the light corresponds to a conductive condition of the transistor 328. So long as the line 262 is relatively negative, i.e., effectively grounded, the negative supply through resistor 329 maintains the base of transistor 328 negative and the transistor non-conducting. However, if the line 262 is positive, potential at the base of the transistor is positive and conduction occurs resulting in illumination of the light 316 as stated. The resistors 280 and 329 are chosen to provide the proper voltage division for this purpose.

The unit 286 is identical with the unit 282 and the operation is the same, the light 318 being illuminated when the line 260 is positive.

In the case of the next four units 290, 300, 306 and 312 operation is somewhat different, depending on conditions of the pairs of lines to which the associated diodes are connected. For example, considering the unit 290, if either of the lines 258 or 262 is relatively negative, the lower end of the resistor 296 is effectively grounded so that the base of the corresponding transistor is held negative by the connection to the negative supply terminal through the resistor corresponding to 329. On the other hand, if both lines 258 and 262 are positive, flow of current through them is blocked, and the positive supply through resistor 296 provides a positive potential to the transistor base through the voltage divider system, and light 320 is accordingly illuminated. Similar conditions, but related to the corresponding pairs of lines, exist in the control of the units 300, 306 and 312.

It will now be seen that switching operations are effected for both charging the capacitor 224 and for illuminating the lamps, the switching being effected in accordance with the four possible conditions of the binary counter, the conditions of which are stepped in sequence by

the firing of the unijunction transistor 226 upon adequate charging of the capacitor 224. The matrix system provided by the lines 256, 258, 260 and 262 and the connections described controlling the step operations. The switching may be readily followed by considering the following:

When the lines 256, 258, 260 and 262 are respectively positive, negative, negative and positive the green light 322 for the NS highway is illuminated and simultaneously the red light 316 for the EW highway. The next step results in the respective conditions of the lines negative, positive, negative and positive, and the yellow light 320 is illuminated for the NS highway while the light 316 continues red for the EW highway.

The next step results in positive, negative, positive and negative conditions for the respective lines producing illumination of the red light 318 for the NS highway and the green light 326 for the EW highway. The fourth step results in negative, positive, positive and negative conditions for the respective lines, the red light 318 being continued illuminated for the NS highway while the yellow light 324 is illuminated for the EW highway. The sequence is thus the same as that involved in the case of the modification illustrated in FIG. 1. The switching sequence is identical with what has been described in detail for FIG. 1 with respect to the charging operations involved through the resistors 72 and 74, during a showing of yellow lights, and through the resistors 64, 66, 68 and 70 and their connections 112 and 114 for the green lights, with association of the proper red lights. Positive supplies are controlled through the transistors 168 and 170, and in view of the same switching cycle and taking into consideration the mere fact that switching is accomplished differently, it will be unnecessary to trace the charging paths which through the relay contacts and through the function switch contacts and resistors are the same as previously described. In view of the correspondence between the function switch steps of the two modifications it will be evident that the automatic, semi-automatic and fixed time operations are the same as previously described.

It will be evident that various modifications may be made involving even the substitution for the relays 22 and 24 of solid state switching arrangements. Further, it will be evident that by extensions of what has been described for FIG. 2 the system is adaptable to the traffic control of more elaborate intersections.

Having described the system specifically as it functions in various modes, it may be helpful to now review in more general terms the fundamental principles underlying the invention. In a digital-type traffic control system of the type heretofore known, vehicles are counted one by one to determine the various traffic parameters (i.e., volume, density and speed). But these parameters do not reflect the actual traffic conditions as they exist in the region of the intersection. In contradistinction, in the present invention these conditions are translated into an analog value which acts to effect a phase split in the operation of the signal controller at a time best calculated to promote efficient traffic flow. Hence the present system, which is grounded on analog principles, is basically at variance with prior digital systems.

To explain the analog concept in general terms and without regard to any one mode of operation, FIG. 3 shows a detector D in the left lane of a road X which intersects with a road Y. Placed at the intersection is a traffic signal controller TSC which shall, for reasons of simplicity, be of the type having only red and green signals. The controller is capable of functioning in a phase A giving a right of way only to traffic in road X and in a reverse phase B in which this right of way is given only to traffic in road Y. The combination of the two phases constitutes the operating cycle of the controller and the transfer point therein is designated the split. The transfer from one phase to another is effected by a split switch SS which in turn is actuated by a timer T. The timer, when initiated, runs from a start point to a finish point

in an interval whose duration is an analog of the traffic pattern in the lane, the split switch being fired when the finish point is reached.

Detector D encompasses an elongated zone in the left lane in road X, the length of the zone being sufficient to include a plurality of vehicles, the end of the zone being adjacent the intersection. As long as any vehicle or a portion thereof lies within the boundaries of the zone, detector D will produce a 1st value which represents a state of occupancy, but when no vehicle or any portion thereof lies within the zone boundaries, a 2nd value is established representing a state of non-occupancy. If therefore a platoon of vehicles is travelling through the detected zone and one or more vehicles thereof lies fully or partially within its boundaries, detector D yields the 1st value, but when the headway between two vehicles in the travelling platoon is such that at a particular time no one vehicle falls within the zone boundaries, the detector yields the 2nd value. While a high-frequency loop detector has been disclosed for this purpose, it will be obvious that other known forms of presence detectors may be used within the scope of the invention.

Detector D is operatively coupled to timer T. The operation of the timer is expressed in terms of a voltage which rises along a ramp from a zero or minimum level at the start point to a predetermined voltage magnitude or maximum level at the finish point. As shown by the various curves in FIG. 4, the amount of time, in seconds, it takes this voltage to rise from the start to the finish point represents the timing interval which constitutes the analog value. While the timer is described as electronic in character, it will be obvious that equivalent results are obtainable by a mechanical or motor-driven arrangement.

Timer T is arranged so that when it is responsive to the 1st value it runs slowly, this being represented by the maximum setting voltage curve I, where it will be seen that it takes 30 full seconds for the voltage to rise from start to finish. When however the timer responds to the 2nd value, it runs much faster. This is represented by the minimum setting curve II, where it will be seen that the voltage runs from start to finish in exactly 3 seconds, which is ten times as fast as the response to the 1st value.

If therefore there is no traffic in the zone at the time the operation of the timer is initiated and this condition continues, the timer will time out quickly, as in curve II, to cause a split after the three second minimum interval. But if the traffic is such that the zone remains occupied by one or more cars, the timer will time out slowly, as in curve I, to cause a split only after a thirty second interval, thus affording the maximum time to clear traffic through the intersection before the split occurs.

If on the other hand, the traffic pattern is fluctuating so that the zone is intermittently occupied, the detector will yield 1st and 2nd values in a sequence reflecting this condition. Consequently, as shown in curve III, the voltage will rise quickly when a 2nd value is in force, then slow down when a 1st value takes effect, so that the timing interval between start and finish will be made up of successive slow and fast increments (A, X, B, Y, C and Z).

The total interval (Curve III—17 seconds) will therefore be an analog of actual traffic conditions, and will reflect the physical length of the vehicles as well as speed, starting time, headway and other parameters which come into play and to which the detector is sensitive.

In order to further explain why the timer interval constitutes an analog of traffic conditions, some examples will now be given. Assume that a single car is passing through the detected zone at 20 miles an hour. As long as this car or a portion thereof lies within the zone boundaries, a 1st value will be produced which reflects the state of occupancy. As soon as this car is fully outside of the zone boundary, the 2nd value is established. In a simple practical form, these values may be created by a relay which is caused to occupy one switch position when the detector field intercepts the presence of a vehicle and another switch

position when no vehicle is present. In one switch position a timing circuit having a long time constant is introduced in Timer T, while in the other switch position a timing circuit with a short time constant is introduced therein.

If now a second car travels through the zone at exactly the same speed, but the second car is longer than the first, though it will take exactly the same time for the second car to go from the beginning to the end of the zone, it will necessarily take longer for the second car body to clear the end of the zone. This will be reflected in the relative periods of the 1st and 2nd values produced by the travel of the second car. Hence while a digital system will not be able to distinguish between the first and second cars in the example given, in that each car gives a single count and each produces the same speed indication, the analog system will afford an appropriate distinction, for the resultant timing interval will reflect the longer occupancy period of the second car and therefore have a greater duration.

Let us now by way of another example assume a platoon of cars traveling through the zone, all cars having the same speed and being spaced apart with a headway say of 100 feet. The resultant 1st and 2nd values will of course reflect this headway in the relative periods in which the two values are established. If now another platoon of cars travels through the zone and the cars in this platoon are identical to those in the first and are moving at the same speed, but with a headway of 200 feet, this distinction will show up in the values established by the detector and by the resultant timing in period. Thus regardless of how traffic fluctuates, the analog system will produce an analog voltage which is a proper reflection of the existing conditions, and the instant of phase split in the signal controller will be such as to produce right of way signals promoting optimum flow efficiency.

Thus if the detector loop is immediately vacated, the timer will time out on its minimum setting, if the loop is continuously occupied, the timer will time out on its maximum setting, and if the loop experiences a combination of occupancy and non-occupancy states, it will time out at some intermediate point between the minimum and maximum time setting. This analog principle lends itself to various modes of traffic control operation.

Thus in the "semi-actuated" mode, with an intersection of a major and minor artery, minimum green time can be guaranteed on the major artery by means of a detection loop on the minor artery providing a right of way only on demand. That is, the arrival of a car in the minor artery detection zone causes the phase to split and gives the minor artery a green for an interval which is then subject to analog control. This is accomplished by a gate circuit which normally disables the timer and initiates its operation only on the arrival of a vehicle in the minor artery.

In a "fully-actuated with preference" mode, there is full detection in both phases, but the green time reverts to the parent phase (main artery) if there is no demand on the minor artery. Each artery is timed on the analog principle. In "fully actuated without preference" mode the revert feature is omitted, the operation otherwise being the same. In the "fully-actuated, last call" mode there is again full detection on both phases, but green remains on phase until detection on opposite phase, each artery being timed on the analog principle. In the "fully-actuated two phase recall" mode, in the absence of traffic, right of way transfers back and forth on minimum time setting. However, the arrival of traffic will allow green up to the maximum setting of either phase on the analog principle.

It will be appreciated that regardless of the mode, an analog system is used which combines a true presence detector with a timer to produce an analog interval at the end of which a split phase occurs. Differences in modes depend on the manner in which the operation of the timer is initiated and whether timing takes place in the major as well as the minor artery. Analog systems may be installed at a progression of intersections, the systems being coordinated so that the operation of any one intersection is

under the control of the system at a preceding intersection.

While there has been shown and described a preferred embodiment of an analog traffic control system in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without, however, departing from the essential spirit of the invention.

What I claim is:

1. An analog system for controlling vehicular traffic at an intersection of two roads, said system comprising:
 - (a) a traffic signal controller disposed at said intersection and operable in one phase to give a right of way only to traffic in one road and in a reverse phase to give a right of way only to traffic in the other road,
 - (b) a split switch coupled to said controller to cause the phase thereof to transfer from the existing phase to the other phase,
 - (c) a detector disposed in one of said roads to sense either the presence of any vehicle or a portion thereof in a zone having a length sufficient to include a plurality of successively arriving vehicles, or the absence of all vehicles from said zone, said zone terminating at a point adjacent said intersection, said detector yielding a first value representing a state in which the zone is occupied by at least one vehicle or a portion thereof and reflecting the headway between vehicles successively arriving at the zone where said headway is no greater than the length of said zone, and a second value representing a state in which the zone is totally unoccupied,
 - (d) a timer coupled to said detector and responsive to said values, said timer running from a start point to a finish point at a rate which is slow when said first value is in force and which is fast when second value is in force to produce a timing interval which is an analog of traffic flowing through said zone, and
 - (e) means coupled to said timer to actuate said split switch when said interval reaches said finish point to cause a transfer in the phase of said controller and thereby to deny a right of way to the traffic passing through said zone.
2. A system as set forth in claim 1 wherein each lane in the intersecting roads has a detector installed therein, each detector cooperating with said timer to provide analog control for that lane.
3. A system as set forth in claim 2 arranged to provide operation in the semi-actuated mode.
4. A system as set forth in claim 3 arranged to provide operation in the fully actuated mode.
5. Apparatus for control of vehicular traffic at an intersection of two roadways including signal means controlling traffic on said roadways by alternatively permitting or denying access therefrom to the intersection; a presence detector means associated with each of said roadways responsive to the presence of any vehicle in a zone of its corresponding roadway extending from a first point adjacent to said intersection to a second point a substantial distance in advance of the intersection such that there may be simultaneously in said zone a plurality of vehicles one following another; a pair of switching means, one of which is operated by each detector, each switching means having two states, an absence state which is established by its detector as long as no vehicle is present in the corresponding zone and a presence state which is established as long as any vehicle is present in the corresponding zone; an interval timing means having means for controlling its timing rate between an instant of initiation of its operation and attainment of a predetermined state of termination of its operation; cyclical switching means having sequential states within a complete cycle of operation and effective in each state to provide a predetermined condition of said signal means; circuit means for initiation of operation of said timing means controlled by one of said switching means in a presence state established by its detector when a vehicle is in its corresponding zone and

denied access to the intersection; said circuit means also controlling operation of said timing means at one rate when both of said switching means are in presence states, and for controlling operation of said timing means at a different faster rate when that switching means other than the one which initiated the operation of the timing means passes into its absence state; and means controlled by said timing means when it attains said predetermined state to advance said cyclical switching means to the next state of the cycle.

6. Apparatus according to claim 5 in which said interval timing means comprises a resistance-capacitance timing circuit having a variable time constant, and said circuit means for initiation of operation of said timing means provides current flow in said timing circuit, the said pre-

determined state of said timing means being a predetermined charge of said capacitance.

7. Apparatus according to claim 5 in which said resistance-capacitance timing circuit comprises means providing alternative resistances to establish different time constants of said assembly.

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