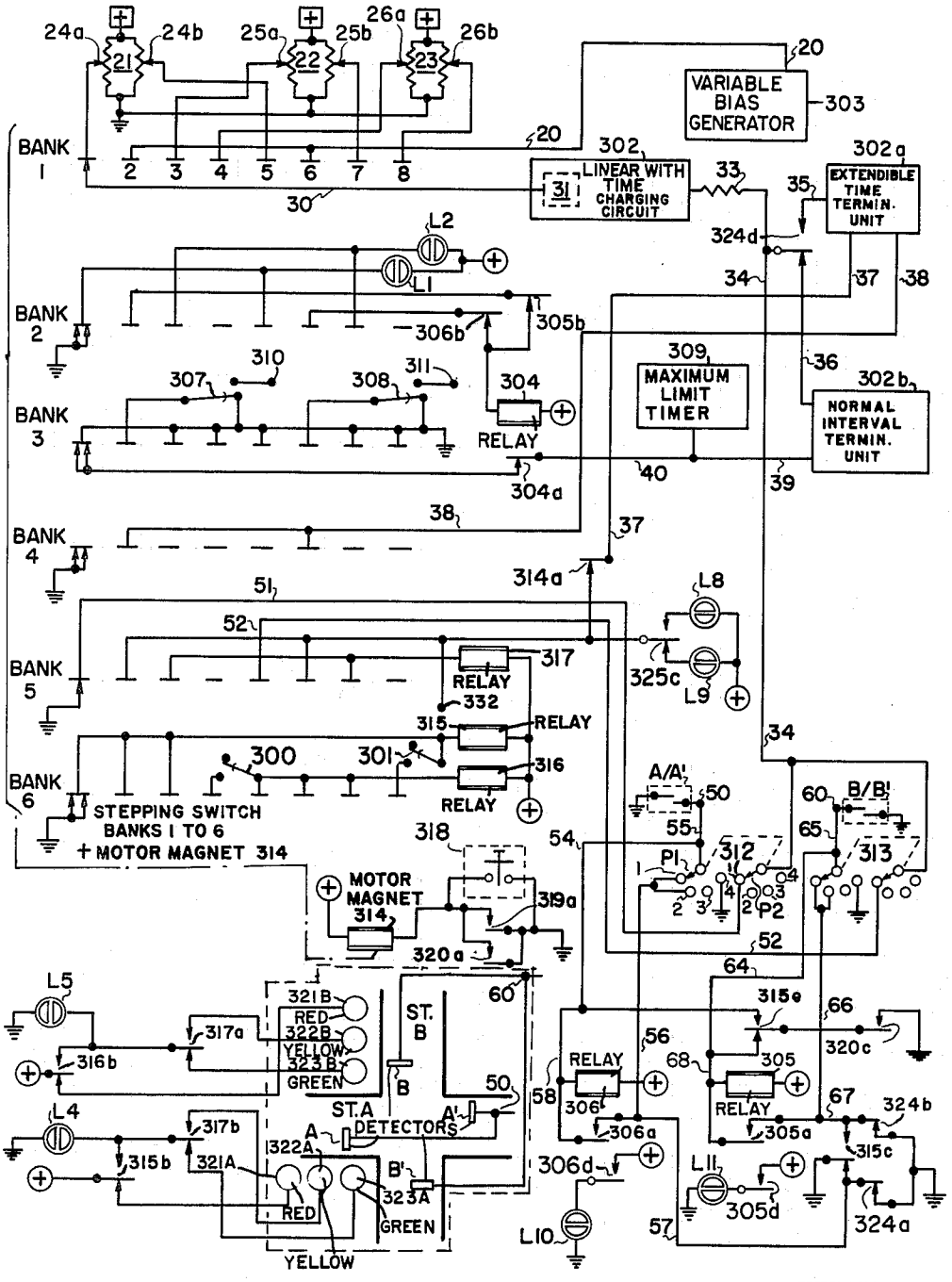
Feb. 8, 1966 C. L. DU VIVIER 3,234,505

TRAFFIC CONTROL SYSTEM OF THE ACTUATED TYPE WITH IMPROVED TIME CONTROL

Filed Aug. 18, 1961 3 Sheets-Sheet 1



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FIG. 1

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TRAFFIC CONTROL SYSTEM OF THE ACTUATED TYPE WITH IMPROVED TIME CONTROL

Filed Aug. 18, 1961 3 Sheets-Sheet 2

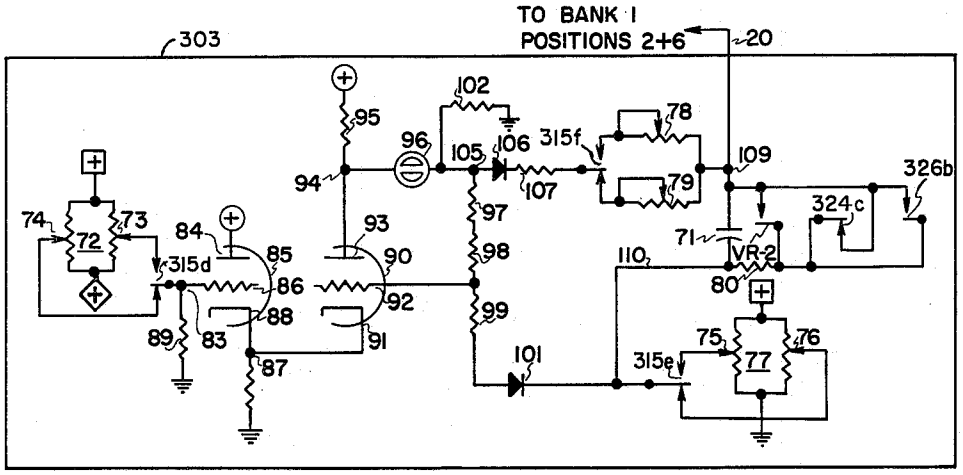


FIG.2

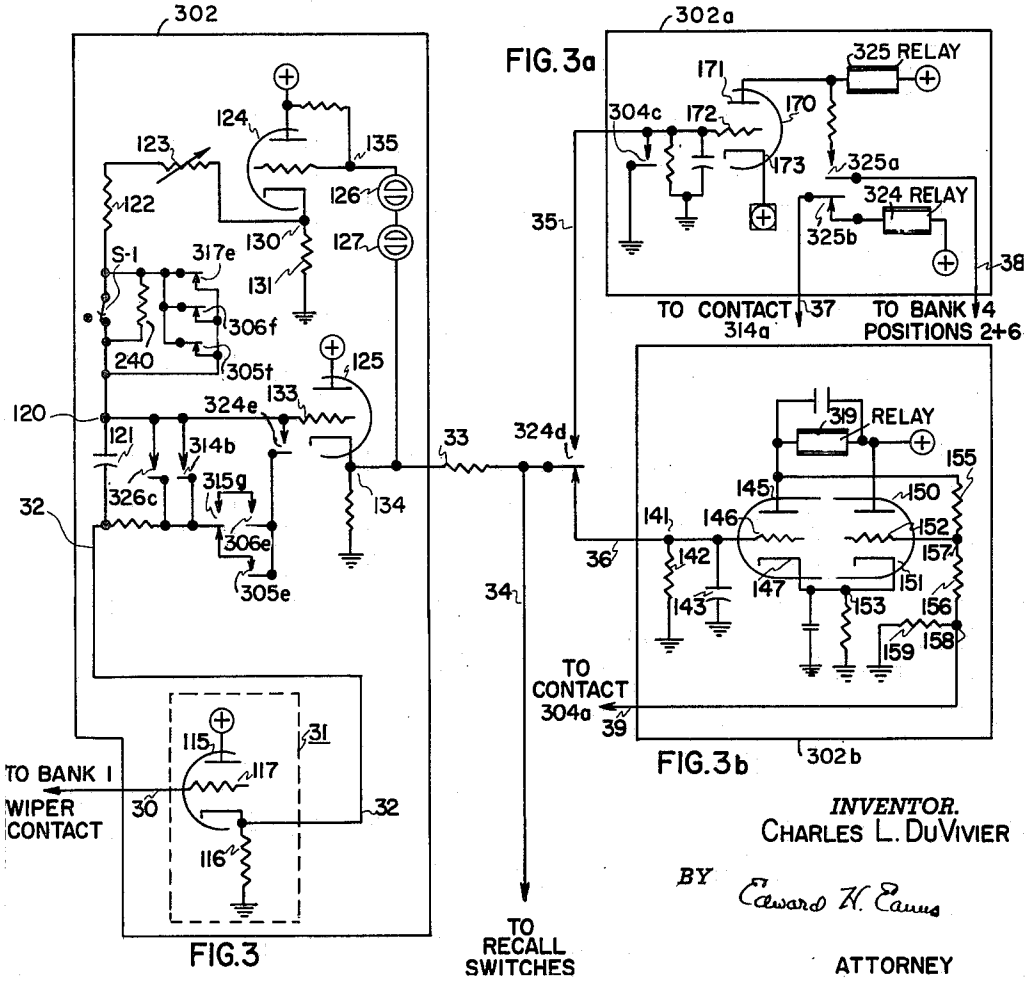


FIG.3

FIG.3a

FIG.3b

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TRAFFIC CONTROL SYSTEM OF THE ACTUATED TYPE WITH IMPROVED TIME CONTROL

Filed Aug. 18, 1961 3 Sheets-Sheet 3

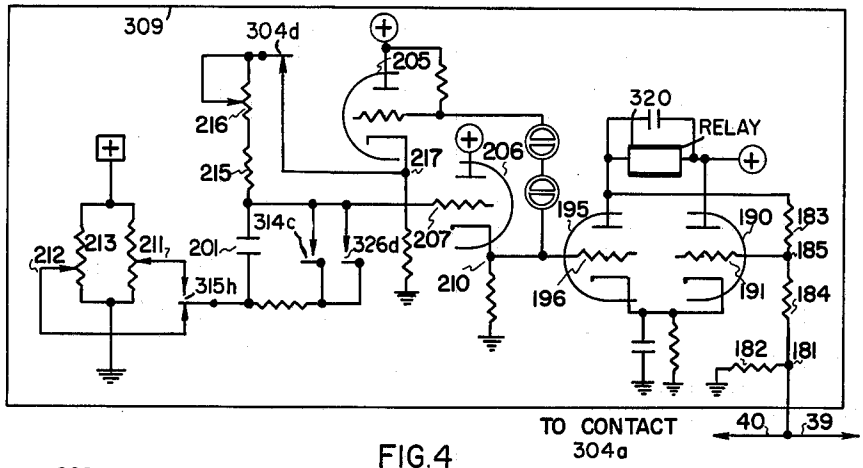


FIG.4

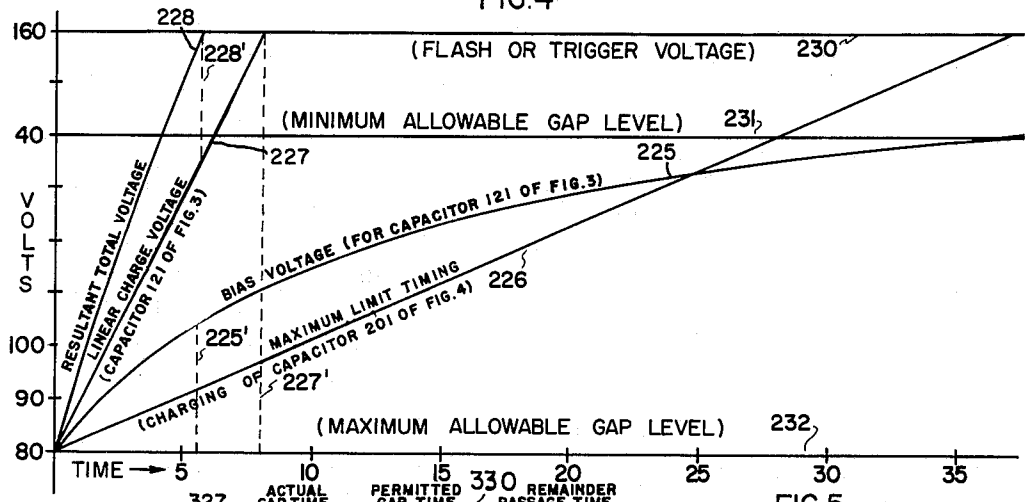


FIG.5

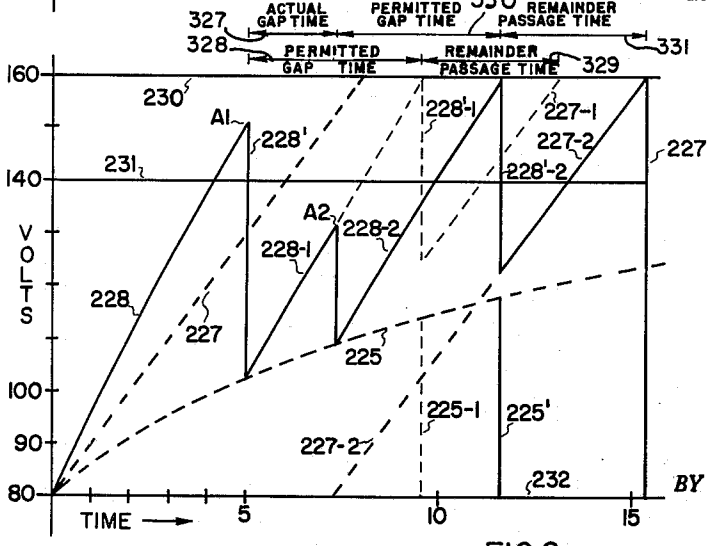


FIG.6

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TRAFFIC CONTROL SYSTEM OF THE ACTUATED TYPE WITH IMPROVED TIME CONTROL

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9 Claims. (Cl. 340—37)

This invention relates to traffic control systems for control of right-of-way of traffic at a junction of traffic lanes. More particularly the invention relates to an improved traffic signal control system, of the actuated type, employing one or more vehicle detector devices in the intersecting lanes, traffic right-of-way signals at the intersection and a traffic signal controller of the full actuated type for providing transfer of right-of-way between the several intersecting streets or lanes successively for timed periods, such transfer being made in response to traffic actuation by waiting traffic and timing, of one or more intervals of a right-of-way period, responsive to actuation of right-of-way traffic.

In the present system, actuation of a traffic detector in a traffic lane in which the stop signal is being displayed causes response which determines that right-of-way shall be transferred to that lane at the first opportunity. If there is no traffic entering the intersection from the lane in which the "go" signal is being displayed, the right-of-way is transferred from the latter lane to the former lane, usually with an intervening "caution" signal display for a brief period for the latter lane.

If traffic is moving in the lane in which the "go" signal is displayed actuation of the traffic detector in the lane in which the "stop" signal is being displayed causes the right-of-way to be transferred thereto at the first break of a predetermined time in the moving of right-of-way traffic. If no such break occurs in the right-of-way traffic, right-of-way will be transferred at the end of a predetermined maximum period and automatically returned after serving the waiting traffic on the other lane.

In this system, actuation of a vehicle detector by right-of-way traffic during the "go" period causes such "go" signal period to be extended under certain conditions. The "go" period for each traffic lane is divided into two parts. During the first part of this period any actuation of the traffic detector in the lane in which the "go" signal is being displayed is of no effect. This first part of the "go" period, called the "initial interval," is to allow for standing traffic to get into motion.

After the expiration of the initial interval the "go" signal will continue to be displayed for an interval of time at least sufficient for a moving vehicle to progress from the traffic detector through the intersection. This last named interval is called the "extendible vehicle interval."

During the "vehicle interval," actuation by traffic having the right-of-way extends the right-of-way period for a time interval sufficient to allow the actuating vehicle to progress from the detector to the intersection. This is accomplished by reset of the vehicle interval timer. As the right-of-way period continues, and the timer is reset by moving right-of-way vehicles, the period in which the timer may be reset, as by actuation of two succeeding vehicles, is reduced so that the first time gap between two successive actuations that exceeds a progressively reduced permitted time gap fails to reset the timer.

After failure of reset of the resettable period, the right-of-way interval is terminated after a timed period sufficient to permit passage of the last effective actuating vehicle through the intersection.

The present system includes a new and more efficient means and manner of timing and extending the time increments of the vehicle interval in response to actuation of right-of-way traffic.

My present controller employs one composite timer for timing the entire "vehicle intervals," which includes the resettable part of the vehicle interval as well as the "passage time."

My improved apparatus includes an improved composite time control circuit employing linear-with-time charging of a timing capacitor and controlled bias voltage application to the timing capacitor. Electrical isolation of the timing capacitor provides for operation of a trigger circuit without effect on the capacitor.

Operation of the trigger circuit is accomplished by the presence of a predetermined total voltage across the timing capacitor and an additive bias voltage in series. The predetermined total voltage may result from the accumulated charge on the timing capacitor plus a steady bias voltage or may result from the accumulated charge plus a variably increased bias voltage, with both the charge and the bias voltage independently controlled applied to the capacitor. The "predetermined total voltage" is sufficient to overcome a high fixed cut-off grid bias at the input tube of the trigger circuit to operate the trigger circuit.

Thus, dual, independent control of the voltage of a timing capacitor, with the capacitor electrically isolated from the trigger circuits provides for the simultaneous timing of a progressively reduced resettable vehicle time increment and a constant length passage time with the passage time extending beyond the resettable vehicle time increment a varying time, which depends upon the amount of time the associated resettable vehicle time increment has been reduced.

The present invention discloses an improved full actuated local traffic signal controller which may be part of a traffic control system, for use at an intersection in which the "go" or green period of each phase of the traffic signal cycle includes a locally adjustable, stable initial interval and an extendible interval with the extendible portion of the green period made up of multiple parts. This initial portion, which is unextendible, is for the purpose of clearing out all vehicles which have arrived and are waiting during the last red period, between the detector and the intersection stop-line.

After termination of the initial interval the extendible portion of the green period may be timed if there is a demand for transfer of right-of-way.

If there is no demand for transfer of right-of-way the controller moves into the position in which the extendible interval may be timed, and assumes what may be referred to as a rest condition.

In the rest condition a maximum limit timing circuit, which may time the maximum time the controller may be permitted to remain in the extendible interval, after demand for transfer of the right-of-way is received, is forced to rest and a variable bias generating unit, which is used to set the passage time, and reduce the allowable gap time from a maximum allowed gap time to a minimum allowed gap time, is held in quiescent state so that the maximum allowed gap time is not reduced.

During such rest condition a linear-with-time charging

circuit is operating and charging a timing capacitor linearly, over a steady bias voltage impressed by the quiescent variable bias generating unit.

In the event of absence of actuation by traffic receiving right-of-way and absence of actuation demanding transfer of right-of-way the charge on the timing capacitor may increase to or above a value that would normally cause termination of the interval without resulting in termination of the interval.

In the event of actuation by traffic receiving right-of-way the linear charge on the timing capacitor may be discharged to again charge from its starting or base value. This action may be repeated as often as there are actuations by traffic receiving right-of-way so long as there is no demand for transfer of right-of-way.

If the controller moves into a position in which the extendible interval is timed with a demand for transfer being made, operation of the maximum limit timer, the variable bias generating unit and the linear-with-time charging circuit are initiated simultaneously as soon as the wiper contacts of the several banks of line switches make contact with the position in which the extendible interval is timed. Operation of these three circuits establishes and starts to time a maximum time limit that the controller may remain in the current position; starts to time a preset time increment referred to as a passage time and starts to reduce, from a maximum to a minimum time, the time during which an actuation by traffic having right-of-way must occur, measured from the start of the interval or the last actuation by traffic having right-of-way, in order to extend the green period of the phase.

If the controller moves into an extendible interval position without a demand for transfer of right-of-way the controller will assume a rest condition until such time as a demand for transfer of right-of-way is received. If at the time such transfer demand is received the charge on the timing capacitor is at or above the value that would normally cause termination of the interval; upon such transfer demand, then termination of the interval will occur immediately after receipt of such demand for transfer.

If at the time of such transfer demand the charge on the capacitor is below the value at which termination of the interval may occur, due to repeated discharge of the capacitor by actuation of right-of-way traffic or due to the controller not having been in the position sufficiently long to have the value of the charge increased to such level, then the interval will not immediately terminate. The maximum limit timer will become operative and begin to time the maximum time limit that the controller may now remain in the current position. The variable bias generating unit will start to reduce from a maximum toward a minimum time during which an actuation from right-of-way traffic must be received in order to extend, for another time increment, the extendible interval. This time, during which such actuation by right-of-way traffic must be received, measured from the start of the interval or the last actuation, which ever last occurred, is referred to as the allowed gap time. This allowed gap time is variable and may be reduced from a maximum gap time to a minimum gap time over a preset time period.

During timing of the extendible portion of the green period when there is a demand for transfer of right-of-way each actuation of the detector on the street having right-of-way permits the green time to be tentatively lengthend by a preset time increment, referred to as a passage time. So long as the time gap between actuations of two successive vehicles of right-of-way traffic is less than the time-reduced allowable gap, the preset time increment or passage time may be reset so that the passage time will begin to be retimed. This may extend in small increments of time, the total time of the extendible interval, up to a maximum limit as timed by the maximum limit timer.

However, once the time gap between actuations of two successive vehicles of right-of-way traffic exceeds the allowable time gap, reset of the passage time is no longer permitted for the current interval and additional extension of the extendible interval terminates by operation of the extendible timer terminating unit. The remainder of the current timed passage is timed out from the termination of the timing of the allowable gap time, with the remainder of the passage time being equal to the mount of time the allowable gap has been reduced, at the time of termination of the last allowable gap time. At subsequent termination of the passage time, the green period of that phase is terminated by the normal interval terminating unit.

The passage time may be adjusted as desired to allow an increment of sufficient green time for an actuating vehicle of right-of-way traffic to enter the intersection once the vehicle has crossed the vehicle detector, but to terminate the green period thereafter if no additional actuations on the same phase occur within a foreshortened allowable gap time. If another vehicle actuates the vehicle detector of the same phase, prior to expiration of the foreshortened gap time, measure from the time of actuation of the preceding vehicle, the unexpired passage time is cancelled and another passage time increment is added. Thus, cancellation of unexpired passage time and timing of another passage time increment may continue until the gap time between two successive actuations exceeds the permitted gap time or the maximum permitted time of the extendible interval is exceeded—whichever first occurs.

If the gap time between two successive vehicle actuations exceeds the permitted gap time, or if no additional actuations occur, the extendible part of the timed interval is terminated by an extendible time terminating unit and the remainder of the passage time is timed, at the end of which the interval is terminated by a normal interval terminating unit. If successive time gaps between successive vehicle actuations do not exceed the permitted gap time and the time of the extendible part of the interval reaches the maximum permitted time of the interval, the interval will be terminated by the maximum limit timer, which automatically assures return of right of way without further traffic actuation to the phase so terminated, as soon as the other phase right-of-way timing is completed.

An object is to provide an improved traffic control apparatus in which transfer of right-of-way from one traffic lane to the other traffic lane of interfering lanes is determined by the time spacing of right-of-way vehicles reaching or exceeding a time spacing limit which is reduced progressively with time in response to the first waiting vehicle on the interfering lane.

Another object is to provide an improved apparatus in which the charging circuit of the interval timer is electrically isolated from the trigger circuit of the timer so that operation of the trigger circuit does not affect the condition of the charging circuit.

Other objects will become apparent from a reading of the specification in connection with the drawings in which:

FIG. 1 is a schematic diagram partly in block and partly in circuit form, representing one form of the present invention in which vehicle traffic at the intersection of two streets is controlled by actuation of traffic approaching the intersection;

FIG. 2 is a schematic circuit diagram of an electronic variable-bias generating circuit;

FIG. 3 is a schematic circuit diagram of the linear-with-time charging circuit;

FIG. 3*a* is a schematic circuit diagram of the extendible time terminating unit;

FIG. 3*b* is a schematic circuit diagram of the normal interval terminating unit;

FIG. 4 is a schematic circuit diagram of the maximum limit timing circuit;

FIG. 5 is a graphic representation of variation of voltages in the timing circuit with respect to time and

FIG. 6 is a graphic representation of variation of voltage between the positive terminal of the timing capacitor and ground with respect to time.

TWO PHASE STEPPING SWITCH CONTROL

Referring to FIG. 1 in more detail one form of a two-phase, full-actuated traffic control system is illustrated with the traffic controller controlling traffic signals controlling the intersection of two streets, A and B.

It should be noted that although six banks of a multi-position stepping switch or line switch are illustrated, the illustrated components may represent a cyclic switching or cyclic actuating means or a step-by-step or a rotary cyclic cam contact means or any other multi-contact cyclic means providing equivalent functions.

The several banks of the stepping switch include eight positions, each with positions 1, 2 and 3 associated with one phase of the traffic signal cycle, for example phase A and positions 5, 6 and 7 associated with the opposite phase of the traffic signal cycle, for example phase B. During phase A right-of-way is withdrawn from phase B or street B and during phase B right-of-way is withdrawn from phase A or street A. Position 4 serves a dual purpose (note bank 6, position 4), position 4 may, with switch **300** open as illustrated, be associated with phase A and provide an "all red" timed interval, or other auxiliary phase A clearance interval, after the normal yellow or clearance interval of phase A, and, with switch **300** closed, position 4 may become associated with the phase B positions, becoming either a timed interval of the green period of phase B, timed in advance of the normal initial interval or a skip position, according to adjustment of the charging circuit as described below.

Position 8 is comparable to position 4, except that position 8 is associated with switch **301** and, with switch **301** open, as illustrated may be associated with phase B and provide an "all red" timed interval or other auxiliary phase B clearance interval after the normal yellow or clearance interval of phase B, and with switch **301** closed position 8 may become associated with the phase A positions, becoming either a timed interval of the phase A position, timed in advance of the normal phase A initial interval or a skip position according to adjustment of the charging circuit. It should be noted that the interval timed in position 4 is timed through position 4 of bank 1 and the interval timed in position 8 is timed through position 8 of bank 1.

Generally, the positions of bank 1 serve to complete part of the charging circuit for the R–C timing circuits used for timing the various timed intervals of the time increments of the right-of-way period and clearance period. A positive direct current (D.C.) voltage, for example +75 volts D.C., may be employed. Between this positive D.C. potential and a substantially lower potential, as for example, ground zero, may be an impedance from which a desired potential between +75 volts D.C. to zero, may be picked off by an adjustable tap. Such picked-off potential may be used to bias a timing capacitor in an R–C timing circuit, to time an interval in a well known manner, or to lift the timing capacitor above ground value to adjust the timing of the circuit by adjusting the amount of charge necessary to be applied to the timing capacitor at a controlled, preset rate so as to obtain a predetermined voltage charge in a desired time.

It will be noted that the respective positions 1, 3, 4, 5, 7 and 8 of bank 1 individually provide individually adjustable, stable potential to block **302**, LINEAR WITH TIME CHARGING CIRCUIT, via a wiper contact and lead **30**.

The block **302** illustrated in circuit form in FIG. 3 includes a broken line box **31** which represents a means of coupling the wiper contact lead to the input to the rest of block **302**.

In positions 2 and 6 the output of block **303**, VARIABLE BIAS GENERATOR, applied via line **20** is applied to the wiper of bank 1 and through the lead **30** to the block **302**.

Bank 2 serves to illuminate indicator **L1** in positions 1 and 5, indicating the initial interval of phase A, in position 1, and phase B, in position 5, is being timed. Further, indicator **L2** is illuminated in positions 3 and 7 to indicate that the clearance interval of phase A, in position 3, and phase B, in position 7, is being timed.

Positions 2 and 6 of bank 2 are included in individual parallel control circuits for the relay **304**. Since the present controller is a full actuated controller, the controller must be "called" away from one phase to the other phase via actuation on the phase not then receiving right-of-way. This is a technique that is well known in the art of traffic control and is employed in many full actuated controllers. It will be noted for example, that one control circuit for relay **304** includes position 2 of bank 2, which is a phase A position, and a normally closed contact **305***b*, of relay **305**, the phase B detector relay. The other parallel control circuit for relay **304** includes position 6, which is a phase B position, and a normally closed contact **306***b* of relay **306**, the phase A detector relay.

Relay **304** may only be energized with the wiper contacts in position 2 or 6 and is employed to indicate the presence of a call for the phase not then being accorded right-of-way.

With the wipers of the line switches in contact with position 2, energization of the phase B detector relay **305**, indicating a call for transfer of right-of-way to phase B, will open contact **305***b* and deenergize relay **304**. Similarly the wipers of the line switches in contact with position 6 energization of the phase A detector relay **306**, indicating a call for transfer of right-of-way to phase A, will open contact **306***b* and deenergize relay **304**. In all positions other than 2 and 6 there is always an incomplete circuit so that relay **304** is deenergized in such other positions.

In all positions of bank 3, with switches **307** and **308** closed, as illustrated, a ground connection is supplied via normally closed contact **304***a* of relay **304**, via lead **40** to the block **309**, MAXIMUM LIMIT TIMER, and via lead **39** to the block **302***b* NORMAL INTERVAL TERMIN. (terminating) UNIT. The use of such ground connection will be more fully described in reference to the more complete description of FIG. 3*b* and FIG. 4.

The switches **307** and **308** are known in the art as "coordination" or "yield" control switches. When the present controller is used in a coordinated system of traffic signal controllers the switches **307** and/or **308** may be adjusted to the "up" position and the terminal **310** and/or terminal **311** may be connected to a master or other controller which may supply a ground connection only at a particular time and the present controller would be permitted to leave position 2 and/or 6 respectively only at the particular time in a background cycle, for example. This is a feature that is well known in the art of traffic control and can be used to coordinate individual local controllers with a master controller in a master controlled traffic control system.

Bank 5 is associated, in positions 1 and 5 with the recall switches **312** and **313** respectively.

Position 2 and position 6 of bank 5 provide a ground connection via normally closed contact **314***a* of motor magnet **314** through lead **37** to the block **302***a* EXTENDIBLE TIME TERMIN. (terminating) UNIT.

Positions 3 and 7 supply a ground connection via the wiper contact to relay **304**, which is one of the signal control relays. As described more fully below, the contacts of relay **304** cooperate with other contacts of other signal control relays to provide the yellow or clearance signal of phase A or phase B and the green or go signal of phase A or phase B.

The positions 4 and 8 are unconnected in the bank 5.

Bank 6 in positions 1, 2 and 3 provide a ground con-

nection via the wiper contact to energize the relay **315** and positions 5, 6 and 7 provide a ground connection via the wiper contact to energize the relay **316**, the relays **315** and **316** cooperating with the relay **317**, all of which are the signal control relays. Position 4 is associated with the switch **300** and position 8 is associated with the switch **301**.

MOTOR MAGNET OPERATION

The motor magnet **314** is representative of one means of sequentially stepping the wiper contacts of the line switch banks from one position to the next succeeding position, all wipers being moved in unison. The motor magnet is normally denergized and may be energized manually by closure of push-button **318**, which may be remotely located. Energization of the relay **319**, found in FIG. 3*b*, will close the parallel circuit via contact **319***a* and also energize the motor magnet **314**, while energization of relay **320**, found in FIG. 4, will also close a third parallel energizing circuit via contacts **320***a* to energize the motor magnet **314**.

Along with the sequential stepping of the wipers of the line switch the motor magnet **314** also opens contact **314***a*, associated with positions 2 and 6 of bank 5 and, closes contact **314***b*, found in FIG. 3 and **314***c* found in FIG. 4, each time the motor magnet is energized, the respective contacts returning to their normal positions upon deenergization of the motor magnet **314**.

An indicating circuit coupled with relays **315** and **316** may be employed for indicating when the "all red" or other auxiliary interval, such as provided for in positions 4 and 8 with switches **300** and/or **301** open, are being timed.

INTERSECTION TRAFFIC SIGNAL CONTROL

In the lower left part of FIG. 1 the signal control circuits, an intersection of two roadways including St. A and St. B, with vehicle detectors A and A′ in St. A and vehicle detectors B and B′ in St. B, and associated traffic signal lamps are represented. Along Street A, are three circles numbered **321A**, **322A** and **323A** representing red, yellow and green lamps respectively. It should be understood that one side of each represented lamp is to be assumed connected to ground to complete the signal control circuit; such ground connection has been omitted for convenience. Along the Street B, are three circles numbered **321B**, **322B** and **323B** for red, yellow and green lamps respectively. It should also be understood that one side of each lamp is to be assumed connected to a ground connection to complete the control circuit.

With the relay **315** energized and relays **316** and **317** deenergized, such as in positions 1 and 2, the moving part of contact **315***b* is pulled up so that a signal circuit is completed through the normally closed contact **317***b* to illuminate the lamp **323A** on Street A. Another signal circuit is completed through the normally closed contact **316***b* to illuminate the lamp **321B** on Street B. Also indicator **L4** is illuminated through the pulled-up contact **315***b* to indicate the phase A part of the cycle is being shown.

In position 3, the relay **315** is maintained energized via bank 6, and the relay **317** is energized via bank 5. This relay combination maintains illumination of the lamp **321B** on Street B. The lamp **323A** on Street A is extinguished and the lamp **322A** on Street A is illuminated via the operated contacts **315***b* and **317***b*.

In position 4 with switch **300** open, as illustrated, the signal control relays **315**, **316** and **317** are all deenergized and both lamps **321A** and **321B** on each street are illuminated.

With switch **300** closed positions 4, 5 and 6 complete circuits to energize relay **316** while both relays **317** and **315** are deenergized. The moving arm of contact **316***b* is pulled up and the lamp **323B** on Street B is illuminated the lamp **321A** on Street A is illuminated through the normally closed contact **315***b*. Indicator lamp **L5** is also illuminated and indicates that the phase B part of the cycle is being shown.

In position 7 relay **316** is maintained energized, via bank 6, and relay **317** is energized via the position 7 of bank 5. The relay **317** pulls up the moving arm of its contacts **317***a* and the lamp **323 B** on Street B is extinguished and the lamp **322 B** on Street B is illuminated. The lamp **321A** on Street A is maintained illuminated.

In position 8 with switch **301** open, as illustrated, all signal control relays are deenergized and both lamps **321A** and **322B** on both streets are illuminated. With switch **301** closed, position 8 becomes part of the green period of phase A and is associated with positions 1 and 2 for providing illumination of the lamp **323A** on Street A and the lamp **321B** on Street B.

It should be understood that the illustrated signal control circuits are presented in simplified form and interlocking to prevent illumination of two green signals simultaneously has been omitted for convenience.

On Street A two vehicle detectors A and A′ are represented as rectangles and are joined electrically at junction **50**. It should be understood that the vehicle detectors employed in the present traffic control system may be of any of the well known type detectors sensitive to pressure, magnetism, microwave energy, heat or light, adapted to close a set of normally open contacts upon passage of a vehicle.

On Street B there are represented two vehicle detectors B and B′ which two vehicle detectors are electrically joined at junction **60**.

Above recall switch **312** is a junction **50**, which also represents junction **50**, the junction of detectors A and A′. The set of open contacts surrounded by a broken line box labeled A/A′ represents both vehicle detectors A and A′.

Above recall switch **313** is a junction **60**, which also represents junction **60**, the junction of detectors B and B′. The set of open contacts surrounded by a broken line box labeled B/B′ represents both vehicle detectors B and B′.

Upon closure of the contacts of the detector A and/or A′, a circuit is completed to energize detector relay **306**. With relay **306** energized the relay will pull up the moving arm at contact **306***a* and complete a holding circuit including lead **57** and normally closed contact **324***a* of relay **324** to ground. The relay **324** may be seen in FIG. 3*a*. A parallel holding circuit for the relay **306** may include normally closed contact **315***c* to ground. Energized relay **306** will drop out when contact **324***a* is opened by energization of relay **324** and when relay **315** becomes energized and lifts the moving arm of its contact **315***c* thus opening both described parallel holding circuits.

As will be described below with reference to FIG. 3*a*, relay **324** may be energized only in positions 2 and/or 6 so that if the relay **306** becomes energized the relay may hold in through contacts of relay **324** if the lineswitch is not in position 2; and when the lineswitch wipers do move into position 2 the relay **324** becomes energized and the relay **306** will drop out. In position 2 the relay **306** may be momentarily energized via closure of the detector contacts of the detectors A or A′, but the holding circuits are open and energization of the detector relay **306** would last only so long as the vehicle detector contacts are closed.

Upon closure of the contacts of the detector B/B′ on Street B a circuit is completed to energize detector relay **305**. With detector relay **305** energized the relay will pull up the moving arm at contact **305***a* and complete a holding circuit including the lead **67** and normally closed contact **324***b* of relay **324** to ground or through a parallel circuit, when the moving arm of contact **315***c* has been pulled up so as to provide a connection to

ground. Energized relay **305** will drop out when contact **324***b* is opened by energization of relay **324** and when relay **315** becomes deenergized and drops the moving arm of its contact **315***c* and thus both parallel holding circuits are open.

The relay **324** becomes energized in the positions 2 and 6 so that if the relay **305** becomes energized, the relay may hold in through the normally closed contacts of relay **324** if the lineswitch is not in position 6; and when the lineswitch wipers do move into position 6 the holding circuit through the contact of relay **324** will open and the relay **305** will drop out. In position 6 the relay **305** may be momentarily energized via closure of the detector contacts B or B' but the holding circuit will not be completed and the energization of the detector relay **305** will last only so long as the vehicle detector contacts are closed.

Each detector relay, **306** and **305** has an associated indicator lamp **L10** and **L11** respectively, which lamp, when illuminated, indicates energization of its associated detector relay. Energization of a detector relay may result from actuation of the associated vehicle detector, closure of the associated recall switch or termination of the last associated phase by the maximum limit timer thereby closing contact **320***c*.

Since the present controller includes two separate relay means to operate the motor magnet **314** it may be desired to know which relay means **319** of FIG. 3*b*, or **320** of FIG. 4, has operated the motor magnet **314**. Thus indicator lamps **L6** and **L7** are provided to be illuminated upon closure of contact **319***b* and **320***b* respectively.

Indicator lamp **L8** and **L9** are associated with positions 2 and 6 respectively of bank 5, in which positions the extendible intervals of phase A and phase B respectively, are timed. As previously described each extendible interval is potentially extendible tentatively for another full passage time period when the gap time between two vehicle actuations is less than the allowed gap time. One total passage time includes a permitted gap time period plus the timed period of the remainder of the passage time, with the remainder of the passage time timed after expiration of one completed allowable gap time period. Actuations on the phase receiving right-of-way, occurring during timing of the allowed gap time may cancel the unexpired passage time and may begin the retiming of another passage time. If an allowed gap time is completely timed, without reset of the passage time, then the remainder of the passage time is timed to complete the passage time. During timing of the remainder of the passage time, unexpired passage time may not be cancelled by actuations occurring during such time but actuation during the timing of the remainder of the passage time shall be remembered and cause the controller to return right-of-way to that phase after completion of accord of right-of-way to the next place.

A transfer contact, 325*c* selects between indicators **L9** and **L8** so that illumination of indicator lamp **L9** indicates that an allowable gap time in position 2 or 6 is being timed while illumination of lamp **L8** indicates that the remainder of the passage time is being timed in position 2 or 6.

It may be desired to temporarily suspend or stop the timing of the controller either locally or remotely. Thus a relay and its control circuit may be provided, may be operated by closure of a switch manually operated or automatically operated either local or remotely located. When energized, the relay closes contacts **326***b*, **326***c* and **326***d* located in FIG. 2, FIG. 3 and FIG. 4 respectively, to stop the timing of the timing circuits illustrated in the respective figures, the operation of which will be described below.

PHASE RECALL

It will be noted that each recall switch **312** and **313** includes four positions of a double pole switch **P1–P2**. The description of switch **312** may serve for a description of switch **313** except that switch **312** is associated with phase A components and circuitry and switch **313** is associated with the corresponding phase B components and circuitry.

With the poles **P1** and **P2** of switch **312** in position 1, the output of block **302** through resistor **33** is grounded via lead **34**, pole **P2** of switch **312**, position 1 of switch **312**, lead **51** to position 1 of bank 5 so that with the wipers in position 1, and the poles **P1–P2** in position 1, the normal interval timer of FIGS. 3 and 3*b*, is replaced with the timing performed by the timer of FIG. 4, the maximum limit timer during the timing of the initial interval only.

Further a circuit is completed upon closure of either normally closed contact **324***a* or the normally closed position of contact **315***c* from ground through either of the closed contacts via lead **57**, lead **56**, position 1 or 2 of switch **312**, pole **P1**, lead **54** and **58** the coil of relay **306** to positive power. This circuit, available in positions 1 and 2 of the switch **312**, provides an automatic "recall" of the phase A. The recall of phase A will occur when the wiper contacts of the lineswitch banks are in position 3. Upon energization the relay **306** will lock in through its holding circuit previously described.

The circuit associated with the switch **313**, for recall of the phase B, is completed when the wiper contacts of the lineswitch banks are in position 7, with the ground connection being completed via contact **324***b*, lead **67**, lead **66**, position 1 or 2 of switch **313**, pole **P1** of switch **313**, lead **64** and **68**, the coil of relay **305** to positive power. This circuit, available in positions 1 and 2 of the switch **313** provides an automatic "recall" of the phase B. When the phase B clearance interval is being timed in position 7 relay **305** will be energized and will then lock in through its holding circuit previously described. It should be noted that either switch **312** or switch **313** may be adjusted independent of each other and with both switches **312** and **313** in position 1 or 2, (the switches are illustrated in position 1), each phase, A and B, will be provided with an automatic recall in the clearance period of the respective phase.

Thus with the switches **312** and **313** adjusted to recall the phases A and B respectively, operation of the controller may include automatic recall of both phases with vehicle extension of both phases individually responsive to actuation of vehicles in that particular phase during the normally extendible interval.

With only one of the recall switches positioned for "recall," right-of-way will be returned to its associated phase even in absence of vehicle actuation on that phase. The extendible interval of the "recalled" phase may still respond to actuation of its detector during timing of the extendible interval to extend the extendible interval to its maximum limit.

The position 2 of the respective switches differs from position 1 in that the circuit through the pole **P2** is open so that the output of FIG. 3 through resistance **33** and line **34** is no longer grounded and the normal interval timer, the combined FIG. 3 and FIG. 3*a* may be used to time the initial intervals as described below.

With the switch **312** in position 3, automatic recall of the phase by the recall switch is not provided for.

Position 4 of the switch **312** pole **P1** is connected directly to ground and may be provided as a spring loaded position, for test purposes, so that the poles **P1** and **P2** would only stay on position 4 so long as they are held manually in the position. In position 4, the assumed spring loaded position, an automatic call would be put in via pole **P1** lead **54**, the coil of relay **306** to a positive power supply, regardless of the position in which the wipers of the several banks would be located at that time.

VARIABLE BIAS GENERATING UNIT

Referring more particularly to FIG. 2, which may illustrate one form of circuitry represented by the box **303** in FIG. 1, the preferred form of electronic variable bias generating unit is illustrated as one means of providing a direct current voltage output (via lead **20**), the amplitude of which increases progressively with time. The capacitor **71** is progressively charged, at a controlled rate and the charge on the capacitor is applied, via lead **20**, as an output of the variable bias generating unit to position 2 and position 6 of bank 1 in FIG. 1.

Coordination among the wiper contact, and several relay contacts provides for holding the variable bias generating unit in a quiescent state when the wiper contacts are in contact with positions other than 2 or 6 of the several banks of line switches.

The extendible vehicle interval of the phase A green period is timed in position 2 and the extendible vehicle interval of the phase B green period is timed in position 6. With the wiper contacts in position 2 and in position 6 the variable bias generating unit may be released from its quiescent state and begin to generate a D.C. potential across the output capacitor with the output applied via lead **20** through either position 2 or position 6 of bank 1, depending upon the position in which the wiper contact is located, the wiper contact, lead **30**, the coupling unit, represented by box **31**, lead **32** to the lower part of timing capacitor **121** in FIG. 3. As will be more fully described with reference to FIG. 3, circuit **302** is an illustration of the preferred form of linear-with-time R–C charging circuit, the capacitor **121** serving as the timing capacitor.

Returning to the FIG. 2, the variable bias generating unit is provided with dual adjustments and selection between each set of adjustments is made by operation or non-operation of a relay contact. In the present form contacts of the relay **315**, shown in FIG. 1, are employed to select between the sets of adjustments.

When the wiper contacts are in position 2 of the line switch banks, the controller is in phase A of the signal cycle and the relay **315**, in FIG. 1, is energized. When the wiper contacts are in position 6 of the line switch banks, the controller is in phase B of the signal cycle and the relay **315** is deenergized. Thus "transfer" contacts of the relay **315** are employed as one way in which to select between phase A, position 2, and phase B, position 6.

The relay contact **315***d* selects between tap **73** and tap **74** each associated with the potential divider network **72**. With relay **315** energized as with the wiper contacts in position 2, tap **73** is selected by closure of the upper contacts, of contact **315***d*, for phase A and with relay **315** deenergized, as with the wiper contacts in position 6, tap **74** is selected by closure of the lower contacts of contact **315***d*, for phase B.

Likewise contact **315***e* selects tap **75** by closure of its upper contacts in position 2 for phase A and selects tap **76** by closure of its lower contacts in position 6 for phase B. Both taps **75** and **76** are associated with the potential divider network **77**. Further, contact **315***f* selects potentiometer **78** by closure of its upper contacts and selects potentiometer **79** by closure of its lower contacts.

Thus adjustments at **73**, **75** and **78** may be made, each associated with the same phase, phase A for example, and adjustments **74**, **76** and **79** may be made, each associated with the alternate phase, phase B, for example.

The means used to select between phase A adjustments and phase B adjustment is one method that may be employed. Other methods as for example, employing additional line switch banks, when necessary, and use the positions 2 and 6 of the additional line switch banks to serve for selecting between phase A and phase B adjustments may be used in lieu of using relay AG contacts for such selections.

As previously mentioned the circuitry in FIG. 2 is held in a quiescent state in certain parts of each phase (positions 1, 3, 4, 5, 7 and 8 of the line switches) and may be held in a quiescent state in position 2 and position 6. As will be more fully described with reference to FIG. 3*a*, the relay **324** is held deenergized in positions 1, 3, 4, 5, 7 and 8, and may be held deenergized in position 2 and position 6. Thus, normally closed contact **324***c* of relay **324** is employed as one method of holding the circuit of FIG. 2 in a quiescent state. When closed, the contact **324***c* shunts across the capacitor **71** through low resistance **80**. This circuit is also employed to discharge capacitor **71** at termination of the extendible part of the vehicle interval, as more fully described with reference to FIG. 3*a*.

The normally open contact **304***b* of relay **304**, shown in FIG. 1, is employed to cooperate with the contact **324***c*, and also act as a safety circuit, to hold the variable bias generating unit in a quiescent state in position 2 and position 6 unless a "call" for the phase not then receiving right-of-way has been or is received, and if and when such "call" is received, relay **304** will become deenergized as previously described and release contact **304***b* to its normally open condition and open the shunting circuit of the capacitor **71**.

Normally open contact **326***b* serves as another contact for shunting capacitor **71**, and either establishing or maintaining a quiescent state for the circuit in FIG. 2 when desired.

Operation of the circuit of FIG. 2 is the same for the phase A components as for the phase B components except for the difference in adjustment of the respective components.

Typical operation of the circuit of FIG. 2 will now be described with the relay AG deenergized so that its normally closed contact are assumed closed as illustrated, and with contacts **326***b*, **324***c* and **304***b* open.

The tube **85**, which may be one half of a commercially designated 12AU7, for example, is normally conducting, the amount of current passed being controlled by the grid to cathode bias which is relative to the potential applied to the grid **86** from junction **83**.

A voltage divider network, represented by **72**, with resistor elements between one D.C. potential, for example +75 volts, represented by a plus in a square, and a lower D.C. potential, for example +21 volts, represented by a plus in a diamond may be employed, with variable taps **73** for phase A and **74** for phase B, used to tap off potentials which may be applied to the junction **83**, through the closed contacts of contact **315***d* during phase A and phase B respectively.

The voltage value at tap **73** for phase A, and at **74**, for phase B may be measured between junction **83** to ground across resistor **89** and may be adjusted so that the tube **85** may be made to conduct at least at a desired rate or more.

The tube **85** is a cathode follower which establishes the voltage at the cathode of tube **90** at a point established by tap **74** on network **72**.

It should be noted that tube **85** is not essential to the operation of this circuit. If tube **85** is omitted, sufficient current must flow through network **72** so that variations in current of tube **90** do not cause any substantial change in the voltage at tap **74**. The cathode of tube **90** would be connected directly to contact **315***d* under these conditions.

The cathode **91** of tube **90** which may be one half of a commercially designated 12AX7, for example is connected to junction **87** so that the cathode **88** of tube **85** and **91** of tube **90** are at the same voltage level.

The plate **84** of tube **85** is connected directly to the +250 volt D.C. source while the plate **93** of tube **90** is connected to the +250 volt D.C. source through a resistor **95**. Thus the plate potential at **84** is higher than the plate potential at **93** under corresponding conditions.

The current path through the tube **90** follows from the supply, represented by a plus in a circle, resistor **95**, junc-

tion 94, plate 93, through tube 90 to cathode 91, junction 87 and through a cathode resistor to ground. The voltage drop across resistor 95 increases as the current flow through tube 90 increases. A parallel voltage divider circuit also includes the same current supply, resistor 95, junction 94, constant voltage drop lamp 96, junction 105, resistors 97, 98 and 99, diode 101, the closed contacts of contact 315*e*, tap 76 of voltage divider network 77 to ground. It will be noted that grid 92 of tube 90 is connected to the voltage divider circuit between resistor 98 and 99 thus any change in voltage drop across resistor 95 will result in a change in potential on the grid 92. Also adjustment of the tap 75, for phase A and 76, for phase B will change the potential at the grid 92.

A change in the grid 92 potential may change the bias of tube 90 and may effect the amount of conduction through tube 90.

Thus the amount of conduction through tube 90 is a result of the balancing of the effect of the voltage drop across resistor 95, the setting of tap 75 for phase A and 76 for phase B, each of which effect the potential on grid 92 which effects the bias of tube 90 which controls the amount of conduction through tube 90.

The voltage divider circuit and its effect on tube 90 when tap 75 or 76 is readjusted becomes important since adjustment of tap 75, for phase A and 76 for phase B sets the passage time of the extendible interval. The passage time is set by adjusting the base or lowest voltage level of the curve seen in FIGS. 5 and 6 referred to as the BIAS curve. The position of taps 75, for phase A and 76, for phase B also determine the voltage value above ground at which the capacitor 71 will be held.

As the voltage in the voltage divider circuit changes the voltage value at junction 105 will also change. The charging circuit for capacitor 71 includes the source of supply, resistor 95, junction 94, constant voltage drop lamp 96, junction 105, diode 106, resistor 107 the closed contacts of contact 315*f*, potentiometer 78 for phase A and potentiometer 79, for phase B, junction 109 capacitor 71, lead 110, the closed contacts of contact 315*e*, tap 75, for phase A and tap 76 for phase B part of the resistor of network 77 to ground.

The potentiometers 78 and 79 are rate adjustments, which control the rate at which the capacitor 71 will be charged so that the adjustment of potentiometers 78 for phase A and 79 for phase B determine the slope of the curve BIAS in FIGS. 5 and 6 and thus determine the rate of reduction of gap time or the amount of time it will take to reduce the gap time from maximum gap to minimum gap.

Thus since the passage time adjustment, taps 75 and 76, sets the lowest voltage value on capacitor 71 as shown by the BIAS curve in FIGS. 5 and 6 and the time to reduce from maximum gap time to minimum gap times sets the rate of change of the available voltage, adjustment of the taps 75 for phase A and 76 for phase B may change the the voltage value at junction 105. Change in the voltage value at junction 105 changes the applied voltage through the potentiometers 78 and 79 so that the time to reduce from maximum gap time will remain the same and need not be recalibrated or adjusted in the vent of a change in the gap time differential.

The amount of passage time is proportional to the differential between the minimum or base voltage level of capacitor 71 (indicated, for example, as plus 80 volts in FIGS. 5 and 6) and the predetermined flash or trigger voltage of the timing circuit (indicated, for example as +160 volts in FIGS. 5 and 6).

The potentiometers 78 and 79 are used to adjust to the desired time to reduce from the maximum allowed gap time to the minimum allowed gap time. The maximum allowed gap time depends upon the minimum or base voltage level of capacitor 71 (and thus the setting of taps 75 and 76 for phase A and phase B respectively), and the preset flash or trigger voltage of the timing circuit. The minimum allowed gap time depends upon the setting of taps 73 and 74 on network 72 for phase A and phase B respectively, and the same preset flash or trigger voltage level.

The time to reduce from maximum allowed gap time to minimum allowed gap time is independent of the differential between the maximum and minimum allowed gap time. Since the accumulation of charge applied to a capacitor, such as 71, is a function of the setting of potentiometer 78 or 79 (the rate control component) and the magnitude of the voltage applied to the rate control components, and it is desired to have the capacitor 71 charge from a low value to a high value in a given time regardless of the difference between these values, the voltage applied to the rate control potentiometers must be varied through a range of values, being raised as the differential between these two settings increases.

Each time a passage time is readjusted by adjustment of tap 75 or 76 for phase A or phase B, the maximum allowed gap time for that phase is changed and the differential between the maximum allowed gap time and the minimum allowed gap time for that phase is changed. The differential between maximum and minimum gap times may also be changed by changing the minimum allowed gap time as by adjustment of tap 73 and 74 for phase A and phase B respectively.

In order to maintain the time to reduce from maximum allowed gap time to minimum allowed gap time as preset by the potentiometers 78 and 79, without readjustment of the potentiometers each time the differential between gap times is changed, the voltage values across the several parts of the voltage divider circuit, including resistors 95, 97, 98, 99 and tap 75 or 76 and lamp 96, and particularly at junction 105, bettween lamp 96 and resistor 97 are changed, so that the amount of charge applied to the capacitor 71 through the rate controlling potentiometers will be readjusted, according to the change in voltage value so that the differential between the maximum and minimum allowed gap time will be traversed over the same period of time.

When the passage time is increased (thereby increasing the maximum gap time) and the minimum gap time remains the same, the voltage at junction 105 is increased accordingly so that the then increased differential between maximum and minimum gap times may be traversed over the same period of time. When the passage time is decreased (thereby decreasing the maximum gap time) and the minimum gap time remains the same, the voltage at the junction 105 is decreased so that the then decreased differential between the maximum and minimum gap time may be traversed over the same period of time.

The change in voltage at junction 105, in the voltage divider circuit, results from a change in resistance in the voltage divider circuit by adjustment of the taps 75 for phase A and 76 for phase B, so that when the passage time is readjusted, the value of the voltage at junction 105 is automatically readjusted so that the magnitude of voltage applied through the rate controlling potentiometers is changed and the amount of voltage charge accumulated on the capacitor 71 over the same period of time is changed so that the new differential is traversed over the same period of time as preset.

As is well known to those skilled in the art, the voltage across a capacitor being charged through a resistor increases rapidly at first, and then slower and slower as the capacitor voltage approaches the supply voltage. Since the change in voltage becomes very slow after a period of time equalling about 3 times the product of the capacity and the charging resistance (a product commonly called the "time constant") and it is desirable when handling traffic, to cause the allowable gap to be reduced in a much more linear manner, it is necessary to apply a voltage to the rate control component which is some multiple of the difference between the maximum and minimum desired values. The degree of multiplication de-

termines the amount of change-in-rate obtained. The higher this multiplication, the smaller part of a time constant the capacitor will require to reach the desired charge level (voltage) and the more uniform will be the rate of change, hence the more linearly will the gap be reduced. This multiplication is performed by the tube **90** and related components resistors **95**, **97**, **98** and **99** and lamp **96**.

Since the constant voltage drop lamp **96** which may be a neon lamp, for example, requires more voltage to illuminate the lamp than to maintain the lamp illuminated, an illumination sustaining circuit, including a source of power, resistor **95**, junction **94**, lamp **96** and high resistance **102** to ground, keeps the lamp **96** illuminated in the event that the voltage across the divider circuit is insufficient to sustain illumination of the lamp **96**.

Therefore, when released from a quiescent state, the capacitor **71** begins to charge from a preset base voltage level, as determined by the setting of tap **75** or **76**, at a rate controlled by potentiometer **78** or **79** with the potential across the capacitor **71** as measured from junction **109** to ground applied, via line **20** to bank 1 positions 2 in phase A, and 6 in phase B, the wiper contact, lead **30** to the box **302**, shown in circuit form in FIG. 3, and applied to the timing capacitor **121** in FIG. 3 to bias the capacitor **121** with a voltage above ground.

CHARGING CIRCUIT

Referring now to FIG. 3, the linear-with-time charging circuit is illustrated in circuit form and may illustrate the circuitry found in the box **302** in FIG. 1.

Generally, the linear-with-time charging circuit includes a timing capacitor **121** and timing resistors **122** and **123**, of which resistor **123** may be adjusted to adjust the rate of charge, two interconnected triodes **124** and **125**, constant voltage drop lamp **126–127** and a network of contacts for shunting across timing capacitor **121**.

With the shunting circuits of the contact networks closed the capacitor **121** is charged with the potential at junction **130**, in the cathode circuit of tube **124**, through variable resistance **123**, resistor **122**, switch **S–1**, to capacitor **121**. The charging circuit may also include the lead **32** and resistor **116** to a ground connection. The function of switch **S–1** and the shunted circuitry will be later described. The switch **S–1** is here assumed closed, as illustrated.

The cathode follower **115** may be the electrical coupling between the variable bias generating unit of FIG. 2 and the linear-with-time charging unit in FIG. 3 with the grid **117** controlled by the output of FIG. 2 and the bias charge applied to timing capacitor **121** from the cathode of tube **115** via lead **32**.

As the charge from the cathode circuit of tube **124** is applied through the timing resistance **122/123** to capacitor **121** the accumulating charge on the capacitor is applied to the control grid **133** of tube **125** and conduction through tube **125** increases. As conduction through tube **125** increases the cathode potential at junction **134** increases. The potential at junction **134** is applied through resistor **33** to contact **324***d* and, depending upon the position of the moving arm of contact **324***d* via lead **36** to the normal interval timer, represented by box **302***b* in FIG. 1, and illustrated in circuit form in FIG. 3*b* or via lead **35** to the extendible time terminating unit, represented by box **302***a* in FIG. 1 and illustrated in circuit form in FIG. 3*a*.

The voltage at junction **135** which is at a fixed value above the voltage at junction **134** by an amount equal to the voltage drop across the constant voltage drop lamps **126/127** is applied to the grid of tube **124**, which tube is a cathode follower. As the voltage applied to the grid of tube **124** increases, conduction through the tube **124** increases resulting in increased voltage at junction **130**.

The voltage at junction **130** is an amount above the voltage at junction **134** and the voltage at junction **134** is essentially the same as the voltage on capacitor **121** as measured between junction **120** and ground.

The voltage charge on timing capacitor **121** is applied from junction **130** through the timing resistors **122** and **123** and as the voltage at junction **130** increases the rate of charge on capacitor **121** increases thus increasing the conduction of tube **125** and the voltage at junction **134**. As the voltage at junction **134** increases the voltage at junction **135** increases to cause tube **124** to conduct more heavily thus increasing the voltage at junction **130**. Thus the voltage value at junction **130** is progressively increased so that the capacitor **121** is charged substantially linearly with time.

With the relay contact, **324***d* in its normally closed condition, as illustrated in the interconnections between FIG. 3 and FIGS. 3*a* and 3*b*, the voltage at junction **134** may be applied through lead **36** to junction **141**, the potential at junction **141** is applied to the grid **146** of triode **145**. Resistor **142** and capacitor **143** connected in parallel between junction **141** and ground serve as an electrical filter.

The timer illustrated in FIG. 3*b* may be in the form of the electronic timing circuit taught by Peter C. Brockett in his U.S. Patent No. 2,964,625, issued December 13, 1960. Thus the triode **145** is normally non-conducting and the triode **150** is normally conducting. The voltage at cathode **151** of tube **150** resulting from conduction of tube **150** is impressed on the cathode **147** of tube **145** by virtue of the connection at junction **153**. The potential applied to grid **152** of tube **150** is picked-off at point **157** of a potential divider including the coil of relay **319**, resistor **155** and resistor **156**. Junction **158** may be at ground potential, when lead **39**, which is connected via contact **304***a* to the wiper contact of bank 3 (FIG. 1), is grounded or may be at a higher potential when the ground connection is broken (contact **304***a* open).

When the connection to ground via lead **39** is broken, the resistor **159** is included in the potential divider along with resistors **155** and **156** so that the potential at point **157** is sufficiently high to maintain tube **150** conducting very heavily. When lead **39** is connected to ground, the resistor **159** is by-passed and no longer forms a part of the potential divider. Thus the potential divider at junction **157** and on grid **152** would be reduced but still hold tube **150** normally conducting.

With the reduced potential at junction **157**, the potential at junction **134** in FIG. 3, may be increased thus increasing the potential at junction **141**, FIG. 3*b*, and therefore increase the potential applied to grid **146** of tube **145**.

When the potential on grid of tube **145** becomes sufficiently high to overcome the potential on cathode **147**, tube **145** begins to draw plate current and increase the voltage drop across the coil of relay **319**. With increased voltage drop across coil **319** the potential at junction **157** is reduced resulting in tube **150** becoming non-conducting and forcing tube **145** to conduct heavily and operate the relay **319**.

The timed intervals of positions 1, 3, 4, 5, 7 and 8 are timed by cooperation of the linear-with-time charging circuit of FIG. 3 and the normal interval timer of FIG. 3*b* with the lead **39** of FIG. 3*b* connected to ground thus excluding the resistor **159** from the voltage divider circuit of the interval timer and with the variable bias generating unit disconnected from the electrical coupling box **31** and replaced by a selected fixed bias, as more fully described below.

With the wiper contacts of the several banks of line-switches in position 2 or position 6, the relay **324**, in FIG. 3*a* may be energized so long as relay **325** in FIG. 3*a* remains deenergized.

Relay **325** is normally deenergized and in such condition its contact **325***a* is normally open, and **325***b* is normally closed. Contact **325***c*, associated with indicator lamps **L8** and **L9**, in FIG. 1 is also in its normally closed condition so that indicator lamp **L9** is illuminated. With

contact 325*b* closed, relay 324 is energized and contacts 324*a* and 324*b*, in the holding circuit of detector relays 306 and 305 respectively, in FIG. 1, are open. Contact 324*c*, in FIG. 2, is open and thus holds open one of the parallel shunting circuits for capacitor 71. Contact 324*d*, in the connecting circuitry network between FIG. 3 and FIGS. 3*a* and 3*b* is in its pulled-up condition and connects the output from the linear-with-time charging circuit with lead 35, into the extendible time terminating unit of FIG. 3*a*. Contact 324*e* is closed to prepare a discharge circuit, including the upper contacts of 315*g* and contact 306*e* in phase A and the lower contacts of 315*g* and contact 305*e* in phase A, for "wash down" of the charge on the timing capacitor 121 in FIG. 3. The described discharge circuit is used to cancel the unexpired passage time and affect re-timing of the passage time in the extendible part of the vehicle interval timed in position 2 for phase A and 6 for phase B.

EXTENSION TIME TERMINATING UNIT

The extension time terminating unit illustrated in FIG. 3*a* includes a ground control circuit for grounding the output of the linear-with-time charging circuit when relay 304 is energized so as to operate contact 304*c* to its closed position and the relay 324 is energized so as to operate contact 324*d* to connect lead 35 with the output of the charging circuit. A filter including a resistor and capacitor in parallel is connected between the input into FIG. 3*a* and ground. A triode 170 with a relay 325 connected between the power supply and the anode 171 of tube 170 is also included in FIG. 3*a*.

The input into FIG. 3*a* is connected to the grid 172 of tube 170 so that when an output is applied from FIG. 3 to the input of FIG. 3*a* and contact 304*c* is open, the input is applied to the grid 172.

The cathode 173 is illustrated as connected to a potential somewhat above ground, represented by a plus in a circle in a square, so that when there is sufficient charge applied to grid 172, sufficient plate current will flow to energize relay 325. Relay 325 will close its contact 325*a* and complete a holding circuit for the relay 325 which may be completed via lead 38, position 2 or 6 of bank 4, the wiper contact in position 2 or 6 to ground. Contact 325*b* will be operated to open the energizing circuit for the relay 324 and contact 325*c* (FIG. 1) will be operated to extinguish indicator lamp L9 and illuminate indicator lamp L8.

MAXIMUM LIMIT TIMING CIRCUIT

Referring now to FIG. 4, a schematic circuit diagram of an electronic timer, which may illustrate the maximum timer represented by box 309 in FIG. 1 is shown with the lead 40, which is shown connected to contact 304*a* in FIG. 1.

As described in reference to FIG. 3*b*, the lead 40, which may be the same as or a parallel lead to, lead 39 is connected to contact 304*a* and is connected to ground so as to effectively ground junction 181 when the wiper contacts are in positions 1, 3, 4, 5, 7 and 8 and thus exclude resistor 182 from a potential divider circuit including the coil of relay 320, resistors 183 and 184 between a positive potential and ground. When ground is applied to junction 181 the potential at junction 185, between resistors 183 and 184 is lowered so as to hold the tube 190 conducting and hold tube 195 non-conducting but permit the tube 195 to become conducting when the potential applied to grid 196 is sufficiently high.

In positions 2 and 6 the relay 304 may be energized and open its contact 304*a*, this opens the circuit so that junction 181 is no longer at ground potential and adds the resistance of resistor 182 to the potential divider. The addition of this resistance, which may be of the order to 1.5 megohms, for example, lifts the potential at junction 185 and thus the potential on grid 191 so as to maintain tube 190 conductive and maintain tube 195 non-conductive regardless of the potential applied to the grid 196, within circuit limits.

The tubes 195 and 190 in FIG. 4 are comparable to tubes 145 and 150 respectively in FIG. 3*b* and the junctions 181 and 185 in FIG. 4 are comparable to junctions 158 and 157 respectively in FIG. 3*b*.

The timing capacitor 201 in FIG. 4 is comparable to timing capacitor 121 in FIG. 3 and tubes 205 and 206 in FIG. 4 are comparable to tubes 124 and 125 respectively in FIG. 3.

The tubes 205 and 206 of FIG. 4 are interconnected, similar to that also illustrated in FIG. 3 so as to provide a linear-with-time charge to capacitor 201.

The contact 315*b* is used to select between phase A adjustment, tap 211, and phase B adjustment, tap 212, on the potential divider network 213.

The resistor 215 and adjustable resistor 216 are timing resistors with 216 used to adjust the rate of chage through the closed contact 304*d*, from the cathode voltage at junction 217 of tube 205.

The taps 211 and 212 are used to adjust the charging time by biasing, with a steady potential, the timing capacitor 201. This is similar to the operation of the timing circuit of the combined FIGS. 3 and 3*b* when the line-switch wiper contacts are in positions other than 2 or 6 except that in the combined FIGS. 3 and 3*b* the potential applied from any one tap of the potential divider associated with bank 1 in FIG. 1 is applied through the electrical coupling, box 31.

The timer illustrated in FIG. 4 is employed for several purposes. The timer serves as the maximum limit timer for the extendible vehicle interval of any phase. With the switch 312 or 313 in position 1, the timer serves as the timer for the initial interval of phase A or phase B respectively replacing the normal initial interval timer. At other times the timer serves as a safety timer which may terminate any interval in the event that the normal timing circuit fails to operate and terminate the interval in the normal manner.

Contact 314*c* is provided to complete a discharge circuit of timing capacitor 201 upon its closure. Contact 314*c* is closed by operation of motor magnet 314 so that contact 314*c* is closed during the stepping operation of the wiper contacts. Thus at the beginning of each interval the capacitor 201 is substantially discharged to its lowest value.

Contact 304*d* controls completion of the charging circuit for maximum timing capacitor 201.

In position 2 and position 6 relay 304 may be energized if there is no call or demand for transfer of right-of-way to phase B or phase A respectively. If relay 304 is energized contact 304*d* is open and capacitor 201 will not begin to charge. Further, as previously described, contact 304*b* in FIG. 2, is closed to hold the variable bias generating unit in a quiescent state and contact 304*c* in FIG. 3*a*, is closed to ground the output voltage applied to the extension time terminating unit by the linear-with-time charging circuit, FIG. 3, and contact 304*a* is open thus opening the ground connection to the junction 181 in FIG. 4 and junction 158 in FIG. 3*b* which effects the trigger circuit as described below for FIG. 4 and described above for FIG. 3*b*.

Thus with relay 304 energized the maximum limit timing circuit capacitor rests in a discharged condition, prepared to start timing a maximum limit time when a demand for transfer of right-of-way, which may open the energizing circuit for relay 304 and cause the relay to become deenergized, is received. The variable bias generating unit is also held in a quiescent state, prepared to start generating a bias control voltage when relay 304 becomes deenergized. With relay 304 energized, the linear-with-time charging circuit in FIG. 3 is timing the minimum time that the wiper contacts must remain in position 2 or 6. This minimum time is measured from the time at which the wiper contacts reach position 2 or

6 or from the end of a subsequent actuation of the vehicle detector on phase A or phase B respectively.

If the wiper contacts move from position 1 to position 2 or from position 5 to position 6 to effect timing of the extendible vehicle interval of phase A or phase B respectively and there is a demand for transfer of right-of-way, it is desired to limit the time of the extendible interval to no more than a predetermined maximum limit, and for such timing the maximum limit timer is employed and simultaneous initiation of the normal extendible interval time and the maximum limit timer is desired.

If there is a demand for transfer of right-of-way, the relay **304** will be deenergized or maintained deenergized as the wiper contacts move into position 2 or 6, according to when the demand for transfer of right-of-way is received and operation of the maximum limit timer is initiated.

If there is no demand for transfer of right-of-way, there is no need to limit the time period of the extendible interval and the maximum limit timer is held inoperative. This is accomplished by energization of relay **304**, as explained.

Let it be assumed that a demand for transfer of right-of-way has been received prior to advance of the wiper contacts into position 2 or 6 so that the relay **304** is maintained deenergized. With relay **304** deenergized contact **304***a* is closed to place ground via lead **40** on junction **181** of FIG. 4 and via lead **39** on junction **158** in FIG. 3*b*. Contact **304***b* is open to permit operation of the variable bias generating unit, FIG. 2, contact **304***c* in FIG. 3*a* is open to break the grounding of the output of the linear-with-time charging circuit and contact **304***d* in FIG. 4 is closed to permit operation of the maximum limit timer. This occurs as soon as the wiper contacts move into position 2 or 6, and thus simultaneous initiation of the maximum limit timer and the normal extendible interval timer is obtained.

As soon as the wiper contacts move into position 2, for example, to time the phase A extendible vehicle interval, capacitor **201** begins to charge from the voltage applied at junction **217** through contact **304***d*, adjustable resistor **216**, timing resistor **215** to the capacitor **201**. The circuit is completed through the upper contact of **315***h* (relay **315** is energized in phase A), tap **211** to ground. The charge applied to capacitor **201** is applied over the stable bias impressed on capacitor **201** from the network **213**, tap **211**, the upper contacts of **315***h* to capacitor **201**.

The charging curve of the maximum limit timing circuit is represented as the linear curve **226**, MAXIMUM LIMIT TIMING, in FIG. 5.

At the same time as timing capacitor **201** begins to charge the capacitor **121** begins to charge linearly with the charge applied upon a progressively increasing bias, as controlled by the increasing charge on capacitor **71**. The voltage on capacitor **121** as measured between junction **120** and ground now follows the curve represented by **228**, RESULTANT TOTAL VOLTAGE, in FIG. 5 or FIG. 6.

If the charge on capacitor **121** increases so that the tube **170** in FIG. 3*a* passes sufficient current to operate relay **325** and subsequently operates the trigger circuit to operate relay **319**, the interval timed in position 2 will terminate by operation of the normal interval terminating unit, FIG. 3*b*. At termination of the interval by operation of relay **319**, capacitor **121** is discharged to its base bias voltage as described while capacitor **201** in FIG. 4 is discharged to its stable bias voltage by closure of contact **314***c*.

If, however there is sufficient traffic on street A so that the linear charge on the capacitor **121** is successively reduced to its bias value before the voltage on the capacitor becomes sufficient to cause tube **170** to pass enough current to operate relay **325**, the maximum time limit that the wiper contacts may now be maintained in position 2 will be timed by the maximum limit timer.

As the charge on capacitor **201** increases the increased potential is applied to grid **207** of tube **206**. This causes tube **206** to conduct more heavily which increases the voltage at junction **210**.

The voltage applied to the grid of tube **205** remains at a fixed value above the voltage at junction **210** so that the tube **205** conducts sufficiently to maintain junction **217** at a fixed voltage above junction **210**. Since the voltage at junction **217**, which is increasing, is applied to the capacitor **201**, and the value of the charge on the capacitor effects the amount of voltage at junction **217**, thus tube characteristics and component values are such that the charge on capacitor **201** increases linearly-with-time.

The voltage at junction **210** is impressed on grid **196** of tube **195**. When the potential on grid **196** becomes sufficiently high, tube **195** will pass current and force tube **190** to cut-off. Conduction of tube **195** will cause operation of relay **320**.

Energization of relay **320** closes contacts **320***a* in FIG. 1 to energize motor magnet **314**; may close a contact to illuminate an indicator lamp thereby indicating that the interval was terminated by operation of the maximum limit timer; closes contact **320***c* which causes energization of relay **306** and automatically puts in a call or demand for return of right-of-way to phase A after serving phase B. Relay **306** is energized by a circuit from ground through contact **320***c*, the upper contacts of **315***i*, lead **58**, the coil of relay **306** to positive power.

If the last described interval timed had been the extendible vehicle interval of phase B (position 6) then the relay **315** would have been deenergized and the stable bias impressed on capacitor **201** would have been impressed via tap **212** and the lower contacts of **315***h*. Further upon operation of relay **320** closure of contact **320***c* would have caused energization of relay **305** for recall of right-of-way to phase B after phase A has been served. Relay **305** would have been energized by a circuit completed from ground through contact **320***c*, the lower contacts of **315***i*, lead **68**, the coil of relay **305** to positive power.

Upon energization of motor magnet **314** by closure of contact **320***a*, contacts **314***b* and **314***c* are closed to discharge capacitors **121** and **201** respectively. Contact **314***a* is opened to cause deenergization of relay **324** which closed contact **324***c* and causes discharge of capacitor **71**.

With capacitor **201** discharged, conduction through tube **206** is reduced thus reducing the voltage at junction **210** and the potential applied to grid **196**. Conduction through tube **195** ceases causing deenergization of relay **320** and restoring tube **190** to a conductor state.

The contacts of relay **320** are reversed to their normal condition and motor magnet **314** is deenergized and advances the wiper contacts to position 3.

Thus the extendible interval of any phase may be terminated by operation of the maximum limit timer with automatic recall of right-of-way after the next phase has been served.

NO TRAFFIC CONDITION

If there is no traffic on either phase or street both detector relays **306** and **305** will remain deenergized and the minimum time during which the wiper contacts must remain in position 2 or 6 is timed. Since the variable bias generating unit is held in a quiescent state, a minimum stable bias is applied to the timing capacitor **121**. This stable bias is the maximum allowed gap level shown in FIGS. 5 and 6 as +80 volts, for example. The capacitor **121** is charged linearly, over this stable bias. The charge on capacitor **121** may become sufficiently high so that the output of **302** the linear-with-time charging

circuit may operate the tube **170** in FIG. 3*a* if the output of FIG. 3 were not grounded via contact **304***c*.

If the linearly applied charge on capacitor does become sufficiently high so that the output applied via lead **35** may operate the tube **170** and an actuation occurs on the phase not then receiving right-of-way then the relay **304** will become deenergized and reverse its contacts **304***a*, **304***b*, **304***c* and **304***d* to their normal conditions, as illustrated in the several drawings.

The maximum limit timer FIG. 4 will begin to charge timing capacitor **201**; the variable bias generating unit, FIG. 2, will begin to increase the bias on timing capacitor **121** via increase of the charge on capacitor **71** and the output of the linear-with-time charging circuit will be applied to the grid **172** of tube **170** since the ground connection via contact **304***c* will be open.

Tube **170** will pass sufficient current to operate relay **325**. Energized relay **325** will open its contact **325***b* and deenergize relay **324**. Deenergized relay **324** will reverse its contact **324***d* and the output of the linear-with-time charging circuit will be applied via lead **36** to the grid **146** of tube **145** of the normal interval terminating unit. Tube **145** will begin to conduct and cause tube **150** to cease conduction and tube **145** will operate relay **319**.

Energization of relay **319** effects termination of the interval through operation of the motor magnet **314** which closes contacts **314***b* in FIG. 3, and **314***c* in FIG. 4 which contact completes discharge circuits to discharge capacitors **121** and **201** respectively. The motor magnet also causes advance of the wiper contacts to the next position upon its deenergization.

TRANSFER OF RIGHT OF WAY

Returning to the time of advance into position 2 or 6 without a demand for transfer of right-of-way assume now that there is a succession of vehicles along the roadway receiving right-of-way. As previously described the maximum limit timing circuit will be held inoperative, waiting for an actuation demanding transfer of right-of-way, timing capacitor **121** will be charged linearly between successive actuations.

Assuming now that phase A has right-of-way, with each actuation of the detector A or A′ the detector relay **306** will be operated for substantially the length of time the contacts A or A′ are closed. During operation of relay **306** contact **306***e* will be closed to complete a discharge circuit to discharge the linearly applied charge on capacitor **121** to the base bias voltage value. The capacitor **121** will begin to recharge linearly when contact **306***e* opens.

This action will be repeated for each actuation of vehicle detector A or A′ so long as no demand for transfer of right-of-way, via actuation of vehicle detector B or B′, is received.

Assume now, that after several actuations of detectors A or A′ which reset capacitor **121**, that the linearly applied charge on capacitor **121** is now at a value above the base bias voltage but below the value at which tube **170** will pass current to operate relay **325** and an actuation of detector B or B′ is received.

Closure of the contacts of detector B or B′ will complete a circuit to energize relay **305** from ground through contact B or B′, junction **60**, leads **65**, **64** and **68**, the coil of relay **305** to positive power. Relay **305** will pull in and open its contact **305***b* and drop out relay **304**. Relay **305** will also lock-in through its holding circuit as previously described, through contact **305***a* and **315***c*.

With relay **304** deenergized its contact **304***a* closes and places ground on junctions **158** in FIG. 3*b* and **181** in FIG. 4 so that the trigger circuits in FIGS. 3*b* and 4 respectively may operate. Contact **304***c* is opened so that the output of FIG. 3 may be applied to the grid **172** of tube **170** in FIG. 3*a* and contact **304***b* is opened to release the variable bias generating circuit from a quiescent state. Contact **304***d* is closed and the timing capacitor **201** of FIG. 4 begins to charge and time the maximum limit time that the phase A green may now be extended.

It should be noted that prior to a demand for transfer of right-of-way being present when the controller is in an extendible vehicle interval there is no time limit that the controller may remain in position 2 or 6. Also, prior to demand for transfer of right-of-way there is no varying bias on timing capacitor **121** which, as described below, reduces the allowed gap time as the bias increases. The charging of capacitor **121** occurs over a steady bias and the voltage change is linear with time.

Returning to the last assumed condition, the capacitor **121** continues to be charged linearly but now is also impressed with a bias that is increasing in value. This changes the rate at which the voltage between ground and point **120** at the upper side of the capacitor will increase.

Now assume an actuation occurs on phase A. Again the linear charge on capacitor **121** will be discharged, as previously described, but the bias, which has now increased above the base bias voltage level remains unaffected by the actuation. After actuation of A or A′ ceases the linear charge is again applied to the capacitor **121** over the now increased bias level.

Additional subsequent actuation of the B or B′ detector have no additional effect on the controller due to the detector relay being held energized.

Additional subsequent actuations of the A or A′ detector will extend the time of the extendible interval, as previously described, by discharge of the linear charge on the capacitor, but will not affect the progressively increasing bias voltage.

When the voltage on capacitor **121** increases sufficiently to cause relay **170** to pass current relay **325** operates and prepares the timing circuit for termination of the interval.

It should be noted that termination of the extendible interval by the normal interval terminating unit occurs in two steps; first operation of the extendible time terminating unit, which is a preparatory step, which does not affect the charge on the capacitor but may reduce the bias on the capacitor if the bias is in excess of the base bias value and the second step, operation of the normal interval terminating unit. These two steps are indicated by illumination of the indicator lamps L9 and L8 respectively.

Operation of relay **325** causes drop out of relay **324** which closes contacts to open the detector operated discharge circuit, reduce the bias to its base value by discharge of capacitor **71** and transfers the output of the linear-with-time charging circuit from FIG. 3*a* to FIG. 3*b*.

With reduction of the bias on capacitor **121** the charge remains the same but the voltage between ground and point **120** at the upper side of the capacitor is reduced by the amount of reduction of the bias. The capacitor is now charged linearly without possibility of reset by detector actuations since contact **324***e* is now open. When the linear charge or voltage on the capacitor **121** is sufficient, the normal interval terminating unit will operate to terminate the interval, during which the capacitor **121** is discharged, and the wiper contacts are advanced to position 3. Advance of the wiper contacts to position 3 opens the connection between the variable bias generating unit and the electrical coupling and connects the stable bias, from tap **25***a* of network **22** for example to the electrical coupling, which may provide a different bias value from the base bias of the variable bias generating unit.

It should be noted that rate of charge of the capacitor **121** may be on a constant slope as set by a calibration adjustment, by adjustment of adjustable resistor **123** for example. This calibration may remain as adjusted and the time period of the non-extendible intervals may be set by adjusting the appropriate tap such as tap **25***a* for the position 3, phase A clearance interval, to provide a desired value of bias voltage to be impressed on capaci-

tor **121**, which may set the desired time period of the interval to be timed. A time period is determined by the slope of the charge curve and the differential between the base bias voltage on the capacitor and trigger voltage of the trigger circuit which terminates the interval.

It should also be understood that the bias voltage applied to capacitor **121** may vary from one interval to the next according to adjustment of the associated tap with the interval to be timed as the wiper contacts advance from one position to the next in their step by step cycle.

CHARGING AND DISCHARGING CURVES

Referring now to FIG. 5, a graphic representation of the various normal charging and discharging curves is illustrated with the vertical component representing voltage, and the horizontal component representing time. The curves represent the normal, complete charging and discharging that may occur during an extendible interval of any one phase with the value of the charge represented by the various curves measured on the capacitor **121**, from junction **120** to ground.

It is assumed that the time zero starts simultaneously with the start of the extendible interval (at the same time the wiper contacts move into contact with position 2 or position 6) and there is a call or demand for transfer of right-of-way.

The low voltage value on the vertical scale is represented to be at 80 volts above the zero or ground voltage level while the high value of volts is represented to be at 160 volts above ground on a graduated scale marked off in 10 volt segments. It should be understood that the voltage values, although practical for the charging and timing circuits in my improved controller, merely represent voltage values and the line **232**, labeled MAXIMUM ALLOWABLE GAP LEVEL, represented to be at 80 volts, may be set at some other voltage value, if desired. The position of the line **232**, with respect to ground, at the voltage scale is adjusted by the setting of tap **75** for phase A and tap **76** for phase B on the network **77**, seen in FIG. 2, which sets the base voltage for low voltage level on the capacitor **71** in FIG. 2, which in turn determines the conductivity of tube **115** in FIG. 3 which applies the desired bias voltage value by the lead **32** to timing capacitor **121**. The voltage level to which the line **232** is adjusted is therefore the lowest voltage value to which the capacitor **121** may be reduced.

The value, on the volts scale at which line **232** is set, determines the passage time, which is the differential between line **232** and **230**, timed on the charging curve **227**, the LINEAR CHARGE VOLTAGE curve and also determines the maximum allowable gap time, which is the differential between line **232** and line **230**, timed on the charging curve **228**, the RESULTANT TOTAL VOLTAGE charging curve.

The position of line **230**, labeled FLASH OR TRIGGER VOLTAGE on the voltage scale, is determined by the voltage that may be measured on the capacitor **121**, at which the tube **171**, in FIG. 3*a*, will flash or trigger and the tube **145**, in FIG. 3*b*, will trigger. It should be noted that the position of line **230** on the scale of volts is not necessarily the flash or trigger voltage level of the trigger circuit but rather the voltage on the capacitor **121** which will cause the tube **125** of FIG. 3 to conduct and provide sufficient voltage output from junction **134** in FIG. 3 to cause the tube **171** in FIG. 3*a* and the tube **145** in FIG. 3*b* to trigger and pass current when the voltage output from junction **134** is applied to the respective tubes.

The setting of line **231**, the MINIMUM ALLOWABLE GAP LEVEL, on the volts scale determines the minimum allowable gap time. The amount of time of the minimum allowable gap is the traversed time, measured on the curve **228**, RESULTANT TOTAL VOLTAGE between the line **231** and **230**.

The setting of the line **231** is determined by the highest value of the charge applied to the timing capacitor **121** via lead **32** from the cathode circuit of the tube **115**. The value of the highest cathode voltage of the tube **115** so applied to capacitor **121**, is determined by the amount of conduction of tube **115**, which is determined by the value of the potential applied to the grid **117** of tube **115** which is the highest charge on capacitor **71**, as determined by the setting of tap **73** for phase A and tap **74** for phase B. Thus tap **73** in FIG. 2, may be used to set the minimum allowed gap for phase A and tap **73** in FIG. 2, may be used to set the minimum allowed gap for phase B.

The differential between line **231** and **232** is the differential between the maximum allowable gap time and the minimum allowable gap time. The rate at which the differential between line **231** and line **232** will be traversed in time, represented by the curve **225**, BIAS VOLTAGE, is determined by the setting of the potentiometer **78** for phase A and **79** for phase B shown in FIG. 2. Thus the potentiometers **78** in FIG. 2 may be used to determine and adjust the time to reduce from maximum allowed gap to minimum allowed gap for phase A and the potentiometer **79** in FIG. 2, may be used to set the time to reduce from maximum allowed gap to minimum allowed gap time in phase B.

The angle of the line **227**, LINEAR CHARGE VOLTAGE is adjusted by the setting of the adjustable resistor **123** in FIG. 3, which is a calibration adjustment. The passage time may be measured by the traversed time between line **232** and **230** on curve **227**. Since taps **75** and **76** adjust the position of the line **232** for phase A and phase B respectively then taps **75** and **76** respectively may be used to adjust the passage time for phase A and phase B respectively.

The curve **225**, BIAS VOLTAGE represents the bias voltage applied to the capacitor **121**, from the electrical coupling tube **115** cathode, via lead **32**, the lowest value, represented at time zero, is set by the base voltage or low voltage level on the capacitor **71** in FIG. 2, and sets the minimum amount of conduction of tube **115** and thus the value of the lowest voltage applied to the capacitor **121** via lead **32** in FIG. 3. As the charge on capacitor **71**, in FIG. 2 varies, conduction of tube **115** in FIG. 3 varies proportionally and the bias voltage applied to capacitor **121** in FIG. 3 via lead **32** varies according to the amount of conduction of tube **115**.

The amount of linear charge applied to capacitor **121** through the timing resistor **122** and adjustable resistor **123** from junction **130** of the cathode circuit of tube **124** in FIG. 3 is represented by the line **227**, LINEAR CHARGE VOLTAGE. The curve **228**, RESULTANT TOTAL VOLTAGE, is the summation of the curves **225** and **227** and represents the value of the linear charge plus the value of the bias voltage. It was previously described how the capacitor **121** could be biased simultaneously by the voltage applied via lead **32** which is represented by curve **225** and charged by the voltage applied from junction **130** through the timing resistors **122** and **123** which is along the curve represented by line **227** in FIG. 5. The line **228** may represent the charge on capacitor **121** measured from junction **120** to ground. It was also described how either the bias voltage, along the curve **225** or the voltage charge, along the curve **227**, could be individually reduced to their lowest value without effecting the accumulated charge along the other curve. Thus if for example the capacitor **121** was charged along the curve **228** from the line **232** to the line **230**, the FLASH OR TRIGGER VOLTAGE and the trigger circuit in FIG. 3*a* was operated to reduce the voltage bias along the curve **225** to its lowest level, as for example as indicated by the broken line **225'**, the charge on the capacitor would be reduced to the value of the remain-

ing charge, or to the line 227 as indicated by the broken line 228'. By continuing to charge along the linear curve 227 the charge on the capacitor 121 could be again increased to the line 230 at which time the trigger circuit in FIG. 3*b* may be operated terminating the interval and reducing the voltage charge, represented by curve 227' to its lowest level thereby completely discharging the capacitor 121 to its lowest level or to line 232 in preparation for the next interval.

The curve 226, MAXIMUM LIMIT TIMING represents the charging or voltage curve of the maximum limit timer, FIG. 4, and is represented as starting from a common base voltage for convenience. It should be noted that the curve 226 may start at a common voltage level or at another voltage level, according to the setting of the adjustment 211 and 212.

The horizontal component, representing time, is sealed in seconds and graduated in five second units, marked off on line 232 for convenience. This time scale is used for convenience and merely represents one time scale that could be used when associated with the voltage values used herein.

GRAPHICAL SHOWING OF TIMING CAPACITOR OPERATION

Referring now to FIG. 6, a graph illustrating curves which represent the charging and biasing and discharging of the charge and bias of the timing capacitor 121, as measured between junction 120 and ground, which may occur during the extendible interval, is presented to illustrate the cooperative effect within the composite timing circuit.

The vertical component of the graph in FIG. 6 is identical to the vertical component of the graph in FIG. 5, both in character and scale.

The horizontal component of the graph in FIG. 6 is similar to the horizontal component of the graph in FIG. 5 with respect to character but the scale of time value in FIG. 6 is one half again larger than the scale of time in FIG. 5.

The position of the lines 230, 231 and 232 on the vertical scale in FIG. 6 is similar to the position of the identical lines in FIG. 5. However since the horizontal scale of FIG. 6 is larger than that of FIG. 5 the contour of the voltage charging and discharging curves differ between the two graphs to some degree, although corresponding voltage curves are labeled similarly, between the two figures.

For simplification of the drawing, the voltage curve 226, MAXIMUM LIMIT TIMING, has been deleted from FIG. 6 although it is to be understood that the voltage curve would begin at time zero with the beginning of the other voltage curves illustrated in FIG. 6.

It should be assumed that the controller has been operating for a substantial period of time and that there is a demand for transfer of right-of-way. Further assume that the wiper contacts of the line switch move from the position in which the initial interval is timed (position 1 or 5) into the position in which the extendible interval is timed (position 2 or 6) with the timing capacitor 121 completely reduced to its lowest value, here assumed to be +80 volts.

The broken line curve 227 illustrates the linear change of voltage as the capacitor is charged and the broken line curve 225 represents the bias voltage applied, each of which are applied to the timing capacitor 121, as described. The solid line 228 represents the resultant voltage which is the sum of the lines 225 and 227.

The charges applied to timing capacitor 121 accumulate along the curve 228, the bias applied from box 31 via lead 32 to the bottom of timing capacitor 121, in FIG. 3 and the charge from the cathode circuit of tube 124 from junction 130 via adjustable resistor 123 and timing resistor 122 to the top of timing capacitor 121.

After about 5 seconds, as arbitrarily assumed, one of the detectors of the street receiving right-of-way is actuated. This, as previously described, causes energization of the associated detector relay, and the energized relay causes closure of its normally open contacts, in particular contact 306*e* or 305*e*.

If right-of-way is displayed on Street A, relay 315 will be energized and contact 315*g* will be closed in its up position and actuation of detector A or A' will cause energization of relay 306 which will close 306*e*.

For clarity, let it be assumed that the right-of-way is now accorded to traffic on Street B so that relay 315 is deenergized and contact 315*g* is closed in its down position. Further since the moving traffic is on Street B the detectors actuated by the moving traffic will be B and/or B' thus detector relay 305 will be energized and contact 305*e* will be closed each time there is an actuation of detector B or B'.

Closure of contact 305*e* will complete the prepared discharge circuit including contact 324*e* and the lower contact 315*g* discharging capacitor 121, as indicated by curve 228' from point A1 to curve 225. Upon cessation of actuation relay 305 becomes deenergized and the "discharge" circuit opens and capacitor 121 begins to recharge. At this point in time the bias applied to capacitor 121 has not been reduced but is now higher than it was at time zero.

The charging of capacitor 121 begins along curve 228–1.

If an actuation of detector B or B' has not occurred before the curve 228 reaches line 230, such as shown in FIG. 5 the flash or trigger voltage would have been reached and the BIAS VOLTAGE would have been "removed," such as illustrated in FIG. 5 by broken line 225' and 228'. This measured time, although referred to as the maximum gap time may only be a measure of gap time in actual traffic if an actuation on B or B' occurs simultaneously with the start of the interval, otherwise, it is the time during which the first actuation of the interval must occur in order to extend the interval.

The curve 228–1 illustrates the charging curve of capacitor 121 after actuation A1 and assumes that a second actuation on B or B' occurs at time A2. This again "discharges" the capacitor to curve 225.

Above the graph the line 327 represents the time of the actual gap time between actuations while the line 328 represents the time of the permitted gap time. The line 329 represents the time of the remainder of the passage time, as measured in time from the point at which curve 228–1 including its projection, in broken line form reaches line 230, and drops along the line 228'–1 due to the reduction of the BIAS curve at 225–1 to the point at which the biasing curve 227–1, intersects with line 230. The "passage time" is the time included in the time 328 plus time 329.

With cessation of actuation at A2 the voltage on capacitor 121 rises along curve 228–2 with the permitted gap time indicated along line 330. It is now assumed that the gap time between actuations is greater than the permitted gap time and that the voltage curve 228–2 reaches the line 230. This operates the terminating unit of the extendible portion of the extendible interval, FIG. 3*a*. Relay 325 operates to drop out relay 324 which opens its contact 324*e* and opens the discharge circuit FIG. 3, closes contact 324*c* to "discharge" capacitor 71 in FIG. 2 and thus reduce the current flow through the cathode follower in box 31 and thus reduce the curve 225 along line 225' to its lowest level. This reduces the resultant total voltage along line 228'–2 to the curve 227–2 which then charges linearly to the line 230. The line 331 represents the remainder of the passage time while the total passage time actually measured from actuation A2 to termination of the passage time is measured by the lines labeled 330 plus 331.

Termination of the interval timed in the position re-

sults in complete discharge of timing capacitor **121** to its lowest level along line **227'–2**.

If an actuation should occur before the curve **228–2** reaches line **230**, that is within the permitted gap time, the capacitor voltage would be reduced again to the BIAS curve **225**. Additional subsequent timely actuations that occur within the permitted gap time (which is being progressively reduced with the rise of curve **225**) cancel the unexpired gap time and remainder of the passage time. Time of the passage time will begin all over again, however, with each successive cancellation of the unexpired passage time, the gap time is further reduced and the remainder of the passage time, during which resetting of the timing of the passage time may not occur, is increased by the same amount that the gap time has been reduced, so that the passage time remains constant.

If successive actuations should cause extension of the extendible interval for a time up to the maximum limit, as timed by the curve **226**, in FIG. 5, the interval will terminate by operation of the maximum limit timer, FIG. 4, rather than the non-extendible interval terminating unit, FIG. 3*b*.

VOLTAGE NETWORKS

It should be noted that, as more readily seen in FIG. 1, positions 1, 2 and 3 of the line switches are comparable to positions 5, 6 and 7 respectively except that positions 1, 2 and 3 are associated with phase A (Street A herein) and positions 5, 6 and 7 are associated with phase B (Street B herein). With such arrangement the network **21** supplies a voltage for positions 1 and 5 with tap **24***a* connected to position 1 and tap **24***b* connected to position 5 with position 1 used as part of the timing circuit for the initial, non-extendible interval, of phase A and position 5 used as part of the timing circuit for the initial, non-extendible interval, of phase B. The taps **24***a* and **24***b* may be independently adjusted so that each initial interval of the respective phases may be independently timed and at different time intervals, if desired.

Network **22** supplies a voltage for positions 3 and 7 via tap **25***a*, for phase A and tap **25***b* for phase B respectively. Positions 3 and 7 are used as part of the timing circuit for the clearance interval, of phase A and phase B respectively.

The network **23** supplies a voltage for positions 4 and 8 via taps **26***a* and **26***b* respectively.

The voltage applied to positions 1 and 5 via taps **24***a* and **24***b* respectively from network **21** are substantially stable and individually control the cathode follower in box **31** to conduct at a substantially steady rate or value, thus providing a steady or stable bias on the timing capacitor in box **302**. This bias controls the amount of charge necessary to be applied to the capacitor, at a predetermined rate to arrive at a predetermined value which will provide a predetermined amount of conduction of the tubes controlled by the timing capacitor in box **302**.

EFFECT OF SUBSTANTIAL TRAFFIC

Let is now be assumed that the recall switches **312** and **313** are both adjusted to be in the position #3 in which there is no "recall" by the respective switches and the controller is operated as a full traffic actuated controller. Further assume that there is a substantial amount of traffic on both streets, A and B, and that the wiper contacts of the controller have just been advanced from position 8 to position 1.

Relay **315** is energized and relays **317** and **316** are deenergized so that the green signal **323A** on Street A is illuminated and the red signal **321B** on Street B is illuminated. Both detector relays **306** and **305** are here assumed energized, both being locked-in via their respective holding circuit.

The relay **324** in box **302***a* is deenergized so that the contact **324***d* is in its normally closed lower position so that box **302** is connected to box **302***b*; contact **324***b* in box **303** is closed thus shunting capacitor **71** and holding the circuitry in box **303** in a quiescent state and contact **324***e* in box **302** is open to provide against reset of timing capacitor **121**.

The potential tapped off network **21** via tap **24***a* is applied to position 1 of bank 1 and to the wiper contact and, via lead **30** to the cathode follower in box **31**, which functions as previously described, and thence via lead **32** to the box **302** to be applied to the timing capacitor **121** as a stable bias, thus serving to control the amount of charge needed, the charge being supplied at a constant rate, to increase the potential on the capacitor **121** so as to cause tube **125** to conduct sufficiently heavy to cause the tubes **150** and **145** of box **302***b* to reverse their conductive and non-conductive condition respectively, and operate relay **319**.

Energized relay **319** closes its normally open contacts **319***a* and completes a circuit to energize motor magnet **314**. A second relay contact may also illuminate an indicator lamp indicating that the interval is now terminating by action of the interval timer relay **319**.

Motor magnet **314** opens its normally closed contact **314***a*, FIG. 1, and closes its normally open contacts **314***b*, in box **302** (FIG. 3), and **314***c* in box **309** (FIG. 4). Closure of contact **314***b* discharges capacitor **121** as previously described and contact **314***c* discharges capacitor **201** as previously described.

Discharge of capacitor **121** reduces the potential on grid **133** of tube **125** and tube **125** conducts less heavily. Thus the cathode voltage of tube **125** is reduced and the output applied to grid **146** of tube **145** in box **302***b* is reduced and tube **145** becomes non-conductive thus causing relay **319** to become deenergized.

Deenergized relay **319** opens its contacts **319***a* dropping out motor magnet **314**. When motor magnet **314** became energized it engaged a toothed gear (not shown) and upon deenergization the gear is rotated to move the wiper contacts to the next position, position 2.

Position 2 is the extendible vehicle interval timing position. When the wiper contacts arrive in position 2 the output of box **303** (FIG. 2) is connected via lead **20**, to position 2 of bank 1, the wiper contact, lead **30**, box **31**, lead **32** to box **302**. Thus the variable bias generating unit, FIG. 2 is connected to the linear-with-time charging circuit, FIG. 3.

Indicator lamp **L1** is extinguished and the relay **304**, which could be energized in position 2 of bank 2 is held deenergized due to energization of relay **305**, holding contact **305***b* open. With relay **304** deenergized contact **304***a* remains closed and junction **181** in FIG. 4 and junction **158** in FIG. 3*b* are both at ground potential.

The relay **324** in FIG. 3*a* is now energized through its ground connection from the wiper contact of bank 5, position 2, contact **314***a*, lead **37** to box **302***a*, FIG. 3*a*, normally closed contact **325***b* coil of relay **324** to positive power. Relay **324** opens its contacts **324***a*, **324***b* and **324***c*, closes its contact **324***e* and reverses its contact **324***d* the latter contact connecting the output of box **302** via resistor **33** to lead **35** and thus to the grid of tube **170**. Contact **324***a*, FIG. 1, opens and breaks the holding circuit for relay **306**. Contact **324***c*, FIG. 2 opens and breaks the shunting circuit for capacitor **71** and capacitor **71** begins to charge. Contact **324***e*, FIG. 3 closes and prepares a "reset" or discharge circuit for timing capacitor **121** which may be completed, upon actuation of the vehicle detector A or A' and energization of relay **306** which will close contact **306***e*, through the closed upper contacts **315***g*, through a low resistance to the bottom of capacitor **121**.

At the same time capacitor **201** of FIG. 4, the maximum limit timer, also begins to charge and time the maximum time that the wiper contacts may remain in position 2.

As described relative to FIG. 3, the charge on the ca-

pacitor may, during certain of the timing of position 2 be discharged but the bias voltage is retained. This provides for an increasingly reduced extension time increment, as described.

The time interval the wiper contacts are permitted to remain in position 2 may terminate either by the maximum timer operation of relay **320** or by the normal operation of relay **325** followed by operation of relay **319**.

As previously described the motor magnet **314** may be energized via action of relay **319** in FIG. 3*b* or relay **320** in FIG. 4. If the relay **320** is energized and acts to terminate the interval the contact **320***c* will be closed which will complete an energizing circuit for the relay **306** as previously described.

EFFECT ON TRAFFIC LAGGING

Assuming that there is a sufficient gap in traffic on Street A so that the potential across the timing capacitor **121** increases so that tube **125** in FIG. 3, passes current sufficiently heavy to provide sufficiently high voltage to cause tube **170**, in FIG. 3*a* to pass current to cause energization of relay **325**, relay **325** will be energized and lock-in through its holding contact **325***a*, lead **38**, position 2 of bank 4 to ground. Energized relay **325** opens its contact **325***b* and relay **324** becomes deenergized. Contacts **324***a*, **324***b* and **324***c* are released and closed. Closure of contact **324***a* completes the holding circuit for relay **306** through its own holding contact **306***a*. Closure of contact **324***b* completes a parallel holding circuit for relay **305**. Closure of contact **324***c* completes a shunting circuit for the capacitor **71** in FIG. 2 and discharges the capacitor thus reducing the bias voltage being applied to the timing capacitor **121** in FIG. 3 to its lowest value. Contact **324***d* is reversed so that the output of tube **125** in FIG. 3 is connected to lead **36** so that the output voltage from tube **125** in FIG. 3 is applied to the grid **146** of tube **145** in FIG. 3*b*.

It should be noted that the closure of contact **324***c* reduced the bias on the capacitor **121** in FIG. 3 by discharging the capacitor **71** in FIG. 2 and now holds the variable bias generating circuit in a quiescent state but that capacitor **121** from junction **130** continues to be charged, with the bias, if any on the capacitor **121**, held stable in contrast to the varying bias. Thus the potential across the capacitor **121** has been reduced to the value of the linear-with-time charge since the variable bias voltage has been removed and the capacitor **121** is now charged linearly to the point where the tube **125** passes sufficient current to provide sufficient output voltage to cause the tube **145** to begin to conduct and energize the relay **319**.

Operation of relay **319** will cause energization of motor magnet **314** which causes discharge of capacitor **121** in FIG. 3, via closed contact **314***b* and discharge of capacitor **201** in FIG. 4 via closed contact **314***c*. Upon deenergization, motor magnet **314** advances the wiper contacts to the next position, position 3.

Referring momentarily to bank 3 in FIG. 1, particularly the switch **307**, it is assumed that the switch **307** is closed as illustrated. Closure of the switch **307** provides a ground connection to the box **309** and **302***b* so that the junction **181** in box **309** and junction **158** in FIG. 3*b* are at ground. If it is desired to control when the interval timed in position 2 may terminate, then the switch **307** may be positioned so as to connect with the upper terminal **310**. The terminal **310** may be connected to a master or other controller and may supply a ground connection at a desired time so that the controller may move out of position 2 at a desired time.

Along these lines the terminal **332** extending from positions 2 and 6 in bank 5 may be used for connection to either or both terminals **310** and **311** of another controller so that one controller may be used as a master controller for other controllers in a traffic control system.

Referring again to FIG. 3 the purpose of switch S–1 will now be described. It may be desired to temporarily increase the time of the clearance interval of any one phase, under certain conditions.

With switch S–1 closed as illustrated the circuitry network including resistor **240** and contacts **317***e*, **306***f* and **305***f* and shunted and temporary extension of any clearance interval is not permitted.

With switch S–1 open the resistance of the resistor **240** may be added to the resistance of the combined resistors **122** and **123** under certain conditions, and only in a clearance interval. Since the relay **317** is energized only in a clearance interval, position 3 and 7 for example, the contact **317***e* is closed in all other positions so that in all other positions the resistor **240** is by passed by the shunting circuit through closed contact **317***e*.

In order that the controller move into a clearance interval there must be a demand for transfer of right-of-way so that the detector relay of the phase calling for right-of-way is energized, thus its contact either **306***f* or **305***f* will be open. Also in any clearance interval relay **317** is energized and contact **317***e* is open. Thus in a clearance interval for phase A, for example contact **317***e* will be open and contact **305***f* will be open. If an actuation of A or A′ occurs after operation of the extendible time terminating unit and before termination of the clearance interval or if the phase A green period is terminated by operation of the maximum limit timer relay **306** will become energized and the contact **306***f* will open to open the network shunting resistor **240** and insert the resistor **240** into the timing circuit. This increase of the timing resistance will temporarily increase the time period of the current clearance interval.

Temporary increase of the time period of the clearance interval under corresponding conditions may occur during phase B, position 7.

It will be appreciated that while the apparatus disclosed herein represents the preferred embodiment of my invention modification in the design and arrangement of the several parts and substitution of equivalent parts and circuits may be made in manner known to those skilled in the art without departing from the spirit of the invention as defined by the claims.

I claim:

1. In a traffic control system for interfering traffic lanes having traffic actuatable means for the respective lanes, right of way signals and a timing mechanism for controlling said signals to time successive period of accord of right of way successively to said lanes, said timing mechanism including a capacitor, circuit means for charging said capacitor linearly with time subject to time reset by discharge of said capacitor, means for so discharging said capacitor in response to actuation of said traffic actuatable means for the lane having right of way, second circuit means for adding an aiding bias voltage in series with said timing capacitor and progressively increasing with time from an initial bias voltage value, first responsive means coupled to said capacitor and bias to be controlled by the total voltage across said capacitor and said bias for preventing further such discharge of said capacitor by said traffic actuated discharge means and for resetting said second circuit means to maintain its initial bias voltage value in response to a predetermined total voltage to permit said capacitor to continue charging from the resulting lower bias and second responsive means controlled by said total voltage for terminating said right-of-way signal period in response to substantially the same predetermined total voltage resulting from said continued charging of said capacitor when said second responsive means is coupled to said capacitor and bias to be so controlled, and means coupled to said first responsive means to be controlled by operation thereof to so couple second responsive means to said capacitor and bias.

2. In a traffic control system for accord of right of way in succession to intersecting traffic lanes in response to traffic actuation on the respective traffic lanes, traffic actuatable means individual to the respective traffic lanes,

right of way indicating means and a timing mechanism for timing periods of accord of right of way by said indicating means to the individual lanes respectively, said timing mechanism including a resistance-capacitor circuit in which the voltage from one side of the capacitor to a reference is the sum of the voltage from the charge on the capacitor plus a capacitor bias voltage, a trigger circuit coupled to said capacitor to be controlled by said voltage from said one side of said capacitor to said reference, to be operated at a predetermined said voltage, means for charging said capacitor at a linear predetermined time rate, means for varying the bias voltage progressively with time during accord of right of way in one lane to determine a time period therefor according to the charging time of the capacitor between the voltage level of the bias and said predetermined voltage level.

3. In a traffic signal control system for intersecting traffic lanes for extending right-of-way in one of said lanes in response to closely spaced vehicle actuations therein and for initiating a transfer of right-of-way from said one lane to another said lane when the time gap between successive vehicle actuations in said one lane exceeds an allowable time gap, and for providing a further continuation of right-of-way in said one lane for a brief time period after said initiation of transfer to provide a passage time for the last prior actuating vehicle to reach the intersection, a resistance-capacitance based timing circuit for providing the said gap timing and passage timing, said circuit comprising a capacitor, means including a resistance and a voltage source having a constant differential relation to the voltage on said capacitor for charging said capacitor at a linear time rate, means for discharging said capacitor in response to actuation by vehicles having the right-of-way in said one lane, means for providing an aiding bias voltage in series with said capacitor and for increasing said aiding bias voltage gradually with time while said right-of-way period is being so extended, first voltage responsive means coupled to said bias means and said capacitor to be controlled by the total voltage across said capacitor and said bias voltage for operating at a predetermined said total voltage, the difference between said predetermined total voltage and said bias voltage representing said allowable gap, means coupled to said first voltage responsive means to be operated in response to said operation thereof to prevent further vehicle actuated discharge of said capacitor and to substantially eliminate said bias voltage whereby said capacitor can continue to charge toward said predetermined total voltage, second responsive means for operating in response to said total voltage again reaching substantially said predetermined value as said capacitor continues to charge when said second responsive means is coupled to said capacitor, means controlled by the first mentioned responsive means so operating to couple said second responsive means to said capacitor to be so controlled by the said total voltage after said bias voltage has been so substantially eliminated and said capacitor continues to charge, and means operated by said operation of said second responsive means to terminate the accord of right-of-way to said one lane.

4. A combination as in claim 3 and including a cathode follower coupled to said capacitor and said bias voltage means to be controlled by the said total voltage across said capacitor and said aiding bias for so controlling said respective responsive means.

5. A combination as in claim 3 and in which said means providing said bias voltage includes a cathode follower whose output is connected in series with said capacitor, and in which said means for gradually increasing said bias includes a second resistance-capacitance timing circuit having a slowly varying charge on its capacitor which is coupled to the input of said cathode follower to control said output to so increase said bias.

6. In a traffic control system for extending right-of-way on one traffic phase and preventing transfer to another traffic phase by reset of a timer by actuation by successive vehicles on said one traffic phase within a maximum limit, the improved combination comprising a capacitor and resistor connected to a source of power to vary the charge on said capacitor from an initial value progressively toward a different final value for said timer, means for returning the charge on said capacitor substantially to said initial value in response to vehicle actuation on said one phase having right-of-way to so reset said timer, means for providing a bias voltage in series with said capacitor, a cathode follower having said bias voltage and said capacitor coupled to its input, means for progressively varying said bias voltage from an initial level toward another level with time, a first voltage responsive device coupled to the output of said cathode follower to be operated in response to the charge on said capacitor reaching a predetermined level to provide a predetermined voltage to said input, and a second voltage responsive device adapted to be coupled to the output of said cathode follower to be operated at a higher level of charge of said capacitor than said first responsive device to provide a predetermined voltage to said input, means for restoring said bias voltage to said initial level in response to operation of said first voltage responsive device and means for so coupling said second voltage responsive device to said cathode follower in response to said operation of said first voltage responsive device, whereby the same capacitor may provide two different time functions reset from the same traffic actuation related to said right-of-way extension.

7. In a traffic control system for intersecting traffic lanes including "stop" and "go" signals for the respective lanes, traffic actuatable means for the respective lanes and means for controlling such signals to accord right-of-way in succession to the respective lanes in response to actuation of the respective said traffic actuatable means, said signal controlling means including timing means for timing a display period of a "go" signal to one lane and a "stop" signal to the other lane, said timing means including a capacitor, means for varying the charge on said capacitor from an initial value progressively at a predetermined time rate toward a different final value for timing, biasing means for providing a voltage bias in series with said capacitor with respect to a reference, reset circuit means for resetting the charge on said capacitor substantially to said initial value to reset said timing in response to actuation of the traffic actuatable means of said one lane having said "go" signal to provide a part of said "go" signal period extendible by traffic therein, means for responding to a predetermined voltage on said capacitor and said bias with respect to said reference to terminate said extendible part of said "go" signal period, and means for varying said bias progressively at a predetermined time rate from a first voltage value toward a second voltage value in a direction to reduce the difference between said bias voltage and said predetermined voltage to progressively reduce the time period over which said charge is so varied for such timing.

8. A combination as in claim 7 and in which bias varying means includes means for so varying said bias in the "go" signal period for said one lane in response to actuation of the traffic actuated means of the other lane having a "stop" signal.

9. A combination as in claim 7 and in which said means for terminating the extendible part of said signal display period includes means for preventing further said resetting of the charge on said capacitor by said reset circuit means, means for resetting said bias to and maintaining said bias at substantially said first voltage value to permit said progressive variation of said charge on said capacitor to continue for timing a non-extendible part of said "go" signal display period following said extendible part, and said timing means including second responsive means for responding to said predetermined voltage as said progressive variation of charge of said capacitor continues to said predetermined voltage for terminating said second part of said signal display period in response to

the voltage on said capacitor in such continued charge variation reaching said predetermined voltage when said second responsive means is coupled to said capacitor to so respond, and means operated in response to operation of said first responsive means to said predetermined voltage to so couple said second responsive means to said capacitor upon said reset of said bias substantially to its said first value.

References Cited by the Examiner

UNITED STATES PATENTS

2,883,643	4/1959	Du Vivier	340—37
2,925,583	2/1960	Jeffers	340—37

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