Feb. 28, 1967 J. H. AUER, JR., ETAL 3,307,146

OFFSET SELECTOR

Filed March 26, 1964 5 Sheets-Sheet 1

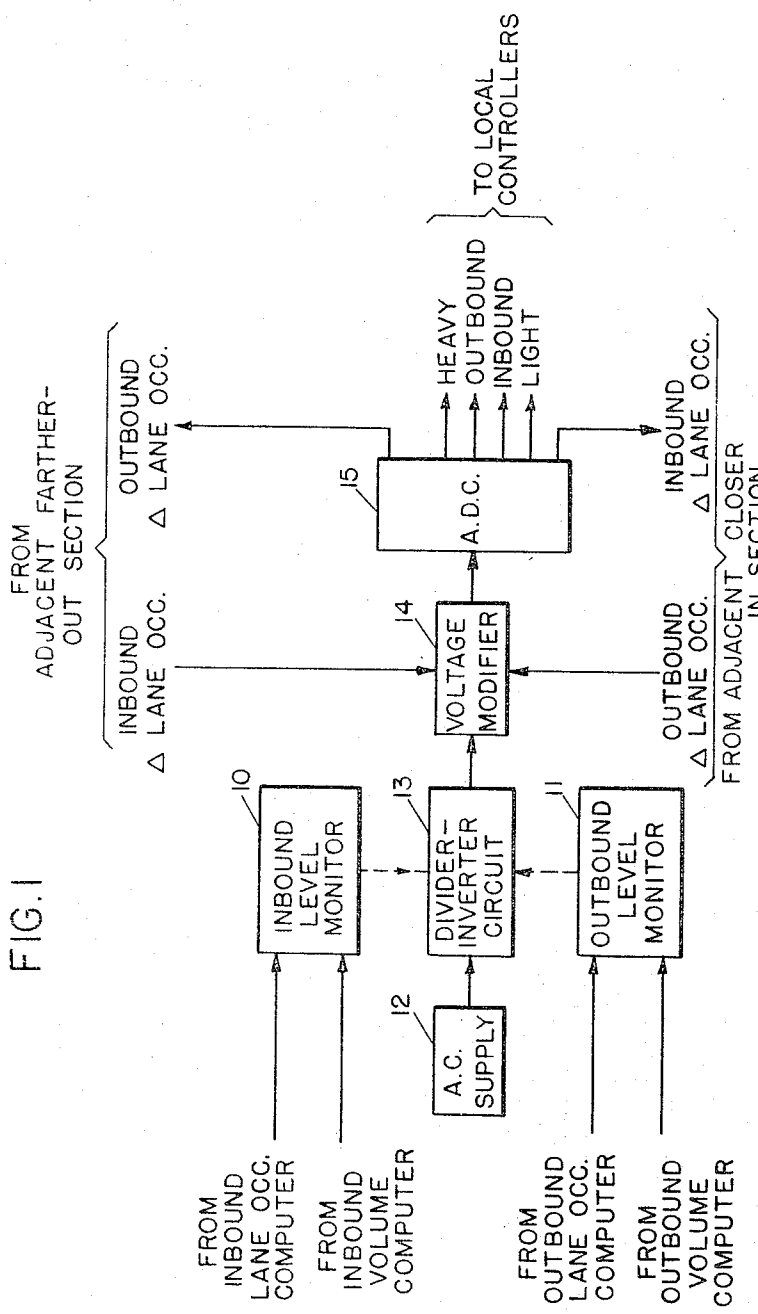


FIG. 1

FIG. 2

OFFSET	ENERGIZED OUTPUT LEADS
LIGHT	LIGHT
AVERAGE	OUTBOUND & INBOUND
PRE-OUTBOUND	LIGHT & OUTBOUND
OUTBOUND	OUTBOUND
PRE-INBOUND	LIGHT & INBOUND
INBOUND	INBOUND
HEAVY	HEAVY

INVENTORS
J.H.AUER JR., L.A.ROSS
AND J.P.HUFFMAN
BY Forest B. Kirkwood
THEIR ATTORNEY

Feb. 28, 1967 J. H. AUER, JR., ETAL 3,307,146

OFFSET SELECTOR

Filed March 26, 1964 5 Sheets-Sheet 2

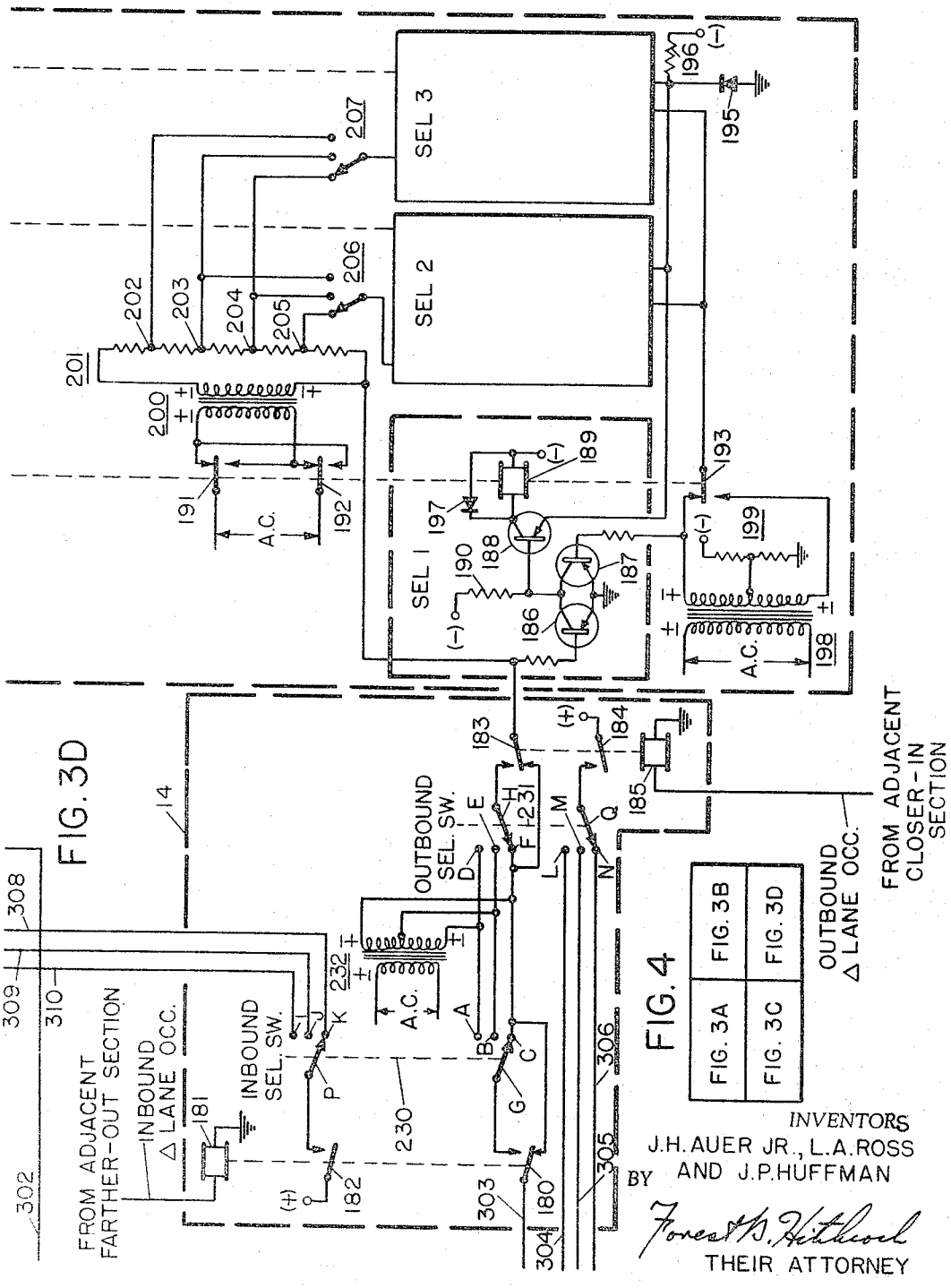


FIG. 3D

FIG. 4

FIG. 3A	FIG. 3B
FIG. 3C	FIG. 3D

INVENTORS
J.H. AUER JR., L.A. ROSS
AND J.P. HUFFMAN
BY Forrest B. Hathcock
THEIR ATTORNEY

Feb. 28, 1967 J. H. AUER, JR., ETAL 3,307,146

OFFSET SELECTOR

Filed March 26, 1964 5 Sheets-Sheet 3

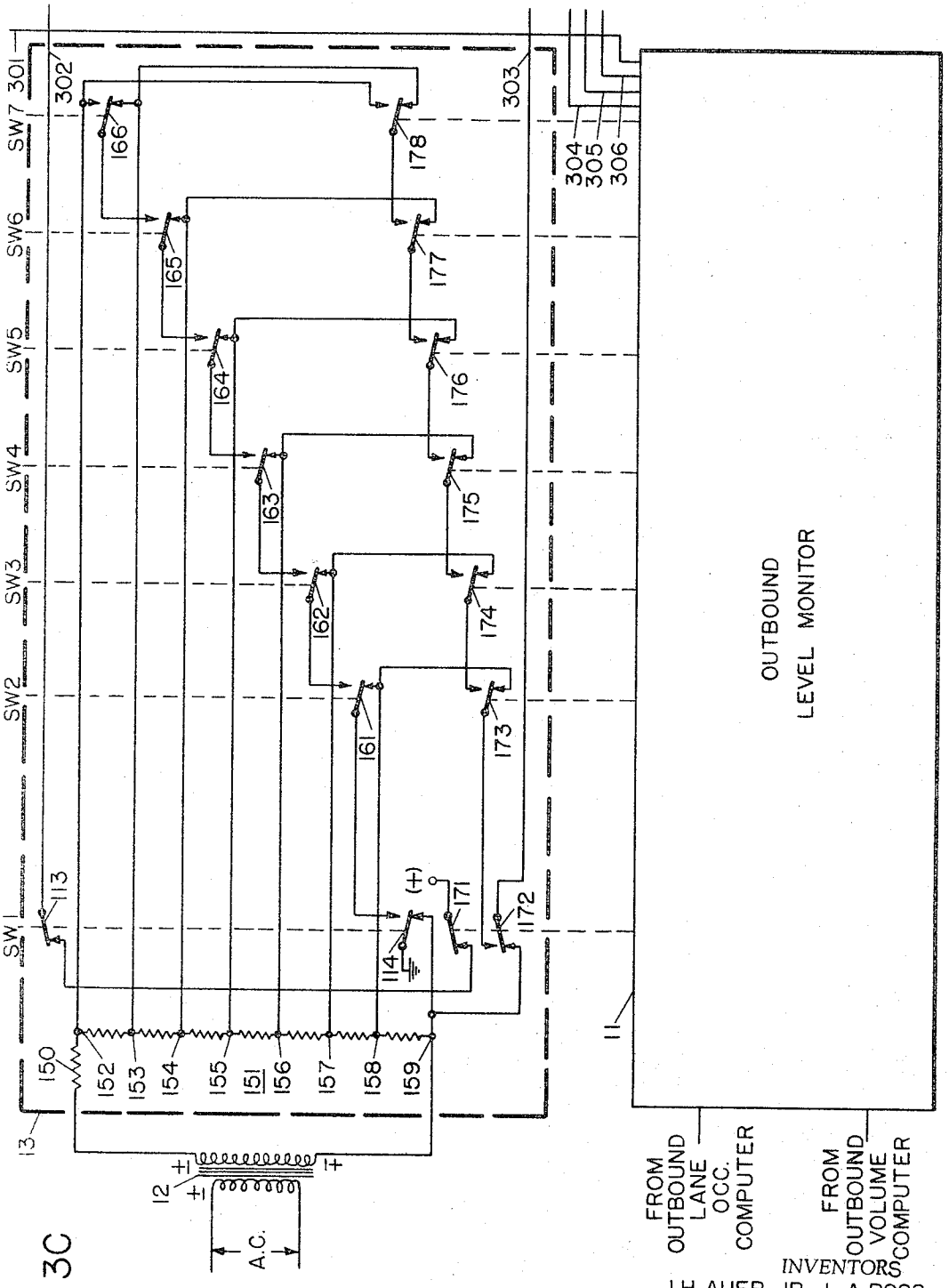


FIG. 3C

INVENTORS
J.H. AUER JR., L.A. ROSS
AND J.P. HUFFMAN

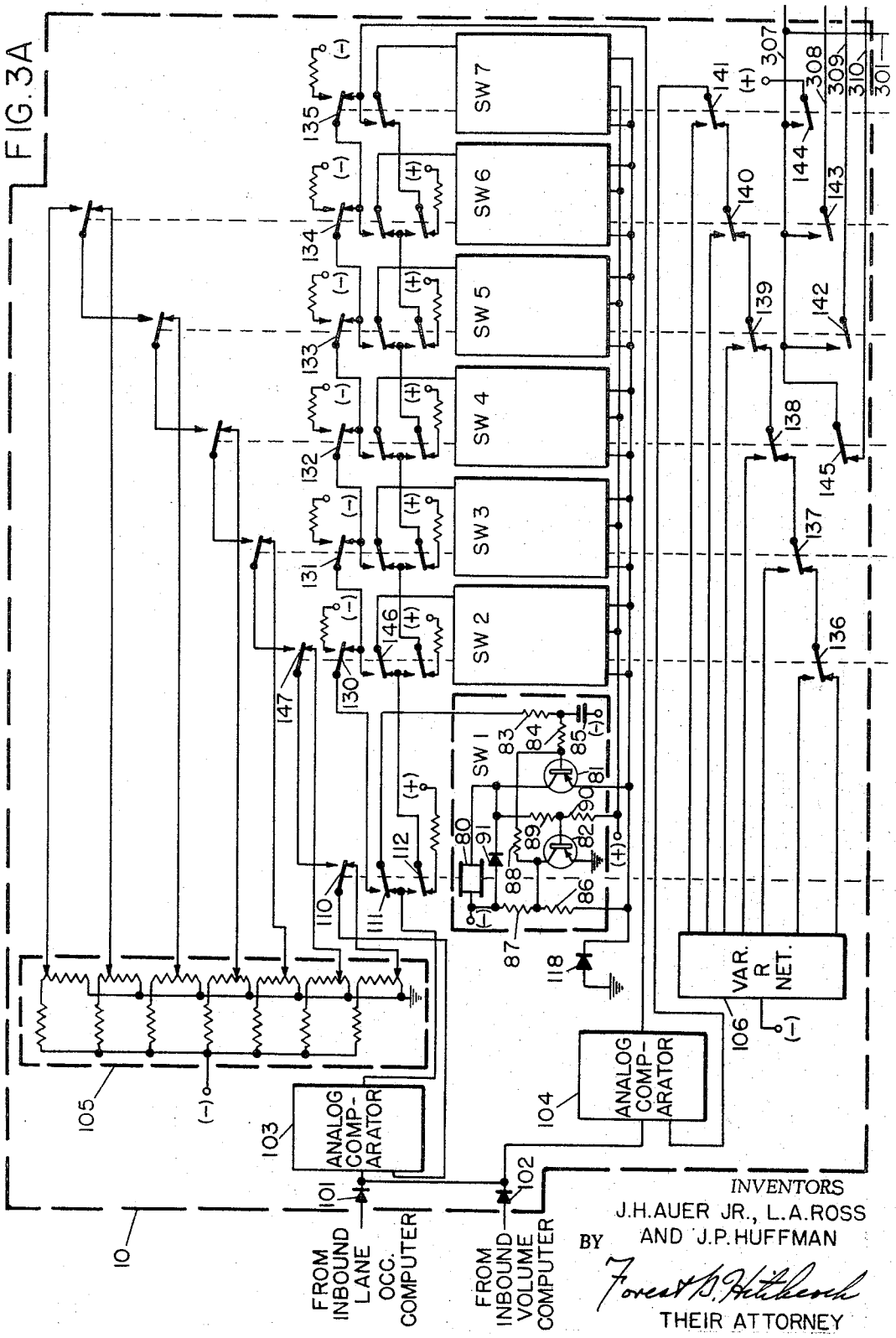
BY Forest B. Hitchcock
THEIR ATTORNEY

Feb. 28, 1967 J. H. AUER, JR., ETAL 3,307,146

OFFSET SELECTOR

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FIG. 3A

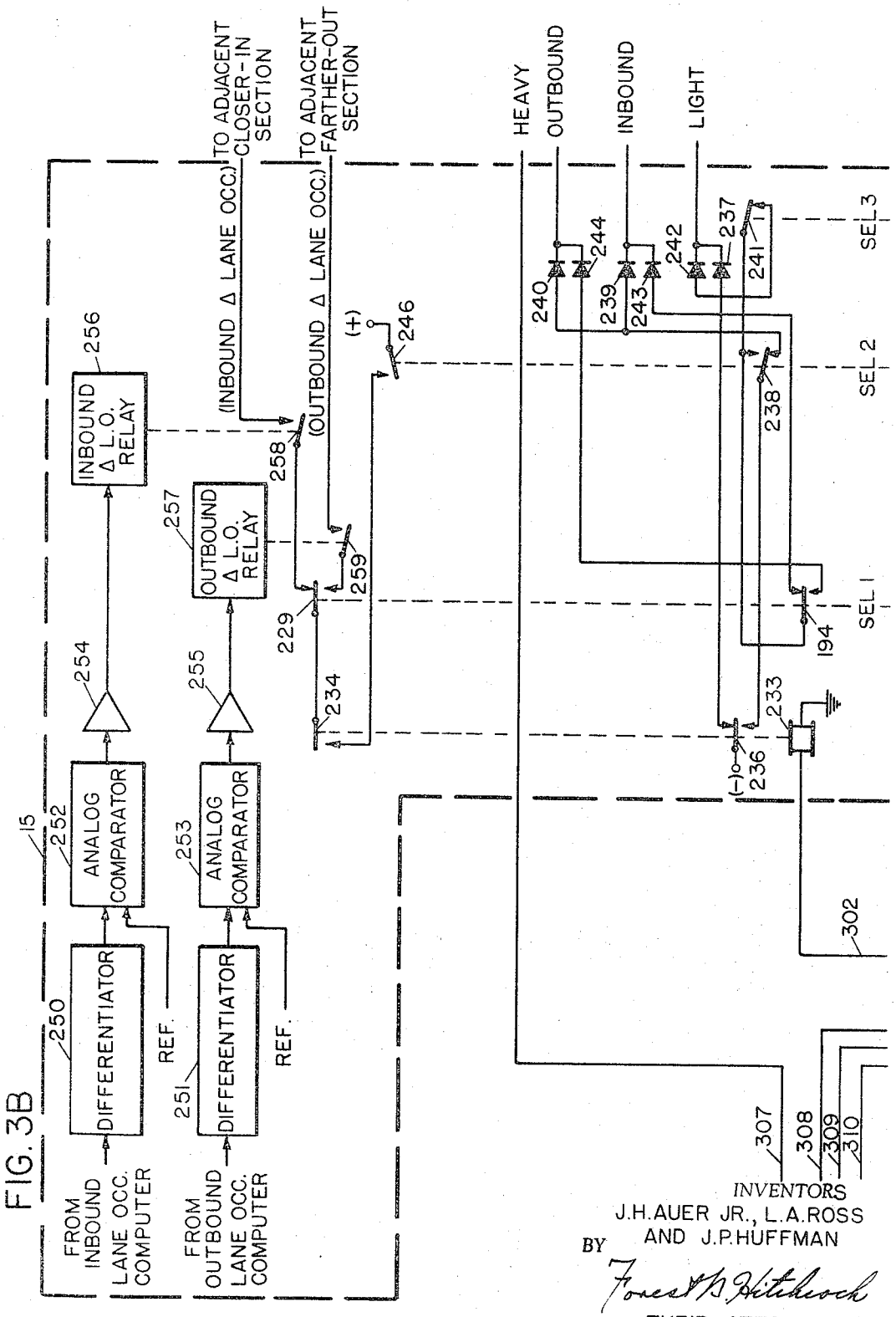


INVENTORS
J.H.AUER JR., L.A.ROSS
AND J.P.HUFFMAN
BY Forrest B. Hutchcroft
THEIR ATTORNEY

Feb. 28, 1967 J. H. AUER, JR., ETAL 3,307,146

OFFSET SELECTOR

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INVENTORS
J.H.AUER JR., L.A.ROSS
AND J.P.HUFFMAN
BY Forest B. Hitchcock
THEIR ATTORNEY

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3,307,146

OFFSET SELECTOR

John H. Auer, Jr., Fairport, and Lyle A. Ross and Jerry P. Huffman, Rochester, N.Y., assignors to The General Signal Corporation, Rochester, N.Y., a corporation of New York

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6 Claims. (Cl. 340—35)

This invention relates to traffic control systems, and more particularly to a system for selecting offsets for traffic signals along a section of highway in accordance with demands of traffic.

Offset may be defined as the number of seconds or percent of the time cycle at which a green indication appears at a given traffic control signal after a certain instant used as a time reference base. In order to progress traffic smoothly along an urban arterial highway, successive traffic signals encountered by arterial vehicular traffic should be green. This requires that the offset for each successive traffic signal be greater than the offset for the preceding traffic signal. For proper control of each traffic signal, a plurality of offsets should be provided for the signal. Only one particular offset may then be selected by energization of one or more leads from a central control point to each traffic signal controller.

To avoid congestion and facilitate arterial traffic flow, it is necessary to control signal offsets in accordance with demand on the highways. Since traffic varies with the time of day, day of the week, weather conditions, etc., the most efficient way to achieve such control is to provide offsets for the controllers which are automatically selected in accordance with traffic demands on the highway. Although it is possible to pre-program offsets in a traffic control system, such pre-programming fails to take account of unexpected conditions; instead, pre-programming restricts operation of the controllers to a rigid schedule. This prevents the flexibility of operation which is especially desirable under adverse weather conditions, inadvertent traffic stoppages such as those due to vehicular mishaps, etc.

Another problem encountered particularly in traffic signal control along arterial highways in larger cities is that of controlling a relatively large number of traffic signals along an artery from a single control system in response to demands of traffic. Interconnection of the signals is necessary in order to promote smooth traffic flow, since efficient control of signals along a section of highway requires that all traffic conditions within that section be taken into account along with significant conditions within both sections adjacent that section.

The invention as herein proposed permits individual control of traffic signal offsets at each traffic signal local controller along a section of artery from a single offset selector. This is accomplished by dividing the artery into a number of arterial sections, each section encompassing a plurality of local controllers. For an artery of length sufficient to require use of a large number of local controllers, there is associated with the controllers a plurality of offset selectors. Each offset selector provides offset signals for the local controllers in the arterial section associated therewith based upon actual traffic conditions within the section and specified significant conditions within adjacent sections on either side. This is accomplished by interconnecting the offset selector for each arterial section with the offset selectors for the adjacent sections on both sides, permitting specified congestion conditions in each adjacent section to be sensed. Hence, offset changes can be produced progressively along the artery, enabling traffic to flow through the artery within a minimum of delay.

Two traffic control parameters which may be used in combination to reflect traffic conditions along a highway to a high degree of accuracy are lane occupancy and volume. Lane occupancy may be defined as the percentage of highway which is vehicle-occupied at any given instant of time; however, since this is a spatial concept, continuous measurement of which is rather difficult, lane occupancy is more frequently expressed as a percentage ratio of vehicle presence time to total time at any specified point. This ratio is a close approximation of spatial lane occupancy, provided traffic is moving along at a relatively constant speed. Besides being an accurate measure of traffic conditions, the parameter of traffic lane occupancy may readily be computed with a minimum of equipment and circuit complexity.

Traffic volume may be expressed as the number of vehicles passing a particular point during any given period of time. This parameter is a fairly accurate measure of traffic congestion, provided traffic is free-flowing; however, as congestion increases, and speed of traffic is restricted accordingly, traffic volume no longer represents an accurate measure of traffic congestion, since the rate of vehicles passing a fixed point during a given interval of time is substantially decreased, indicating low congestion when, in actuality, congestion is at a very high level.

The invention contemplates utilization of both lane occupancy and volume parameters, in order to provide highly accurate selection of offsets in accordance with actual traffic conditions, comprising first and second level monitors, each of which selectively provides a discrete output in accordance with a given level of input voltage amplitude. The first level monitoring means is responsive to the greater one of inbound lane occupancy and volume parameters within a specified section of arterial highway, and the second level monitoring means is responsive to the greater one of outbound lane occupancy and volume parameters within the specified section of highway. Outputs of the level monitors are used to selectively control a voltage divider and phase inverter circuit which provides an output voltage in accordance with both inbound and outbound lane occupancy and inbound and outbound volume conditions within the section. The output voltage produced by the voltage divider and phase inverter circuit is then coupled to a voltage modifier which discretely alters the latter output voltage in response to a sharp change in lane occupancy in either direction, occurring within either section of highway adjacent the specified section. The output voltage produced by the voltage modifier is applied to analog-to-digital conversion means, which selectively provides one or more discrete output voltages in accordance with the amplitude of applied voltage, thereby producing the proper offset for the specified section.

Each level monitor comprises first and second analog comparator means having a first input responsive to analog traffic congestion voltages, a group of n switching means where n represents any integer greater than one, a plurality of reference voltages, first circuit means re-

sponsive to the switching means for controlling coupling one of the reference voltages to a second input of the first analog comparator means, second circuit means responsive to the switching means for controllably coupling another of the reference voltages to a second input of the second analog comparator means, means coupling output voltage from the first analog comparator means to the input of the $(n-1)$th switching means when said $(n-1)$th switching means is deenergized, and means coupling output voltage from the second analog comparator means to the input of the $(n-1)$th switching means and from the first analog comparator means to the nth switching means when said $(n-1)$th switching means is energized.

Accordingly, one object of this invention is to provide selection means for producing offset signals for traffic controllers along a highway in accordance with demands of traffic.

Another object is to provide a system for selecting offffsets for traffic controllers along a highway in accordance with either volume or lane occupancy conditions, whichever is greater, in both inbound and outbound directions.

Another object is to provide a novel level classification circuit for selectively producing discrete output voltages in accordance with the amplitude of applied voltages.

Another object is to provide a system for selecting offsets for traffic signal controllers located along a section of a vehicular route based upon demands of existing traffic within the section and changing traffic conditions within adjacent sections.

Another object is to provide a traffic control system for a sectionalized artery wherein traffic signal controllers for each section are independently controlled from separate offset selection means which are dependent upon high volume and high lane occupancy conditions within the section controlled therefrom and changing lane occupancy conditions within the adjacent sections.

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

FIG. 1 is a block diagram of an offset selector for a section of artery situated between two adjacent sections of the artery.

FIG. 2 is a chart illustrating offset coding as produced by the offset selector.

FIGS. 3A–3D constitute a partial schematic and partial block diagram showing the system of FIG. 1 in greater detail.

FIG. 4 is a drawing showing how FIGS. 3A–3D are to be assembled.

Turning now to FIG. 1, there is shown a pair of level monitors **10** and **11**. Level monitor **10** is responsive to analog data suplied by lane occupancy and volume computers responsive to traffic in the inbound direction within the section of highway controlled by the offset selector, while outbound level monitor **11** is responsive to analog data supplied by lane occupancy and volume computers monitoring traffic in the outbound direction within the section. The lane occupancy computers may be of the type shown in J. H. Auer, Jr., et al. application Ser. No. 305,967, filed September 3, 1963, while the volume computers may assume any one of well-known configurations.

The inbound and outbound level monitors function as analog-to-digital converters, in that they convert analog input signals into a selected one of a plurality of discrete output signals, in accordance with the amplitude of the input voltage. These discrete output signals are used to provide amplitude and phase control of the voltage produced by an A.C. supply **12**. The amplitude and phase controlled A.C. voltage is then coupled to a voltage modifier **14**. The circuitry involved in controlling the amplitude and phase of the A.C. voltage comprises an adjustable voltage divider and phase inverter circuit, designated divider-inverter circuit **13**. In this fashion, the amplitude of A.C. voltage supplied to voltage modifier **14** is controlled by the setting of divider-inverter circuit **13**, which in turn is responsive to outputs from level monitors **10** and **11**.

Voltage modifier **14** functions to further control the amplitude of A.C. voltage coupled through the system in accordance with predetermined magnitudes of changes in lane occupancy in adjacent sections. Thus, the amplitude of A.C. voltage is controllably increased by changes in excess of a predetermined value in inbound lane occupancy within the adjacent farther-out section, and by changes above a predetermined magnitude in outbound lane occupancy occurring within the adjacent closer-in section. The modified A.C. voltage is then supplied to analog-to-digital converter **15**, which energizes one or more output leads in accordance wtih the amplitude and phase of the applied input voltage. Thus, outputs are supplied which are indicative of light offsets or of an expected preferential offset in the inbound or outbound direction, heavy offset, and a preferential offset in either the inbound or outbound direction. In addition, changes in lane occupancy of a predetermined magnitude in the outbound direction are supplied to the offset selector for the adjacent farther-out section, while similar changes in inbound lane occupancy above a predetermined magnitude are supplied to the adjacent closer-in section. Changes in lane occupancy are herein designated Δ LANE OCC.

The chart of FIG. 2 indicates one type of coding by which offset information may be supplied from analog-to-digital converter **15** to the local controllers situated along the section of highway monitored and controlled by the offset selector. The chart indicates that energization of either the light or heavy output leads indicates either light or heavy traffic, respectively; similarly, energization of either the inbound or outbound leads indicates a preferential offset in the inbound or outbound directions, respectively. Energization of both outbound and inbound leads simultaneously indicates an average offset. Simultaneous energization of the light and outbound output leads indicates an expected preferential offset in the outbound direction, while simultaneous energization of the light and inbound output leads indicates an expected preferential offset in the inbound direction.

Turning next to FIGS. 3A–3D arranged as illustrated in FIG. 4, for a more detailed description of the system, leads **301–310** designate leads interconnecting the apparatus of the figures. Inbound level monitor **10** is shown in detail, while outbound level monitor **11** is illustrated in block form, since it comprises circuitry which duplicates that of inbound level monitor **10**. Analog voltages from the inbound lane occupancy computer are received at the anode of a diode **101**, while analog voltages from the inbound volume computer for the monitored and controlled section are received at the anode of a diode **102**. The cathodes of diodes **101** and **102** are directly coupled to each other and to one input of each of analog comparators **103** and **104**. These comparators algebraically sum the input voltage applied thereto, and when the polarity of the algebraic sum changes, output voltage from the analog comparator abruptly changes from a large amplitude voltage of one polarity to a large amplitude voltage of the opposite polarity.

A pair of variable resistance networks **105** and **106** are also provided. Network **106** is identical in circuitry to that of network **105**, and therefore is shown in block form. Network **105** comprises a plurality of potentiometers, here seven each providing an adjustable negative output voltage. Similarly, network **106** provides seven adjustable negative output voltages.

Level monitor **10** also comprises a plurality of switching circuits SW1–SW7. Since each of these switching circuits is identical in circuit configuration to that of switching circuit SW1, circuits SW2–SW7 are shown in block form. Switching circuit SW1 comprises a relay **80** controlled by a pair of transistors **81** and **82**. Associated

with relay **80** are contacts **110**, **111**, **112**, **113** and **114**. The heel of contact **111** resistively couples a voltage from analog comparator **103** to the base of transistor **81** through a pair of series-connected resistors **83** and **84**. The polarity of voltage supplied to back contact **111** may either be negative or positive, depending upon the polarity of the algebraic sum of voltage supplied to the input of the comparator. A negative reference voltage is supplied to the input of comparator **103** from resistance network **105** through back contact **110**.

The base of transistor **81** is coupled to the negative terminal of the power supply through a capacitor **85** in series with base resistor **84**. The collector of transistor **81** is coupled to relay **80**, the other side of which is coupled to the negative power supply terminal. The emitter of transistor **81** is coupled to ground through a forward-biased diode **118**, which biases the emitter of transistor **81** slightly below ground to assure that the transistor will remain non-conductive when its base voltage is zero. The cathode of the diode is also coupled to the negative supply terminal through a pair of series-connected resistors **86** and **87**. The base of transistor **81** is coupled to the collector of transistor **82** through a coupling resistor **88**. The collector of transistor **82** is also coupled to the point common to resistors **86** and **87**. The collector of transistor **81** is coupled to the positive terminal of the power supply through a pair of series-connected resistors **89** and **90**, while the base of transistor **82** receives bias from the point common to resistors **89** and **90**. The emitter of transistor **82** is grounded, and a diode **91** is shunted across relay **80** in order to short-circuit any surges produced when the relay is deenergized, thereby protecting the transistors.

Operation of switching circuit SW1 occurs in the following fashion. As long as the larger one of the positive input voltages supplied by the inbound lane occupancy computer and inbound volume computer remains below the negative amplitude of voltage supplied by variable resistor network **105** through back contact **110** to analog comparator **103**, the output voltage produced by the analog comparator remains positive in polarity. Hence, positive bias exists on the base of transistor **81**, maintaining the transistor non-conductive. Relay **80** thus remains deenergized.

However, when the larger one of the positive voltages supplied by the inbound lane occupancy and volume computers exceeds the magnitude of voltage supplied to analog comparator **103** through back contact **110**, the output voltage produced by the analog comparator abruptly swings negative. This drives the base of transistor **81** negative with respect to the emitter, rendering it conductive. Current is thereupon supplied to relay **80** through transistor **81**, and the base of transistor **82** is driven in a positive direction. Transistor **82**, which was conducting during the time in which transistor **81** was non-conductive, is thereupon driven out of conduction. The point common to resistors **86** and **87** then swings negative, driving transistor **81** further into conduction, causing relay **80** to energize. During the relay crossover time in which the source of drive for transistor **81** is removed due to front and back contacts **111** being momentarily opened, sufficient drive current is supplied to the base of transistor **81** by capacitor **85** to maintain the transistor in conduction.

When front contact **111** closes, the base of transistor **81** is coupled to the output of analog comparator **104** through a series circuit comprising back contacts **130–135** of switching circuit SW2–SW7, respectively, and resistors **83** and **84**. Depending upon the amplitude of negative voltage supplied to back contact **136** associated with switching circuit SW2, relay **80** will either remain enerigzed or become deenergized. This is so, since a negative voltage is supplied to analog comparator **104** from variable resistance network **106** through a series circuit comprising back contacts **136–141** of switching circuits SW2–SW7, respectively. Assuming the amplitude of voltage at back contacts **136** is sufficiently small so that the algebraic sum of input voltage supplied to analog comparator **104** is positive in polarity, a negative output voltage is produced by analog comparator **104** which maintains transistor **81** in conduction and relay **80** energized. It should be noted, however, that if the magnitude of negative voltage at back contact **136** were greater than the magnitude of positive voltage supplied to the input of analog comparator **104** from the inbound volume and lane occupancy computers, the output voltage produced by comparator **104** would be positive, and transistor **81** would thereby be driven out of conduction causing relay **80** to deenergize. Front contact **111** would then open and back contact **111** would close, thereby resupplying negative voltage to the base of transistor **81**, reenergizing relay **80**. In this manner, an oscillation of relay **80** would occur. However, such condition may be entirely obviated by setting the lowermost potentiometer in variable resistor networks **105** and **106** so as to produce a smaller negative voltage on back contact **136** than exists on back contact **110**. This assures that relay **80** will remain energized over a predetermined range of the larger one of the traffic computer output voltages.

It should be noted that while relay **80** is deenergized, positive voltage is supplied through back contact **112** and a back contact **146** associated with switching circuit SW2 to the input of switching circuit SW2, thereby maintaining the circuit in a deenergized condition. However, while relay **80** is energized, voltage produced by analog comparator **103** is coupled to back contact **146** through front contact **112**. In addition, front contact **110** of relay **80** couples a new value of negative voltage through a back contact **147** of switching circuit SW2 to the input of analog comparator **103**. The amplitude of negative voltage supplied to the input of analog comparator **103** through back contact **147** in series with front contact **110** is preferably of greater value than that supplied through back contact **110** when relay **80** is deenergized. Thus, if the magnitude of the larger one of the input voltage to analog comparator **103** from the inbound lane occupancy and volume computers remains below the magnitude of voltage supplied to the input of analog comparator **103** from back contact **147**, output voltage supplied by analog comparator **103** is positive and is coupled through front contact **112** in series with back contact **146** to the input of switching circuit SW2, maintaining the switching circuit deenergized. However, if the absolute value of the larger one of the input voltages supplied by the inbound lane occupancy and volume computers to analog comparator **103** exceeds the absolute amplitude of negative voltage supplied to the input of analog comparator **103** through back contact **147**, the polarity of output voltage produced by comparator **103** swings negative, providing a negative input voltage for switching circuit SW2. In fashion identical to that described for switching circuit SW1, switching circuit SW2 is energized, closing front contact **136**. At this time, the negative voltage appearing at front contact **136** is supplied through a series circuit comprising back contacts **137–141** of switching circuits SW3–SW7, respectively, to the input of analog comparator **104**. Since the amplitude of negative voltage at front contact **136** is selected so as to be less than the amplitude of negative voltage at back contact **147**, negative input voltage is supplied to switching circuit SW2 from the output of analog comparator **104** through back contacts **131–135** of switching circuits SW3–SW7, respectively, in series with front contact **146** of switching circuit SW2. In this fashion, therefore, a rising input voltage is supplied to analog comparators **103** and **104** from the inbound lane occupancy and volume computers closes the contacts associated with switching circuits SW1, SW2 . . . SW7, in that order.

Outbound level monitor **11**, which is identical in circuitry to inbound level monitor **10**, also provides outputs

from seven switching circuits. Outputs from both the inbound and outbound level monitors are supplied to divider-inverter circuit **13**, for control thereof. The divider-inverter receives an A.C. signal from transformer **12**. A series circuit comprising a pair of resistors **150** and **151** is connected in shunt across the secondary of transformer **12**. Resistor **151** has associated therewith a plurality of taps **152–159**. In addition, divider-inverter **13** also comprises contacts **114** and **161–166** associated with switching circuits SW1–SW6 respectively, and contacts **172–178** associated with outbound level monitor **11**. Tap **152** is coupled to front contacts **166** and **178**. Each remaining tap is coupled to a pair of back contacts in the following manner: tap **153** to back contacts **166** and **178**, tap **154** to back contacts **165** and **177**, tap **155** to back contacts **164** and **176**, tap **156** to back contacts **163** and **175**, tap **157** to back contacts **162** and **174**, tap **158** to back contacts **161** and **173**, and tap **159** to back contacts **172** and **114**. In addition, back contact **113** is coupled to a back contact **171** associated with outbound level monitor **11**, the heel of which receives positive voltage. Front contact **114** is coupled to the heel of contact **161**, while the heel of contact **114** is grounded. In addition, contacts **161–166** are connected in the following manner: front contact **161** to the heel of contact **162**, front contact **162** to the heel of contact **163**, front contact **163** to the heel of contact **164**, front contact **164** to the heel of contact **165** and front contact **165** to the heel of contact **166**. In similar fashion, contacts **172–178** are interconnected; that is, front contact **172** to the heel of contact **173**, front contact **173** to the heel of contact **174**, etc. Output voltage from divider-inverter **13** is supplied from the heel of contact **172** to the heel of a contact **180** of a relay **181** in the circuit of voltage modifier **14**. Relay **181** is energized in response to changes in inbound lane occupancy greater than a predetermined value, occurring within the adjacent farther-out section.

As front contacts **172–178** are sequentially closed by increasing outbound lane occupancy and volume voltages supplied by the outbound lane occupancy and volume computers, A.C. voltage is supplied from source **12** through taps **159–152** in descending order, respectively, to the heel of contact **180**. Similarly, as front contacts **114, 161, 162, 163, 164, 165** and **166** are sequentially closed, ground potential is applied to taps **158, 157, 156, 155, 154, 153** and **152**, respectively, in that order. Hence, in accordance with amplitude of voltage supplied to both level monitors, output voltage is supplied to contact **180** from any of taps **152–159**, while one of taps **152–159** is grounded. In this fashion, selected amplitudes of voltage are automatically chosen from resistor **155** and supplied to the heel of contact **180** with respect to ground. For straightforward operation, the segments of resistor **151** should all be of equal ohmic value; thus, voltage appearing across any pair of adjacent taps on resistor **151** is equal in amplitude to voltage appearing across any other pair of adjacent taps on the resistor. Resistor **150** is used for adjusting the total voltage across resistor **151** in order to control the voltage across each segment of resistor **151**.

Operation of divider-inverter **13** may best be illustrated by considering a few specific examples. For instance, consider the situation in which inbound level monitor front contacts **114, 161** and **162** are closed (denoting the fifth highest inbound congestion level) and outbound level monitor front contact **172** is closed (denoting the seventh highest outbound congestion level). Ground is applied to tap **156** on resistor **151** through front contacts **114, 161, 162** and back contact **163**, in series. Output voltage is supplied to the heel of contact **180** from tap **158** on resistor **151** through back contact **173** and front contact **172**, in series. Since the output voltage is therefore that appearing across two segments of resistor **151**, the amplitude of voltage appearing across taps **156** and **158** exists at the heel of contact **180**, when referred to ground. Moreover, since the output voltage is taken from the voltage divider at a point below that to which ground is applied, a specific phase relationship also exists between taps **158** and **156**, which is used to determine whether the inbound or outbound traffic congestion level is highest, as is shown, infra.

Consider next the situation in which inbound level monitor front contact **114** is closed (denoting the seventh highest inbound congestion level) and outbound level monitor front contacts **172, 173, 174, 175** and **176** are closed (denoting the third highest outbound congestion level). In this condition, output voltage is supplied to the heel of contact **180** from tap **154** on resistor **151**, while ground is applied to tap **158** on resistor **151** through front contact **114** and back contact **161**. Four voltage divider segments on resistor **151** therefore separate the output voltage tap from the ground potential tap on resistor **151**, so that the output voltage referred to ground comprises the voltage across the four segments. Moreover, since the output voltage is taken from the voltage divider resistor at a point higher on the resistor than that to which ground is applied, the opposite phase relationship exists from that given in the example of the preceding paragraph.

Back contact **180** is coupled to a back contact **183** of a relay **185** which is responsive to changes in outbound lane occupancy above a predetermined level, occurring within the adjacent closer-in section. The heel of contact **183** is resistively coupled to the base of a a transistor **186**, which, along with transistors **187** and **188** and a relay **189** comprise a selector circuit SEL1. The collectors of transistors **186** and **187** are coupled to the base of transistor **188**. Negative potential is supplied to the collectors of transistors **186** and **187** through a collector load resistor **190**. The emitters of transistors **186** and **187** are grounded, while the emitter of transistor **188** is biased slightly below ground potential by the forward voltage drop across a diode **195** having its anode grounded and its cathode negatively biased through a resistor **196**. Relay **189** is energized from the collector of transistor **188**, and a diode **197** is shunted across relay **189** in order to protect transistor **188** against inductively-produced surges occurring when the relay is deenergized. The $\pm$ terminal of the secondary winding of a transformer **198** is coupled to a back contact **193** of relay **189**, while the $\mp$ terminal of the secondary winding of transformer **198** is resistively coupled to the base of transistor **187** and directly coupled to front contact **193**. A negative bias voltage is supplied to the centertap of the secondary winding of transformer **198** through a voltage divider **199**. It should be noted that additional selection circuits SEL2 and SEL3 are provided, having circuitry identical to that shown in selection circuit SEL1. The heel of contact **193** supplies one input to each of selection circuits SEL2 and SEL3, comparable to the input to transistor **187** in selection circuit SEL1, while second inputs are supplied to each of selection circuits SEL2 and SEL3 from a pair of selector switches **206** and **207**, respectively, comparable to the input to transistor **186** in selection circuit SEL1.

A pair of front contacts **191** and **192** of relay **189** supply A.C. voltage to the $\pm$ and $\mp$ terminals respectively of the primary winding of a transformer **200**, while back contacts **191** and **192** supply A.C. voltage to the $\mp$ and $\pm$ terminals respectively of the primary winding of transformer **200**. A resistor **201** having taps **202, 203, 204** and **205** is connected in shunt across the secondary winding of transformer **200**. The secondary $\mp$ terminal is coupled to the heel of contact **183**. Taps **203, 204** and **205** on resistor **201** are separately coupled to the contacts of selector switch **206**. Similarly, taps **202, 203** and **204** on resistor **201** are separately coupled to the contacts of selector switch **207**.

Assume now that relays **181** and **185** are deenergized, and that no voltage is present on contact **180**. Under these conditions, relay **189** is energized. This is so, since transistor **186**, having zero voltage applied to its base

through back contact **183**, is in a continuous non-conductive condition, while transistor **187** conducts on each half cycle during which voltage at the ∓ terminal on the secondary winding of transformer **198** is negative.

Because transistors **186** and **187** employ a common collector resistor **190**, collector voltage on transistors **186** and **187** is negative whenever both of the transistors are non-conductive. Thus, transistor **188** is driven into conduction during each half cycle in which both transistors **186** and **187** are non-conductive. Relay **189** is thereby energized by the pulsating collector current, and remains energized during each half cycle in which current flows through collector resistor **190** due to slow dropaway characteristics introduced by diode **197** in a manner well-known in the art.

With zero voltage on contact **180**, such as with back contacts **114** and **172** of divider-inverter circuit **13** closed, the voltage at tap **205** of resistor **201** is out-of-phase with respect to the voltage on front contact **193**. Thus, since the circuitry of selection circuit SEL2 is identical to the circuitry of selection circuit SEL1, output contacts **238** and **246** remain in their deenergized condition. For similar reasons, contact **241** of selection circuit SEL3 also remains in its deenergized condition.

Influence of changes in lane occupancy occurring within adjacent sections is supplied through circuitry comprising an inbound selector switch **230**, an outbound selector switch **231** and a transformer **232**. Relays **181** and **185** determine when the influence of the adjacent sections is to be applied, being associated with the adjacent farther-out and closer-in sections respectively. The increments of output voltage provided on the secondary of transformer **232** are equal in amplitude to the increments of voltage provided across individual segments of resistor **151** in divider-inverter circuit **13**. Taps A, B and C on in-bound selector switch **230** are coupled respectively to taps D, E and F on outbound selector switch **231**. Taps C and F are coupled to the ∓ terminal on the secondary winding of transformer **232**, taps B and E are connected to the centertap of the secondary winding of transformer **232** and taps A and D are connected to ± secondary winding terminal on transformer **232**. Back contacts **180** of relay **181** and **183** of relay **185** are each coupled to taps C and F of the inbound and outbound selector switches. Front contact **180** is coupled to a first armature G on inbound selector switch **230**, while front contact **183** is coupled to a first armature H of outbound selector switch **231**.

Increments of voltage supplied by the secondary winding of transformer **232** may be added to the output voltage provided by divider-inverter circuit **13**, depending upon the condition of influence relays **181** and **185**. The number of increments added for inbound or outbound influence is selected by switches **230** and **231** respectively. Zero, one or two increments of voltage may be added to the voltage produced by divider-inverter circuit **13**, depending upon the setting of the inbound and outbound selector switches.

Voltages appearing between taps **202** and **203**, **203** and **204**, and **204** and **205** on resistor **201** are preferably selected so as to equal the voltage increment appearing between any two adjacent taps on resistor **151** in divider-inverter circuit **13**, while voltage appearing across the lowermost segment of resistor **201** is preferably selected so as to equal one and one-half times the voltage appearing between any two adjacent taps on resistor **151**. This may be accomplished through adjustment of voltage across resistor **151** by proper choice of resistor **150**.

To illustrate offset selection, assume the following conditions are in existence: front contacts **114**, **161**, **162** and **163** in divider-inverter circuit **13** are closed by inbound level monitor **10**, while front contact **172** in the divider-inverter circuit is closed by outbound level monitor **11**. Assume further that armature G of inbound selector switch **230** is set on tap B, armature H of outbound selector switch **231** is set on tap D, selector switch **205** couples tap **204** to selection circuit SEL2, selector switch **207** couples tap **202** to selection circuit SEL3, and relay **181** is energized. Under these circumstances, tap **155** on resistor **151** is grounded, and output voltage produced by divider-inverter circuit **13** is provided from tap **158** of resistor **151**. Hence, the three voltage increments which appear between taps **155** and **158** on resistor **151** now exist on the output of the divider-inverter circuit with respect to ground. In addition, since relay **181** is energized, selector switch **230** adds one increment of voltage to the output voltage of the divider-inverter circuit before it is supplied to the secondary winding ∓ terminal of transformer **200**. Since the phase of voltage on the base of transistor **186** corresponds to the phase of voltage on the base of transistor **187**, and may be designated the ∓ phase, transistors **186** and **187** are both non-conductive during identical halves of each cycle. Thus, relay **189** is energized, as previously described, and the phase of voltage on the secondary winding of transformer **200** then is opposite to the phase of output voltage supplied by the divider-inverter circuit. It will be noted that input voltage supplied to selector circuit SEL2 from the secondary of transformer **198** is in phase with the voltage supplied to selection circuit SEL2 from selector switch **206**. This is because the amplitude of voltage supplied to contact **183** exceeds the amplitude of voltage appearing across the lowermost two segments of resistor **201**; that is, four increments of voltage having the ∓ phase are supplied to contact **183**, and only two and one-half increments of voltage having the ± phase are algebraically added to these within the lowermost two segments of resistor **201**. Hence, since both input voltages to selection circuit SEL2 are of the ∓ phase, the front contacts associated therewith are closed. However, since selector switch **207** provides an input voltage to selection circuit SEL3 from tap **202** of resistor **201**, four and one-half increments of voltage having the ± phase are algebraically added to the four increments of voltage having the = phase supplied to contact **183**. This results in voltage on selector switch **207** acquiring the ± phase, rendering the input voltages supplied to selection circuit SEL3 out-of-phase with each other. Contact **241** thus assumes its deenergized condition. The reason for this may be understood by considering operation of selection circuit SEL1. Thus, whenever the phase of voltage supplied to the base of transistor **186** is opposite to that supplied to the base of transistor **187**; that is, when ground potential is applied to a tap on resistor **151** below the tap from which output voltage from resistor **151** is taken, either transistor **186** or **187** conducts at any given time, so that current flows substantially continuously through common collector resistor **190**. This maintains transistor **188** non-conductive, causing relay **189** to deenergize.

Whenever relay **189** deenergizes, the voltage applied to the primary winding of transformer **200** undergoes a phase reversal, since front contacts **191** and **192** are opened and back contacts **191** and **192** are closed. Similarly, back contact **193** closes and front contact **193** opens, so that both inputs to each of selection circuits SEL2 and SEL3 undergo a phase reversal. Hence, operation of selection circuits SEL2 and SEL3 is unaffected. However, such reversal of contacts **191**, **192** and **193** is necessary, since the voltage increments appearing across the segments of resistor **201** must assume a bucking polarity with respect to the polarity of voltage appearing on contact **183**. Hence, if ground potential is applied to a tap on resistor **151** below the tap from which output voltage is produced, the phase of voltage supplied to the base of transistor **186** is opposite to the phase of voltage supplied to the base of transistor **187**. Under such circumstances, either transistor **186** or **187** conducts at any given time, causing relay **189** to deenergize. This closes back contacts **191**, **192** and **193**, thereby reversing the phase of each input voltage supplied to selector circuits SEL2 and SEL3 from transformers **198** and **200**. Moreover, the

phase reversal on transformer **200** assures that the voltage on each segment of resistor **201** is of polarity to oppose the voltage produced from divider-inverter circuit **13**.

A relay **233** having associated therewith contacts **234** and **236** receives energization through back contacts **171** and **113** in series, which are situated in divider-inverter circuit **13**. Hence, only under light traffic conditions in both directions is this relay energized. Under these circumstances, energy is supplied through front contact **236** in series with a diode **237** to an output indicative of light offset. On the other hand, when relay **233** is deenergized, indicating that an offset condition other than light exists, back contact **236** provides energy to the heel of contact **238** associated with selection circuit SEL2. Back contact **238** provides inbound and outbound offset information through diodes **239** and **240**, respectively. Front contact **238** provides energy to the heel of contact **241** associated with selection circuit SEL3. Back contact **241** provides energization of the light offset output lead through a diode **242** in series with front contact **238** and back contact **236**. The inbound offset output lead in also energized through a diode **243** in series with a front contact **194** of relay **189**, front contact **238** and back contact **236**, while the outbound offset output lead is energized through a diode **244** in series with back contact **194**, front contact **238** and back contact **236**. Those skilled in the art will recognize that diodes **237**, **239**, **240**, **242**, **243** and **244** are necessary to protect against "sneak" circuits, which constitute undesired current paths.

Voltage modifier circuit **14** includes a second portion of inbound selector switch **230** comprising taps I, J and K and a second portion of outbound selector switch **231** comprising taps L, M and N. The second portion of inbound selector switch **230** is controlled by an armature P which is ganged with armature G, while the second portion of outbound selector switch **231** includes an armature Q which is ganged with armature H. Energization of armature P is supplied from a front contact **182** of relay **181**, while energization of armature Q is supplied from a front contact **184** of relay **185**. A plurality of front contacts **145**, **142**, **143** and **144** are driven from switching circuits SW4, SW5, SW6 and SW7 respectively, in inbound level monitor **10**. The heels of contacts **145**, **142** and **143** are coupled to taps I, J and K, respectively, of inbound selector switch **230**, while front contacts **145**, **142**, **143** and **144** are coupled to gether to provide energization of the heavy offset output lead. Hence, when relay **181** is energized, if armature P of inbound selector switch **230** is coupled to a closed one of front contacts **145**, **142** or **143**, the heavy offset output lead is energized. Moreover, since the heel of contact **144** is coupled to the positive voltage source, closing of front contact **144** energizes the heavy offset output lead regardless of inbound lane occupancy conditions in the adjacent farther-out section. Circuitry similar to that comprising contacts **145**, **142**, **143** and **144** also exists in outbound level monitor **11**, and is likewise coupled to the heavy offset output lead, as indicated by wire **301**, so that energization of relay **185** may provide energization of the heavy offset output lead, depending upon whether taps L, M or N in outbound selector switch **231** are coupled to closed front contacts in outbound level monitor **11**.

Changes in lane occupancy at rates in excess of predetermined amounts are supplied to apparatus controlling traffic signals in either adjacent section. Thus, outputs from the inbound and outbound lane occupancy computers for the section associated with the circuitry herein discussed are provided to differentiator circuits **250** and **251**, respectively. Outputs from differentiator circuits **250** and **251** are supplied to analog comparators **252** and **253**, respectively. Reference potentials are supplied to second inputs in each of analog comparator circuits **252** and **253**. Output voltages produced by analog comparators **252** and **253** are coupled through amplifiers **254** and **255**, respectively, to an inbound lane occupancy relay **256** and an outbound lane occupancy relay **257**, respectively. Relay **256** has associated therewith a front contact **258**, while relay **257** has associated therewith a front contact **259**.

Energization of inbound lane occupancy relay **256** occurs in the following manner. Assume the output voltage from the inbound lane occupancy computer for the adjacent farther-out section changes. Differentiator circuit **250** provides an output voltage of amplitude dependent upon slope of the change in inbound lane occupancy computer output voltage amplitude. Analog comparator **252** then compares the amplitude of voltage supplied by differentiator **250** with a predetermined reference voltage, and whenever the magnitude of differentiator output voltage exceeds the magnitude of the reference voltage supplied to comparator **252**, an abrupt change in output voltage polarity is provided by comparator **252**, which is amplified and supplied to inbound lane occupancy relay **256**, energizing the relay. The energized condition of inbound lane occupancy relay **256** signifies that a change in inbound lane occupancy in excess of the predetermined rate of change is occurring. However, when the inbound lane occupancy computer output voltage begins to level off, output voltage provided by differentiator **250** decreases. When the magnitude of output voltage provided by differentiator **250** diminishes to a value below the magnitude of the reference voltage supplied to analog comparator **252**, the polarity of output voltage provided by comparator **252** again abruptly changes, and inbound lane occupancy relay **256** thereupon deenergizes. Operation of the circuitry associated with outbound lane occupancy relay **257** occurs in a fashion identical to that described for inbound lane occupancy relay **256** in response to changes in outbound lane occupancy occurring within the adjacent closer-in section.

With relay **233** deenergized, indicating that traffic congestion conditions in either or both directions are other than light, and with front contact **246** associated with selector circuit SEL2 closed, indicating a moderate difference in congestion levels in the inbound and outbound directions, positive voltage is supplied to the heel of a contact **229** of relay **189**. Energization of relay **189** indicates an excess in inbound congestion over outbound traffic congestion, while deenergization of relay **189** indicates an excess of outbound traffic congestion over inbound traffic congestion. Front contact **229** is coupled to the heel of contact **258**, while back contact **229** is coupled to the heel of contact **259**. Hence, with relay **189** energized, energization of inbound lane occupancy relay **256** provides, to the adjacent closer-in section, a signal indicative of a rate of change in inbound lane occupancy greater than a predetermined value, while when relay **189** is deenergized, energization of outbound lane occupancy relay **257** provides, to the adjacent farther-out section, a signal indicative of a rate of change in outbound lane occupancy greater than a predetermined value.

To briefly recapitulate operation of the circuit of FIGS. 3A–3D, the level monitors **10** and **11** are responsive to the greater one of the lane occupancy and volume voltages produced by lane occupancy and volume computers responsive to traffic in the inbound and outbound directions, respectively. In accordance with the amplitude of voltage applied to the level monitors, the amplitude and phase of A.C. voltage coupled through divider-inverter circuit **13** is affected. This voltage is then modified, if so desired, within voltage modifier circuit **14**, so as to increase or decrease the amplitude of output voltage produced by the divider-inverter circuit, provided that a change in lane occupancy above a predetermined rate is taking place in an adjacent section. Output voltage provided by voltage modifier circuit **14** is then coupled to analog-to-digital converter **15**, wherein relay **189** contained in selection circuit SEL1 is actuated in accordance with the phase of voltage received from voltage modifier

circuit **14**, which is indicative of the direction in which traffic congestion is greatest. In addition, voltage produced by voltage modifier circuit **14** is bucked by voltage within resistor **201**, requiring that the amplitude of voltage supplied by voltage modifier circuit **14** to resistor **201** must exceed two predetermined levels in order to energize both of selection circuits SEL2 and SEL3. The deenergized condition of selection circuit SEL2 energizes both the inbound and outbound offset output leads, indicating existence of an average offset. Energization of selection circuit SEL3 prevents any light offset indication by opening back contact **241**. A heavy offset is indicated whenever a predetermined one of the four highest output levels of level monitor **10** or **11** is produced, along with a signal from the appropriate adjacent section indicative of a rate of change in lane occupancy above a predetermined level, as well as whenever the highest output level of level monitor **10** or **11** is produced, regardless of adjacent section traffic conditions. Indications of a change in inbound or outbound lane occupancy occurring above a predetermined rate within the monitored section are also produced, provided at least one of the two directions of traffic within the section is not at a light congestion level, and provided further that the difference between congestion levels in either direction within the section is of sufficient magnitude to energize selection circuit SEL2.

Thus, there has been shown an offset selector utilizing both lane occupancy and volume parameters in order to provide accurate selection of offsets in accordance with actual traffic conditions. The system utilizes novel level classification circuits for selectively producing discrete output voltages in accordance with amplitude of applied input voltages, and facilitates traffic movement by providing control for a sectionalized artery wherein traffic signal controllers for each section are independently controlled from separate offset selection means which are dependent solely upon the volume or lane occupancy conditions within the controlled section, whichever is more significant, and changing lane occupancy conditions within the adjacent sections. Within each section, use is made of volume parameters at low congestion levels and lane occupancy parameters at high congestion levels to provide highly accurate representation of traffic conditions within the section.

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

What is claimed is:

1. In a traffic control system, means for selecting offsets in accordance with actual traffic conditions comprising, inbound lane occupancy measuring means responsive only to inbound traffic and producing a signal representative of inbound lane occupancy, inbound volume measuring means responsive only to inbound traffic and producing a signal representative of inbound volume, first level monitoring means having said inbound lane occupancy and volume signals applied thereto and providing a selected one of a plurality of outputs in accordance with their amplitude, outbound lane occupancy measuring means responsive only to outbound traffic and producing a signal representative of outbound lane occupancy, outbound volume measuring means responsive only to outbound traffic and producing a signal representative of outbound volume, second level monitoring means having said outbound lane occupancy and volume signals applied thereto and providing a selected one of a plurality of outputs in accordance with their amplitude, a signal source, means controlled by the outputs of said first and second level monitoring means for controlling the signal produced by said source, and output means controlled by said signal provided by said source for selecting a particular one of said offsets.

2. The means of claim **1** wherein the means controlled by the outputs of said first and second level monitoring means comprises voltage divider means having a plurality of taps, means coupling said signal produced by said source across said voltage divider means, means responsive to said first level monitoring means for applying ground potential to any one of said taps, and means responsive to the second level monitoring means for coupling the signal from any one of said taps to said output means.

3. The means of claim **1** wherein each said level monitoring means comprises first and second analog comparator means, each said comparator means having a first input responsive to said inbound lane occupancy and volume signals, at least a pair of switching means, a plurality of reference voltages, first circuit means controlled by said switching means for controllably coupling one of the reference voltages to a second input of the first analog comparator means, second circuit means controlled by said switching means for controllably coupling another of the reference voltages to a second input of said second analog comparator means, means coupling the output voltage from said first analog comparator means to the input of a first one of the switching means when said first switching means is deenergized, and means coupling the output voltage from the second analog comparator means to the input of the first switching means and from the first analog comparator means to the input of the second switching means when said first switching means is energized.

4. The means of claim **1** wherein each said level monitoring means comprises first and second analog comparator means, each said comparator means having a first input responsive to said inbound lane occupancy and volume signals, a group of n switching means where n represents any integer greater than 1, a plurality of reference voltages, first circuit means controlled by said switching means for controllably coupling one of said reference voltages to a second input of said first analog comparator means, second circuit means controlled by said switching means for controllably coupling another of said reference voltages to a second input of said second analog comparator means, means coupling the output voltage from first analog comparator means to the input of the $(n-1)$th switching means when said $(n-1)$th switching means is deenergized, and means coupling the output voltage from the second analog comparator means to the input of the $(n-1)$th switching means and from the first analog comparator means to the input of the nth switching means when said $(n-1)$th switching means is energized.

5. In a traffic control system, means for selecting offsets in accordance with actual traffic conditions comprising, inbound lane occupancy measuring means and outbound lane occupancy measuring means each producing a signal representative of lane occupancy of a corresponding direction of traffic, first and second level monitors receiving said lane occupancy signals produced respectively by said inbound and outbound lane occupancy measuring means and each producing a selected one of a plurality of discrete outputs in accordance with the level of lane occupancy signal applied thereto, an alternating-current means source, means coupling said inbound and outbound lane occupancy signals to said source to control the phase and amplitude of said voltage, and means controlled by the phase and amplitude of said voltage for selecting a desired one of a plurality of offsets.

6. The system of claim **5** in which both said inbound and outbound lane occupancy measuring means produce signals representative of lane occupancy of traffic only in a predetermined section of highway, said system further including second lane occupancy measuring means responsive only to traffic in an adjacent section lying to one

side of said predetermined section and third lane occupancy measuring means responsive only to traffic in an adjacent section lying to the other side of said predetermined section, both said second and third lane occupancy measuring means providing signals representative of lane occupancy in the respective section, and means responsive to changes in the lane occupancy signals produced by said second and third lane occupancy measuring means for controlling the amplitude of the signal produced by said alternating-current source.

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NEIL C. READ, *Primary Examiner.*

THOMAS B. HABECKER, *Examiner.*