

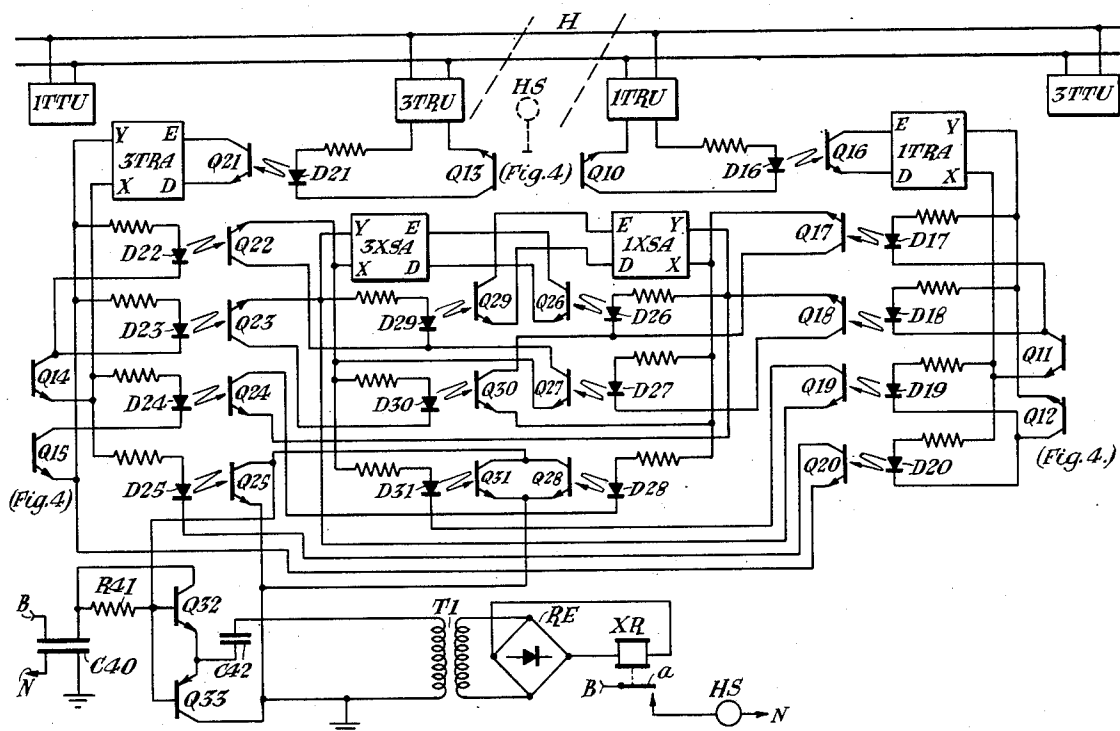
- [54] **FAIL-SAFE SOLID STATE HIGHWAY CROSSING PROTECTION APPARATUS**
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[22] Filed: **Mar. 2, 1973**
[21] Appl. No.: **337,596**
[52] **U.S. Cl.**..... **246/130, 317/148.5 R**
[51] **Int. Cl.**..... **B611 1/02**
[58] **Field of Search**..... **246/125, 130 R, 128;**
317/148.5 R

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[57] ABSTRACT
Solid state static relays, with contact circuits including insulated signal couplers formed by light emitting diodes and light responsive transistors, are used as track circuit detectors and directional stick devices in highway crossing protection systems. Each relay control circuit requires modulated switching across control input terminals to condition that relay to an energized state which activates front contact couplers. Absence of the modulated switching or a continuous circuit across the terminals conditions the relay coil circuit to activate only back contact couplers. A solid state directional logic network for highway crossing protection is formed by a selected circuit arrangement of insulated coupler elements which fulfills in a fail-safe manner the Boolean functions representing the directional crossing protection logic. The crossing protection device is controlled through an output buffer circuit by other selected couplers representing the control functions by which the device is activated only for approaching trains.

13 Claims, 4 Drawing Figures



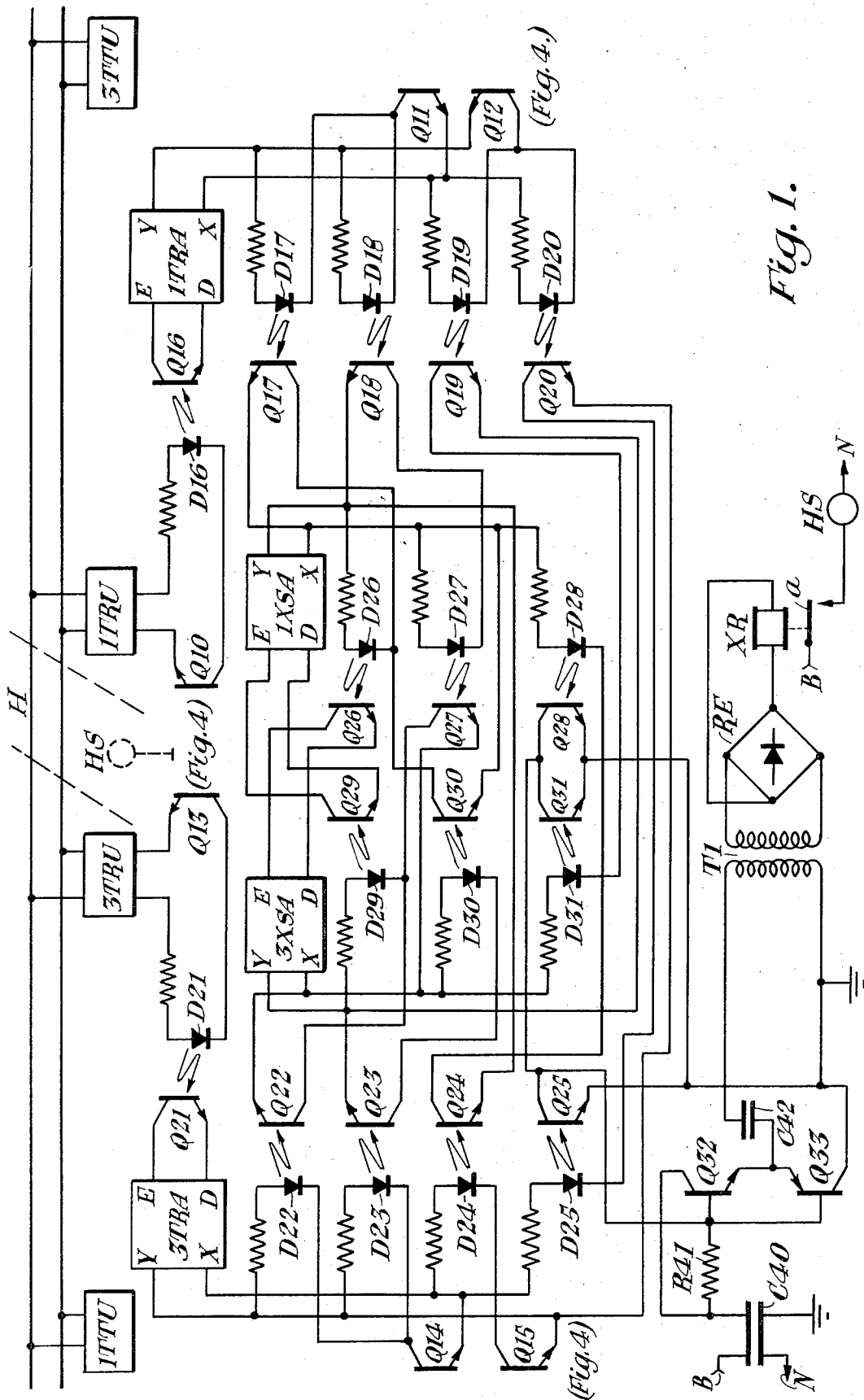
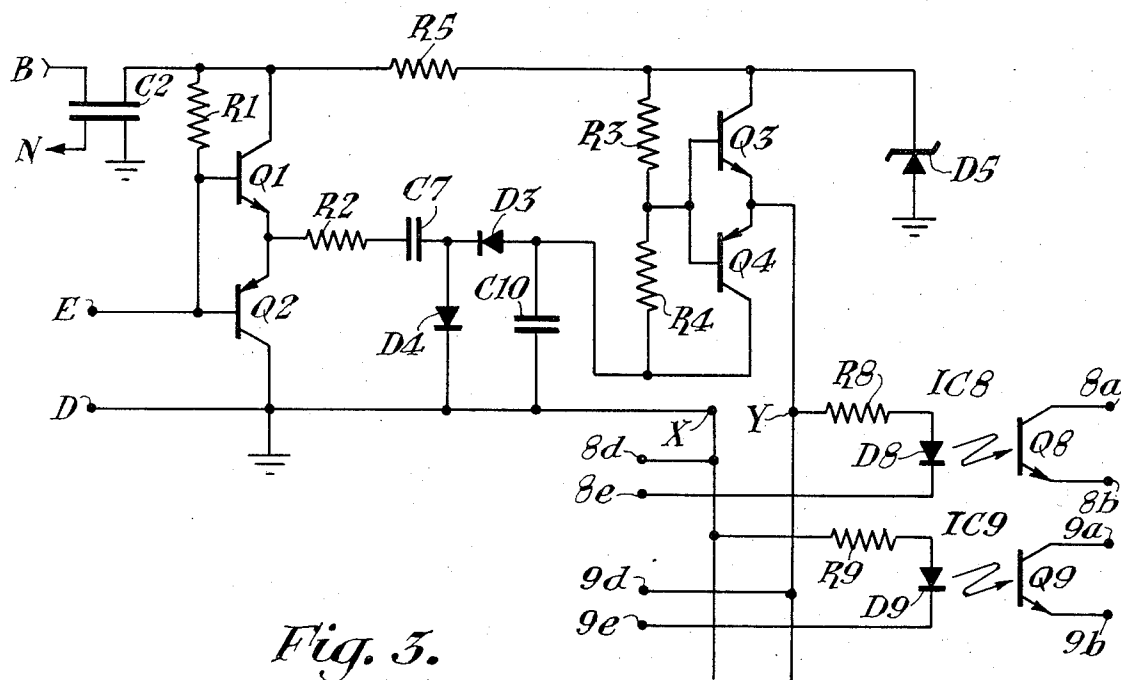
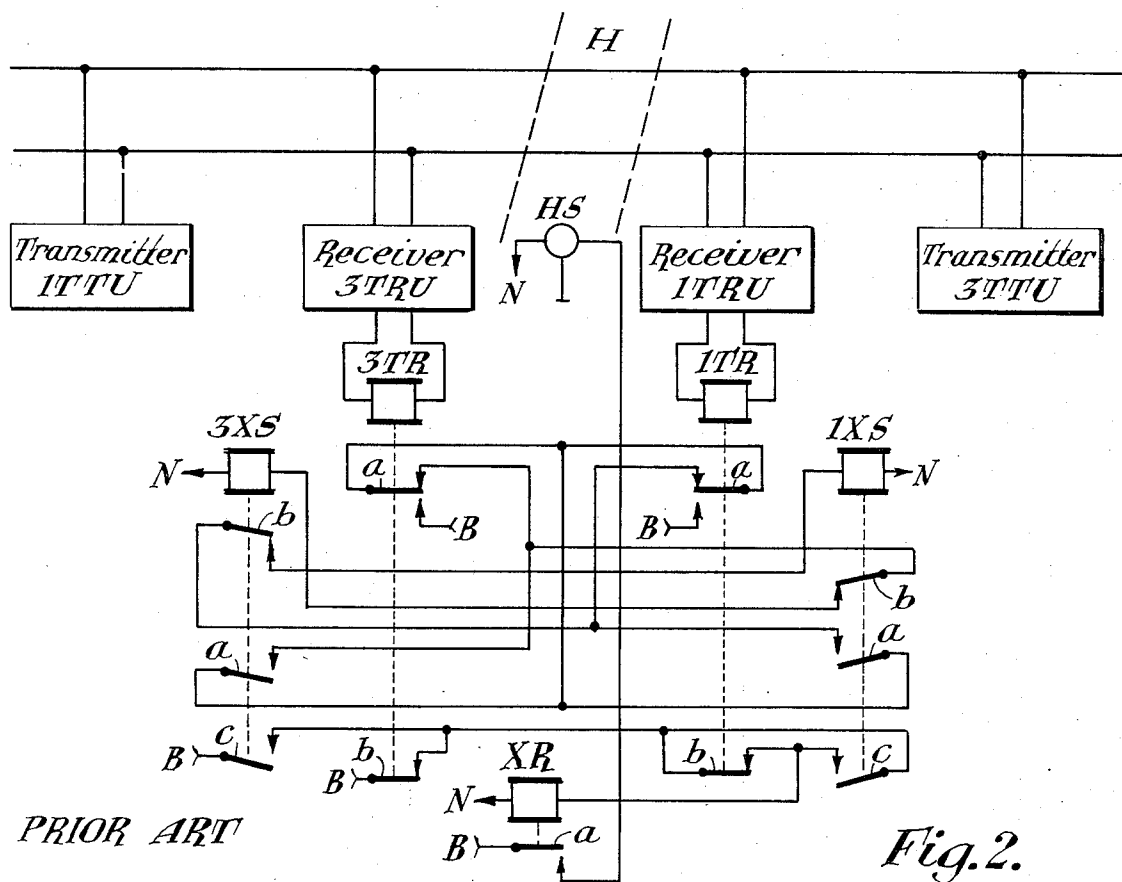


Fig. 1.



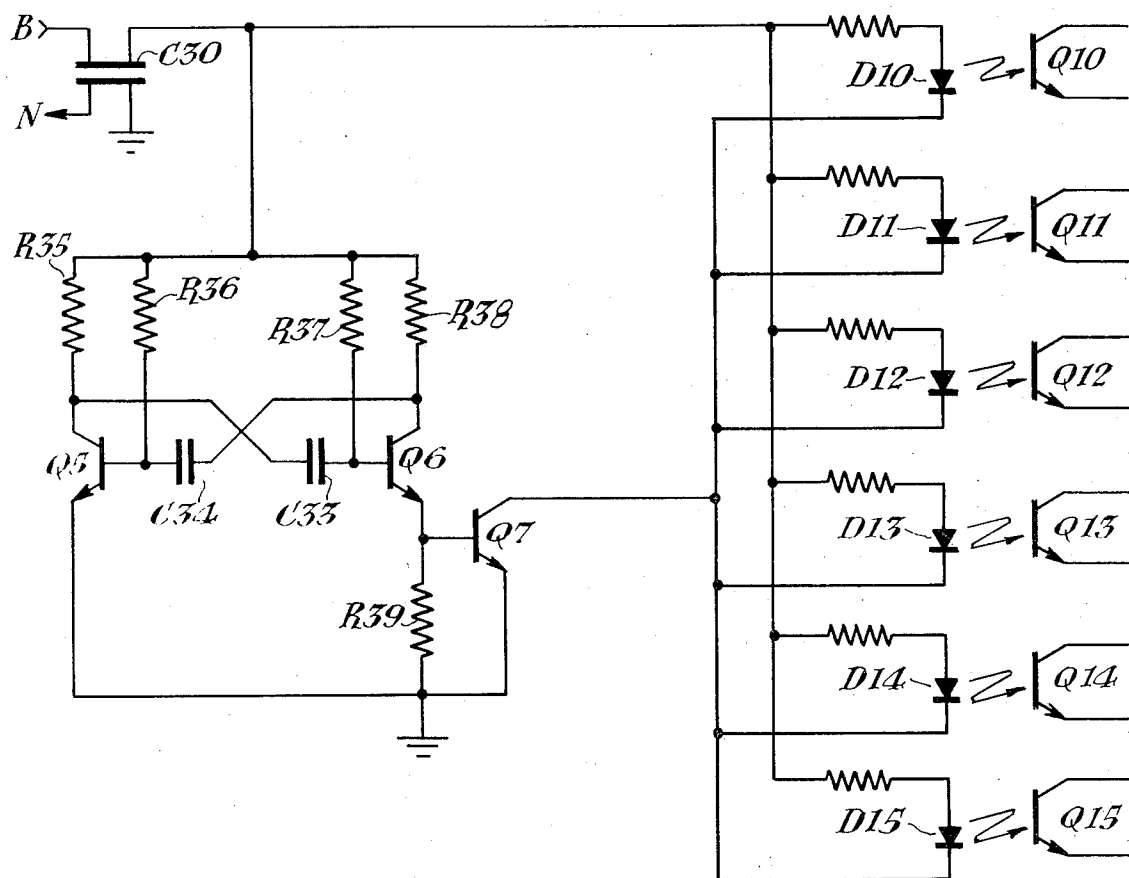


Fig. 4.

FAIL-SAFE SOLID STATE HIGHWAY CROSSING PROTECTION APPARATUS

My invention pertains to fail-safe solid state highway crossing protection apparatus. More particularly, this invention relates to a highway crossing signal protection scheme in which solid state light emitting and responsive devices are used to provide logic control circuits for activating and deactivating the crossing warning units at the proper times with respect to the movement of trains across the highway.

There is at present a desire to improve the systems used for protecting highway traffic where such highways intersect railroads in grade crossings. One feature of any improvement is to reduce the cost of the installation and its subsequent maintenance since any reduction in cost will make possible more installations with the same financial outlay. This is particularly important to railroad companies with limited capital funds. An improved reliability of such systems is also important in increasing confidence and respect of highway users in the operation of such warning systems. Conversely, if the reliability can be increased, there will be less ignoring of warning indications or devices with a reduction in a number of crossing accidents. One manner in which the cost may be reduced is to replace the relay logic circuits of conventional design using large, expensive, vital type relays with solid state logic circuitry with equal or improved fail-safe characteristics. Such solid state circuits also require less operating energy and, therefore, are cheaper to operate. Solid state apparatus also, in general, requires less maintenance and is easier to repair than the conventional relays and individually wired circuits.

Accordingly, it is an object of my invention to provide an improved, fail-safe highway crossing protection system using solid state elements in the control logic circuitry.

Another object of the invention is a highway crossing protection signaling system in which fail-safe solid state static relay devices replace the vital electromechanical relays in the control logic circuitry.

Still another object of the invention is a fail-safe solid state control logic arrangement for highway grade crossing protection systems.

A further object of my invention is a fail-safe arrangement using light emitting diodes and light responsive transistors as logic elements to provide a protection system for highway-railroad grade crossings.

Yet another object of the invention is a highway crossing protection system in which the directional logic circuits are comprised of solid state static relays which have fail-safe characteristics and which control a vital crossing relay to activate the warning devices.

A still further object of the invention is to provide a highway crossing protection system in which illumination emitting and illumination responsive solid state devices provide fail-safe train detection and direction logic circuitry for controlling a final vital crossing relay which activates the warning signals or devices.

It is also an object of my invention to provide a highway crossing protection system in which algebraic formulas designating control logic functions for operation of the warning devices are performed by solid state logic elements using light emitting diodes and light responsive transistors.

Other objects, features, and advantages of the invention will become apparent from the following specification and appended claims when taken in connection with the accompanying drawings.

SUMMARY

In practicing the invention, solid state logic elements, also defined as static relays, are incorporated into the highway crossing protection system in both the train detection function and the directional logic function. Only the final crossing relay controlling the protection devices is retained as a conventional electromechanical, vital type relay. Each static relay or logic element has a first electronic solid state circuit which is equivalent to the coil of an electromechanical relay. A second type of solid state electronic circuit simulates or is equivalent to the switching contacts of a conventional relay. Depending upon the drive connections from the coil circuit, a second type circuit is equivalent to a front or a back contact of the conventional relay, and thus represents a yes or no logic function, respectively. A single solid state coil circuit element may drive any reasonable number of second type or contact circuits connected in both front and back configuration. As specifically illustrated, each second or switching type circuit is composed of an illumination emitting diode, such as a light emitting diode, and an illumination responsive semiconductor, or specifically, a light responsive transistor. Each pair of these units is physically positioned to couple so that the light emitting diode output actuates the light responsive transistor, resulting in an insulated signal coupler device. Obviously, other arrangements providing such an insulated signal coupler may be used. In order to provide fail-safe characteristics to the logic element or static relay, the coil circuit is designed to require a modulated control or switching input in addition to an operating energy input to produce an output which will actuate the front contact coupler circuits. If the control input is absent, or is unmodulated, only the back contact type switching circuits can be actuated by the coil circuitry. Of course, if the operating energy is lost from the coil circuit, none of the contact circuits are active and no relay output can occur.

In applying the logic elements to a crossing protection system, the logic concept in Boolean algebra form is developed from a conventional relay type crossing signal system. A static relay coil circuit then replaces each conventional track detector and directional stick relay winding. Contact circuits of the static relays are then arranged circuitwise to fulfill the algebraic formulas for a crossing warning logic operation. A modulation or pulsing source for the system is provided to supply the modulated or pulsed switching control inputs required by the static relay coil circuits in order for them to activate the front contacts when appropriate. The train detector circuits are also supplied with control input energy from overlay track circuit receivers which are part of the approach warning section detector track circuits for the crossing. The final output signals from the logic circuitry are applied through an output buffer circuit with a rectifier component to operate the crossing relay. The crossing relay is normally energized to hold or lock out the warning device except when a train approaches. The crossing relay, of course, releases in response to the detection of train occupancy of an approach section to actuate the warning signals

and devices. In addition, any failure in the solid state logic circuits, either the coil or contact circuitry, or a loss of the modulation of the control inputs, causes the crossing relay to release to actuate the warning signals in a fail-safe manner.

BRIEF DESCRIPTION OF THE DRAWINGS

I shall now describe in more specific detail and terms the highway crossing protection arrangement embodying the features of my invention, and will then point out the novelty in the appended claims. During this specific description, reference will be made from time to time to the accompanying drawings in which:

FIG. 1 is a partly a schematic but principally a circuit diagram of a highway crossing protection system employing solid state logic elements and embodying the features of my invention.

FIG. 2 is a diagrammatic illustration of a conventional prior art overlap type highway crossing protection system employing conventional relays on which the logic algebra employed in my invention is based.

FIG. 3 is a circuit diagram of a logic element or static relay device usable in the system of FIG. 1.

The circuit diagram shown in FIG. 4 is a suitable modulation or pulse source for supplying modulation or switching pulses to the static relays and other logic circuits in the arrangement of FIG. 1.

In all figures of the drawings, similar reference characters designate the same or similar parts of the apparatus. In each of the drawings, a source of direct current operating energy is provided for the apparatus. This source is not specifically shown, since any suitable known type may be used, and only its positive and negative terminals are designated by the references B and N, respectively. It will be understood that wherever either of these reference characters appears in any of the circuit drawings, a connection to the corresponding terminal of the direct current operating energy source is designated.

DETAILED DESCRIPTION

Referring initially to the prior art arrangement shown in FIG. 2, I shall first lay the groundwork and develop the Boolean algebra expressions for the crossing logic on which the arrangement embodying my invention is based. A stretch of railroad track, shown across the top of FIG. 2 by a conventional two-line symbol, is intersected by a highway H, shown by the dashed lines. A highway signal device HS, operable to warn highway traffic of the approach of a train, is shown in the vicinity of the crossing. The device HS is representative of any of the several warning or protection means presently in common use at highway crossings, including flashing signal lights with or without gates or barriers and other newer types of warning devices. The device HS is activated when the crossing relay XR releases to close its back contact *a*. This completes a circuit between terminals B and N of the source through the operating mechanism of signal HS, as shown in a schematic fashion which will be understood by those familiar with the art.

The stretch of track is equipped for highway crossing protection by two well-known overlap detector track circuits which are overlapped at the crossing itself to provide a positive ring or protection island track section. Each overlap track circuit includes a track transmitter TTU having an assigned distinctive frequency

and a receiver unit TRU tuned to respond only to the frequency of the associated transmitter. For example, the track circuit provided for the approach warning section on the left includes transmitter 1TTU rail connected at the remote end and receiver 1TRU connected across the rails at the crossing but on the opposite side of the highway from its associated transmitter. These transmitters and receivers are well-known units, and any one of several types may be used to provide a selected frequency track current and a tuned or selective response thereto, respectively. Each receiver unit provides, when it is receiving the proper track current from the rails, a direct current output for controlling the associated detector track relay. For example, track relay 1TR, associated with track receiver 1TRU for the left track circuit, is energized and picked up when no train is occupying any portion of the left approach warning track section. Relay 1TR is deenergized and releases when this track section is occupied by any part of a train. Relay 3TR is associated with the opposite approach track section and operates or responds to the track section occupancy conditions in a similar manner.

The arrangement is also provided with a directional stick relay for each direction of train movement, the directional relays 1XS and 3XS being associated with the correspondingly numbered track relays. However, each of these XS relays is energized and picks up when a train approaches in the opposite direction of travel and the other track relay releases. For example, relay 3XS is energized, when a train approaches from the left, by a circuit extending from terminal B of the source over back contact *a* of relay 1TR, which closes when the train passes transmitter 1TTU, front contact *a* of relay 3TR, back contact *b* of relay 1XS, and the winding of relay 3XS to terminal N. Relay 3XS picks up and closes its own front contact *a* to complete a first stick circuit also including back contact *a* of relay 1TR and back contact *b* of relay 1XS. Eventually, when the train crosses the highway to enter the other or corresponding track section, relay 3TR releases and closes its back contact *a* to complete the final stick circuit for relay 3XS which otherwise includes back contact *b* of relay 1XS and front contact *a* and the winding of relay 3XS. This relay then remains energized until the train, having cleared the crossing, finally clears the other approach warning section in the reverse direction, that is, as it recedes from the highway.

During this period that the train is receding, front contact *c* of relay 3XS bypasses the open front contact *b* of relay 3TR in the energizing circuit for relay XR. Relay 3TR, of course, is released since the train is occupying the right-hand approach warning section as it recedes from the crossing, and thus has interrupted or shunted the flow of current in the corresponding track circuit. More specifically, relay XR is normally held energized by a circuit including in series front contacts *b* of relays 3TR and 1TR. Thus, relay XR releases when this train, approaching from the left, occupies the left approach section and causes the release of relay 1TR to open its front contact *b*. When the train clears the highway and relay 1TR is again energized and picks up to close its front contact *b*, an energizing circuit for relay XR then exists including the front contact and front contact *c* of relay 3XS. When the train eventually clears the stretch of track, relay 3TR will again pick up to close its front contact *b* and restore the normal ener-

gizing circuit for relay XR. When this occurs, the opening of back contact *a* of relay 3TR will interrupt the remaining stick circuit for relay 3XS which then releases or resets to its normal deenergized condition. A similar sequence of events in the reverse order will occur when a train moving from right to left traverses the stretch of track shown and crosses the highway. It is obvious that during the period that relay XR is released, its closed back contact *a* will retain the highway warning device HS activated.

With a review of the preceding discussion and considering the circuits shown in FIG. 2, the Boolean algebra logic equations for a typical single track highway crossing with overlap can then be written. The equation for energization of relay XR becomes:

$$XR = (1TR + 1XS) \cdot (3TR + 3XS) \quad (1)$$

Considering together both pickup and stick circuits for the directional relays 1XS and 3XS, the logic equations from an inspection of FIG. 2 are:

$$1XS = \overline{3XS}[(1TR \cdot \overline{3TR}) + 1XS(\overline{1TR} + \overline{3TR})] \quad (2)$$

$$3XS = \overline{1XS}[(\overline{1TR} \cdot 3TR) + 3XS(\overline{1TR} + \overline{3TR})] \quad (3)$$

The relays 1XS and 3XS are actually used as set, reset type flip flop logic elements for which, as specifically shown,

$$1XS = \overline{3XS} \cdot \overline{3TR} \cdot 1TR \quad (4)$$

$$3XS = \overline{1XS} \cdot \overline{1TR} \cdot 3TR \quad (5)$$

The reset equations for these relays as flip flops then may be stated:

$$\overline{1XS} = 3XS + (1TR \cdot 3TR) \quad (6)$$

$$\overline{3XS} = 1XS + (\overline{1TR} \cdot 3TR) \quad (7)$$

Since the set and reset equations for relays 1XS and 3XS constrain only one to be on or picked up at any one time, the equation (1) for relay XR may be then rewritten, for logic element implementation, in the following expanded form:

$$XR = (1TR \cdot 3TR) + (1TR \cdot 3XS) + (3TR \cdot 1XS) \quad (8)$$

It is to be noted that, in the prior art circuitry of FIG. 2, an unnecessary front contact of the associated track relay is included in the energizing circuit for each XS relay. Since the corresponding dependent back contact completes the final stick circuit for the associated directional relay while the train recedes from the crossing, this redundant use of the front contact saves an independent contact structure on the track relay, an economy measure. However, such dependent front and back contacts (yes and no logic functions) are not pos-

sible when using insulated signal couplers. Therefore, the equations (2) and (3) for relays 1XS and 3XS may be simplified for implementation by logic elements by eliminating the front contact function of the associated track relay and rewriting as follows:

$$1XS = \overline{3XS} \cdot [\overline{3TR} + (1XS \cdot \overline{1TR})] \quad (9)$$

$$3XS = \overline{1XS} \cdot [\overline{1TR} + (3XS \cdot \overline{3TR})] \quad (10)$$

These final functional equations (8), (9), and (10) are then the basis for the logic arrangement embodying the features of my invention and implementation in a fail-safe static relay logic element form is shown in FIG. 1.

I shall refer now to FIG. 3 for the circuitry of a solid state logic element or static relay usable in the conventional blocks incorporated in the arrangement shown in FIG. 1 and illustrated separately for convenience and simplicity in order to avoid excess circuit details in that figure. Actually, the circuit for the static relay, as shown in FIG. 3, is initially disclosed and is claimed in Letters Patent of the U.S. Pat. No. 3,746,942, issued July 17, 1973, to C. R. Brown et al., for a Static Circuit Arrangement. Although fully disclosed in this patent, I shall briefly describe the relay circuit and operation for convenience herein. The static relay circuit consists of two parts which may be considered as analogous to the coil of an electromechanical relay and to the switching contacts of such a relay. The portion equivalent to the coil or relay winding is that in FIG. 3 shown above the pair of terminals X and Y, while the second portion shown below these two terminals is equivalent to the switching contacts of an electromechanical relay. Direct current operating energy for the coil circuit and for the relay in general is supplied from terminals B and N of the local source which are connected to the upper and lower plates of a four-terminal capacitor C2, shown in the upper left of FIG. 3. One of the remaining two terminals of capacitor C2 supplies positive potential to the electronic coil circuit, while the other remaining terminal is connected to a common ground terminal. Capacitor C2 isolates the direct current supply voltage from any high frequency signals and thereby prevents interaction between the various circuits connected to the same direct current source.

An input circuit is formed by a pair of complementary transistors Q1 and Q2 and a biasing resistor R1. The transistors Q1 and Q2 are connected in an emitter-follower configuration which, in turn, is connected between the positive potential bus and ground terminal. The common connection of the two emitter electrodes is connected to feed a diode pump rectifier circuit comprising resistor R2, capacitor C7, diodes D3 and D4, and another capacitor C10. The upper plate of capacitor C10 is connected to a potential divider network formed by resistors R3 and R4, the common junction of which is connected in multiple to the base electrodes of another pair of complementary transistors Q3 and Q4. These two transistors are also connected in emitter-follower configuration to form an output circuit. The common junction point of the two emitter electrodes of transistors Q3 and Q4 forms a first intermediate signal terminal which is designated by the reference character Y. A second intermediate signal terminal,

designated by the reference X, is connected to the lower plate of capacitor C10. A Zener diode D5, connected between the collector electrode of transistor Q3 and ground, limits the amount of negative voltage which may be developed on capacitor C10. A current limiting resistor R5 is connected between capacitor C2 and Zener diode D5. The coil circuit portion of the static relay is further provided with a pair of control input terminals, designated by the references D and E. Terminal E is connected to the common junction between the base electrodes of transistors Q1 and Q2, while terminal D is connected to terminal X, the lower plate of capacitor C10, the cathode of diode D4, and in common with all these points to the ground terminal.

The electronic contact circuit portion of the static relay consists of a plurality of insulated signal couplers, each connected in one of two alternative circuit patterns across the coil signal terminals X and Y. Only two such contact circuits are shown, one of each type, designated by the reference characters IC8 and IC9. It will be appreciated that any reasonable number of such solid state contact circuits may be controlled by the electronic coil circuit of the static relay. Each insulated coupler comprises an illumination or light emitting diode and an illumination responsive semiconductor, specifically a light responsive transistor. For example, the insulated coupler IC8 includes the light emitting diode D8 and the light responsive transmitter Q8. A current limiting resistor is connected in series with each such light emitting diode, for example, resistor R8 in series with diode D8. The insulated signal coupler elements are so constructed that the base of the light responsive transistor, such as Q8, is only subject to illumination to which it is responsive when a predetermined polarity of an intermediate signal, i.e., the voltage across terminals X and Y, is applied to the associated diode, here diode D8, to render the diode conducting in the forward direction. For extreme safety or fail-safeness, it is preferable to so select these light emitting diodes that they will not break down in the reverse direction at any voltage which is less than the supply voltage of the coil circuit, that is, the voltage of the local source illustrated by the terminals B and N. As will be described shortly, the contact circuit IC8 is equivalent to a back contact of an electromechanical relay which is closed, i.e., active, when the relay winding is deenergized and the relay released. Conversely, the contact circuit arrangement IC9 is equivalent to a front contact of an electromechanical relay which is closed (active) when the relay winding is energized.

In describing the operation of the static relay of FIG. 3, it is first assumed that terminals B and N of the source are connected to capacitor C2 but that no circuit connection exists across control input terminals D and E, that is, these terminals are open-circuited. Under this condition, the potential at the upper plate of capacitor C10 has a positive value because the input circuit formed by transistors Q1 and Q2 is quiescent since no modulation input appears on terminals D and E. The amount of voltage across capacitor C10 is equal to the sum of the voltage drops across diodes D3 and D4. The voltage potential at terminal Y under these conditions is somewhat more positive than the voltage at the upper plate of capacitor C10 and is in fact equal to the voltage at the junction point of resistors R3 and R4, if the voltage drop across the base-emitter junction

of transistor Q3 is neglected or ignored. Thus, terminal Y is more positive than terminal X when the control input switching circuit across terminals D and E is open. If the circuit across the input terminals 8d and 8e for coupler IC8 is closed, even intermittently, diode D8 is forward biased and current flows so that diode D8 emits light or at least pulses of light. Transistor Q8 responds to this light and becomes conductive, that is, completes a circuit between output terminals 8a and 8b through the collector to emitter path of the transistor. Under these conditions, even if a circuit is completed across the input terminals 9d and 9e of coupler IC9, diode D9, with opposite polarity connections, in reverse biased by the potential across terminals Y and X and no current flows. Thus, no light is emitted from diode D9 to enable transistor Q9 to complete a circuit between its collector and emitter electrodes. This condition is analogous to an electromechanical relay with its winding deenergized and armature released to lose back contacts, the circuit element IC8 being equivalent of a back contact. Conversely, front contacts of the deenergized relay are open, for example, the contact circuitry or coupler IC9. It is to be noted that a similar contact condition or operation will exist, i.e., back contacts active, if a continuous circuit connection is closed across the control input terminals D and E of the winding portion.

However, if a contact, or preferably a static switch, connected across control input terminals D and E is closed intermittently at a frequency which is sufficient to operate the diode pump circuit arrangement formed by diodes D3 and D4, resistor R2, and capacitor C7, this operation produces a negative potential on the upper plate of capacitor C10, and thus also at the junction point between resistors R3 and R4. Accordingly, the emitter-follower transistor configuration Q3 and Q4 produces a corresponding negative potential at terminal Y. In other words, under this condition, the potential at terminal X is positive with relation to terminal Y. Diode D9 will now be forward biased when a circuit is closed across the corresponding input terminals 9d and 9e. Current thus flows through diode D9 which then emits light to which transistor Q9 responds and becomes conducting. This completes a circuit between output terminals 9a and 9b of coupler IC9. At the same time, diode D8 is reverse biased if a circuit is completed across terminals 8d and 8e so that no current flows and transistor Q8 remains open-circuited. The condition now assumed is analogous to an electromechanical relay with an energized winding so that its front contacts, here represented by coupler IC9, are closed or active, while back contacts equivalent to coupler IC8 are open or inactive.

Reviewing briefly, it is obvious that, in the absence of intermittent switching across control input terminals D and E of the coil portion of the static relay, the potential on terminal Y will be positive with relation to the potential on terminal X and the relay coil or winding is considered to be deenergized, i.e., in an inactive state. The opposite condition, i.e., when intermittent switching or modulation is applied across terminals D and E, will activate the coil circuit so that terminal X is positive with relation to terminal Y and the coil is considered to be energized. In this latter condition, front contact couplers, such as IC9, are active, i.e., provide a closed circuit between output terminals, and back contact couplers, such as IC8, are inactive. In the con-

verse condition, with the coil circuit deenergized, contact couplers IC8 are active and couplers such as IC9 are inactive. Similar conditions will apply to any other insulated circuit couplers which are included in the same relay circuit and, as previously indicated, a reasonable number of such signal couplers, as required for the logic functions to be performed by the static relaying circuit, may be controlled by one coil circuit.

From the above description, it will be appreciated that, in order to function, the relay circuit must be supplied signals from a suitable pulse switching circuit or source connected across its control input terminals D and E. This is in addition, of course, to the operating energy from terminals B and N of the local source connected across two of the terminals of capacitor C2. The pulse source is used to generate the static switching signals which are applied to terminals D and E and may also be applied to input terminals of the circuit couplers such as terminals 8d, 8e and 9d, 9e, respectively. A typical such pulse source is illustrated in FIG. 4. This pulse source is similar to that shown in FIG. 2 of the previously mentioned Brown et al. U.S. Pat. No. 3,746,942. However, a brief description is included herein for convenience.

Referring to FIG. 4, a direct current supply voltage from terminals B and N is connected through a four-terminal decoupling capacitor C30 to a relaxation type oscillator in the form of a free-running or astable multivibrator. This multivibrator includes a pair of transistors Q5 and Q6, coupling capacitors C33 and C34, and resistors R35, R36, R37, and R38. The multivibrator may be tuned to a typical operating frequency on the order of, for example, 10 KHz. The emitter electrode of transistor Q6 is connected through a resistor R39 to the ground terminal and is also connected directly to the base electrode of the switching or drive transistor Q7. The collector electrode of transistor Q7 is connected in multiple to the cathodes of a series of light emitting diodes D10 to D15 which are each part of a different insulated signal coupler of a bank of six such couplers included in the pulse source circuitry. It is to be noted that, in the subsequent description, any diode or transistor whose reference character includes a suffix between 10 and 31 is a light emitting or light responsive element, respectively, and is part of an insulated signal coupler logic element. The anode electrodes of diodes D10 through D15 are each connected through a current limiting resistor and thence in multiple to terminal B of the local source through the upper plate of capacitor C30.

The alternate conductive and nonconductive conditions of transistor Q6 periodically turn transistor Q7 on and off. This periodic conduction and nonconduction of transistor Q7 causes the light emitting diodes to alternately emit illumination and extinguish as current flows through them in multiple. As the light emitting diodes are pulsed on and off in phase with the frequency of the multivibrator, each associated light responsive transistor is alternately conducting and nonconducting, also in phase with the frequency of the multivibrator and with each other transistor of the bank of signal couplers. Thus the pulse circuit operates to produce isolated pulse switching by mutually isolated semiconductor devices, that is, the transistors Q10 and Q15 of these signal couplers. This switching of these transistors is identical, i.e., in phase. It will be appreciated shortly that such phase coherence is necessary for

all contacts of static relaying circuits included in any interlocked scheme for operating a particular control circuit, here the logic circuitry of the highway crossing protection system. As will be apparent in the subsequent description, these pulse transmitters are used to provide the modulated switching inputs for the various relay coil circuits and other contact arrangements of the logic circuitry in FIG. 1.

I now refer to FIG. 1 and to the crossing protection system shown therein using solid state logic elements of the static relay type. Across the stop, again illustrated by a two-line symbol, is the same or at least an equivalent stretch of railroad track intersected by a highway H. A highway warning device HS, as used in FIG. 2, is also provided although here illustrated at the crossing only by a dotted symbol since the control circuit is shown elsewhere in the circuit diagram. Two overlay track circuits are provided to detect the approach of trains in the same manner as shown and described in FIG. 2. Each overlay track circuit has a transmitter and receiver unit connected to the rails with an overlap portion between the circuits at the highway. The same reference characters for the transmitters and receivers are used as in FIG. 2. However, the track relay energized or supplied by the output signal of each track receiver unit is now of the static type shown in FIG. 3, each designated by a similar reference character but with the suffix A to distinguish between the electromechanical relays of FIG. 2 and the static relays of this figure.

The coil circuit portion for each static relay is represented by a conventional block, labeled with the associated reference character. The control input terminals D and E and the output terminals X and Y leading to the contact circuit portions are illustrated. The coil circuitry, including the direct current supply from terminals B and N, is as shown in FIG. 3 and described in connection therewith. The direct current output signal from each overlay track receiver is applied to the control input terminals of the associated relay through an insulated coupler circuit. For example, the output of receiver ITRU is coupled to input terminals D and E of relay ITRA through an insulated signal coupler comprised of diode D16 and transistor Q16. In series with diode D16 is the collector-emitter path of light responsive transistor Q10 which provides the modulation or pulsing source for this relay input. Transistor Q10, of course, is part of a signal coupler shown in the pulse source arrangement of FIG. 4. Only the transistor elements of the pulse source couplers are shown in FIG. 1 for convenience and to simplify the circuit diagram.

Therefore, when the left approach warning track section crossing is unoccupied, the output from receiver ITRU is applied through an AND circuit, including circuit coupler D16-Q16 and transistor Q10, to input terminals D and E of relay ITRA. The alternate conducting and nonconducting conditions of transistor Q10, as a result of the operation of the pulse source multivibrator, modulates the output from receiver ITRU to provide the necessary modulated switching input which the relay requires in order to assume its so-called energized condition. Thus, with the track unoccupied and the switching input to terminals D and E thus modulated, relay ITRA is activated to its energized condition so that its output terminal X is positive with relation to the associated terminal Y. Accordingly, front contact circuits of this relay will be active, that is, will

be in the so-called closed circuit condition. If there is no output from receiver ITRU, usually because the corresponding track section is occupied, relay ITRA is deenergized, terminal Y is positive with relation to terminal X, and back contact circuit couplers are active. If there is any circuit fault in transistor Q10 or transistor Q16, so that this circuit either is open or remains continuously completed, relay ITRA also assumes its deenergized state so that terminal Y is positive and back contacts are active. This is a fail-safe operation since the deenergized condition of the track relay is the safe condition. A similar operation of relay 3TRA in accordance with the output of track receiver 3TRU through transistor Q13 and the insulated coupler including diode D21 and transistor Q21 will be apparent from a study of the drawings taken in connection with the immediately preceding description.

Each of the track relays TRA is provided with two back and two front contact circuit couplers. For example, relay ITRA has two back contact circuit couplers including diodes D17 and D18 and the associated transistors Q17 and Q18. These diodes are forward biased when output terminal Y has a positive potential. The front contact circuit couplers, which become active when terminal X has a positive potential, include diodes D19 and D20 and their associated transistors Q19 and Q20, respectively. The back and front contact couplers are controlled separately, to provide a pulsed output, by transistors from the pulse source of FIG. 4. For example, diodes D17 and D18 in multiple are connected in series with the collector-emitter path of transistor Q11, while diodes D19 and D20 of the front contacts are similarly connected to the collector-emitter path of transistor Q12. Referring to relay 3TRA, its back contacts include diodes D22 and D23 with their associated transistors Q22 and Q23. For pulse operation, these diodes, in multiple, are connected in series with the collector-emitter path of transistor Q14 from the pulse source. Front contact circuit couplers of this relay 3TRA include diodes D24 and D25 and their associated transistors Q24 and Q25. Diode D24 is connected in series with transistor Q15 to provide a pulse output from this front contact. However, it is to be noted that diode D25 is connected in series with the collector-emitter path of transistor Q20 in one of the front contact circuits of relay ITRA, so that relay ITRA must also be in its energized condition with front contacts active for any switching output to occur from transistor Q25 of this front contact circuit coupler of relay 3TRA. The pulsing for this output is provided by transistor Q12, which action is in cooperation with the front contact coupler of relay ITRA. Therefore, an output from transistor Q25 represents the logic AND function ($ITR \cdot 3TR$), which is one element of equation (8) previously discussed.

In this crossing protection arrangement, the directional stick relays are also of the static type and their coils are conventionally indicated by the blocks designated by references 1XSA and 3XSA. The directional and stick logic control is then provided by contact circuit couplers of the various relays TRA and XSA. Each XSA relay has two front and one back contact circuit couplers but each coupler also includes control from other contacts as well as from the associated relay coil circuit portion. Pulsing in each case is accomplished at the other relay contacts and not direct from the pulse source of FIG. 4. Since the XSA relays are used as set,

reset flip flop logic elements, these functions are implemented by supplying the relay control input from its own output through other reset devices, the latter of which may be, for example, relay contact circuits of the other XSA relay. As a specific example, the switching input connected across terminals D and E of relay 3XSA is provided by transistor Q26 which is a part of a back contact circuit coupler of relay 1XSA. However, it will be noted that the circuit through diode D26 of this back contact circuit coupler is connected in series with the collector-emitter paths of transistors Q17 and Q30 in multiple. Said in another way, diode D26 is connected in series with the collector-emitter path of transistor Q17 or transistor Q30 to provide an alternative OR function. Transistor Q17, of course, is part of a back contact circuit coupler of relay ITRA and represents the function $\overline{ITR}$, i.e., the left approach warning track section occupied. Transistor Q30 is part of a front contact coupler of relay 3XSA but its associated diode D30 is also in series with the collector-emitter path of transistor Q23. Since transistor Q23 is part of a back contact circuit of relay 3TRA, transistor Q30 then represents the function ($\overline{3TR} \cdot 3XS$). In other words, transistor Q30 periodically conducting represents the right track section occupied by a train moving left to right.

Combining the various functions which are represented in diode D26 with the basic function of transistor Q26 as a back contact of relay 1XSA, transistor Q26 then represents the function, in symbol form, $\overline{IXS}[\overline{ITR} + (\overline{3TR} \cdot 3XS)]$. The ($\overline{IXS} \cdot \overline{ITR}$) portion of this function (as expanded) represents the pickup circuit for relay 3XSA, with reference to equation (10) and the prior art circuit for relay 3XS in FIG. 2. The other portion of the expanded function, ($\overline{IXS} \cdot \overline{3TR} \cdot 3XS$), represents the stick circuit for relay 3XSA, again with reference to equation (10) and the FIG. 2 arrangement. The input to terminals D,E of relay 1XSA from transistor Q29 represents similar logic functions to provide the pickup and stick energy for relay 1XSA, as may be developed by reference to the drawings and the preceding description, including equation (9) and the prior art circuitry shown in FIG. 2.

The crossing relay XR, which is retained in this arrangement as an electromechanical vital type relay, is directly controlled by an output buffer circuit. This buffer circuit will accept the pulsed switching function from the logic circuitry to produce a direct current output voltage of a fixed polarity in order to energize the relay winding. Relay XR is the same, or at least serves a similar function, as the similarly referenced element of the FIG. 2 arrangement. In other words, when the relay is released, upon the approach of a train, and closes its back contact *a*, the crossing signal or other warning device is actuated to protect the highway traffic. Otherwise, relay XR is energized to interrupt the control circuit for the protection devices at the crossing. The circuit of the buffer amplifier includes a four-terminal capacitor C40 which has two of its terminals connected to terminals B and N of the local direct current source. The other two terminals of capacitor C40 are connected, through the ground bus, across the collectors of a pair of complementary transistors Q32 and Q33 which, in turn, are connected in emitter-follower arrangement. The common input, i.e., the base electrodes connected together, is connected through resis-

tor R41 to the upper plate of capacitor C40. The common junction of the emitter electrodes of these two transistors is connected by a coupling capacitor C42 to the primary winding of transformer T1, the other terminal of which winding is connected, in common with the collector electrode of transistor Q33, to the ground terminal. The secondary winding of this transformer is coupled by a full-wave rectifier RE to the winding of relay XR. Thus, a direct current voltage is developed across the rectifier output to energize the relay when a pulsating switching function appears across the input electrodes of transistor Q33. This pulsating input is supplied by transistors Q25, Q28, and Q31 whose collector-emitter paths are connected in multiple, that is, in OR function circuit arrangement, across the base and collector electrodes of transistor Q33.

It was previously described that transistor Q25 represents the function (1TR·3TR). Transistor Q28 is in front contact relation to relay 1XSA but its associated diode D28 is also connected in series with the collector-emitter path of transistor Q24, a front contact of relay 3TRA. Thus transistor Q28 represents the logic function 1XS and 3TR, i.e., (1XS·3TR), which is the second element of equation (8). Transistor Q31 is in front contact relationship with relay 3XSA while its associated diode D31 is connected in series with the collector-emitter path of transistor Q19, a front contact circuit of relay 1TRA. Therefore, transistor Q31 represents the logic function (3XS·1TR) which is the final element of equation (8). Therefore, since the collector-emitter paths of transistors Q25, Q28, and Q31 are connected in multiple, that is, in OR function association, the input circuit for transistor Q33 provides the combined logic function (1TR·3TR) + (1XS·3TR) + (3XS·1TR). This fulfills the right half of equation (8) and controls the pulse or switching input which actuates the buffer circuit to energize relay XR. Relay XR, in turn, controls the crossing warning device, actuating such device when none of these individual AND functions of the control logic circuitry controlling this relay are satisfied.

The arrangement of the invention thus provides a fail-safe crossing protection system using principally solid state logic elements or static relays. These relays provide both train detection and directional logic control. Since the coil circuits of the static relays require a modulated control switching input to be energized, any open or short in the light responsive transistors included in the relay control circuits will interrupt the modulated input and result in the relay coil circuitry assuming its deenergized state. Under this condition, back contact circuit couplers only are active which fulfills the requirements of fail-safe characteristics. The use of light emitting diodes and light responsive transistors as insulated circuit couplers for the relay contacts isolates the various parts of the logic and control circuitry to increase the fail-safeness by eliminating any cross reactions or interreactions between circuit elements if circuit faults occur. The resulting logic control and highway protection system is a safe, efficient, and economical arrangement.

Although I have herein shown and described but a single arrangement embodying the features of my invention, it is to be understood that various changes and modifications may be made within the scope of the appended claims without departing from the spirit and scope of the invention.

Having thus described my invention, What I claim is:

1. A highway crossing protection system for a stretch of railroad track intersected by a highway, having a protection device at said crossing selectively activated to warn highway traffic of an approaching train occupying an approach warning section along each direction of movement, comprising in combination,
 - a. first and second train detection means, one for each approach warning section, each responsive to the presence or absence of a train within the corresponding section or detecting the occupancy condition of that section,
 - b. a static train detector relay means associated with each train detection means and coupled for registering the absence of a train in the corresponding warning section only when also supplied with a modulated control switching signal,
 - c. a first plurality of insulated signal couplers controlled by the first static detector relay means to first and second states as a train absence or presence in the corresponding section is detected,
 - d. a second plurality of insulated signal couplers controlled by the second static detector relay means to first and second states as a train absence or presence in the corresponding section is detected,
 - e. direction registry means controlled jointly by said first and second plurality of signal couplers for registering the direction of a train approaching the crossing in an approach section and for retaining that direction registry while that train recedes from said crossing in the opposite approach section,
 - f. another pair of static relay means associated with said direction registry means and activated only when also supplied with a modulated control switching signal,
 - g. a third plurality of insulated signal couplers selectively controlled by said direction registry static relay means to first and second states selectively as one or the other train direction is registered,
 - h. each static direction registry relay means coupled to said first, second, and third pluralities of insulated signal couplers in a manner for selectively activating one predetermined direction relay means only to register the direction of an approaching train and for retaining that relay means activated until that train clears the opposite warning section during its receding movement from said crossing,
 - i. a source of modulated switching signals coupled to each static relay means for providing a modulated switching signal to activate the relay when other required input conditions coexist, and
 - j. control means for said protection device controlled jointly by said first, second, and third plurality of signal couplers for activating said device when an approaching train occupies one approach warning section and for deactivating said device when that train occupies only the other approach section while receding from said crossing.
2. A crossing protection system as defined in claim 1 in which,
 - a. said modulated switching signal source is coupled to said static detector relay means through additional insulated signal couplers controlled by said source, and

- b. said modulated switching signal source is coupled to said static direction registry relay means through said first and second plurality of insulated signal couplers jointly with other additional insulated signal couplers controlled by said source. 5
- 3. A crossing protection system as defined in claim 2 in which, each insulated signal coupler comprises an illumination emitting diode and an illumination responsive semiconductor. 10
- 4. A crossing protection system as defined in claim 2 in which, each insulated signal coupler comprises a light emitting diode and a light responsive transistor. 10
- 5. A crossing protection system as defined in claim 4 in which each train detection means further includes, 15
 - a. an alternating current overlay track circuit having a transmitter coupled to the rails at the remote end of the corresponding approach warning track section and a receiver coupled to the rails at said crossing on the opposite side of the highway from the associated transmitter, 20
 - b. each transmitter supplying an alternating current of distinctive frequency through the rails to the associated receiver which is responsive only to an input of that frequency for providing an output signal, 25
 - c. each receiver output being coupled by a separate insulated signal coupler controlled by said modulation switching source to the associated static detector relay means for supplying a modulated activating signal when the corresponding section is unoccupied by a train. 30
- 6. A highway crossing protection system for a stretch of track intersected by a highway, with a protection device at said crossing to warn highway traffic of the approach of trains within an approach warning section for each direction of train movement, comprising in combination, 35
 - a. a train detection means for each approach warning section responsive to the presence of a train within that section and including a static type detector relay normally activated when the section is unoccupied by a train, 40
 - b. a train direction registry means including a pair of static type direction relays activated at times for registering the direction of movement of a train traversing the stretch, one relay for a first direction and the other relay for a second direction, 45
 - c. each static relay including a solid state coil circuit network and a plurality of contact circuits each comprising an insulated signal coupler, preselected contacts being active when said coil circuit is activated, the remaining contacts being active when said coil circuit is nonactivated, 50
 - 1. said coil circuit network being activated only when also supplied with a modulated control switching signal, 55
 - d. a source of modulated switching signals coupled to each detector relay coil circuit network for activating a particular relay when the associated train detection means detects the corresponding approach section nonoccupied, 60
 - e. a circuit network including contact couplers of said detector relays and of both said direction relays and further controlled by aid modulation sig- 65

- nal source, connected for activating, when a train is first detected, a single direction relay selected in accordance with the approach section occupied and for retaining that selected relay activated while the detected train traverses said crossing and recedes through the opposite direction approach section, and
- f. a control circuit means including contact circuits of said detector relays and of said direction relays and connected for actuating said crossing protection device to warn highway traffic when an approaching train occupies the approach section in its direction of movement, for deactuating said device when that train clears said crossing and occupies only the approach section for the opposite direction of movement, and for retaining said device deactuated when both sections are unoccupied.
- 7. A crossing protection system as defined in claim 6 in which, 6
 - a. each relay contact insulated signal coupler comprises an illumination emitting diode and an illumination responsive semiconductor so positioned that each semiconductor is responsive only to illumination from the associated diode, 10
 - b. said modulated switching signal source is coupled to the diode of each said contact signal coupler for modulating the conducting period of each associated semiconductor to provide fail-safe characteristics to the operation of said direction relays and said protection device control circuit means. 15
- 8. A crossing protection system as defined in claim 6 in which, 20
 - a. each relay contact insulated signal coupler comprises a light emitting diode and a light responsive transistor responsive only to illumination from the associated diode, 25
 - b. said modulated switching signal source is coupled to the diode of each said contact signal coupler for modulating the conducting period of each associated transistor to provide fail-safe characteristics to the operation of said direction relays and said protection device control circuit means. 30
- 9. A crossing protection system as defined in claim 8 in which each train detection means further includes, 35
 - a. an alternating current overlay track circuit comprising, 40
 - 1. a transmitter coupled to the rails at the remote end of the corresponding approach warning section and operable for supplying a track current having a preselected distinctive frequency, 45
 - 2. a receiver coupled to the rails at said crossing on the opposite side of the highway from its associated transmitter and responsive only to track current having the distinctive frequency of the associated transmitter for providing an output signal when the corresponding section is unoccupied, 50
 - b. each receiver being coupled by a separate insulated signal coupler to the associated detector relay coil circuit network, the coupling being also controlled by said switching signal source, for supplying a modulated activating signal to that relay coil circuit network when the corresponding approach section is unoccupied. 55
- 10. Control logic circuitry for a highway crossing protection system including an approach warning track

section or each direction of train movement, each provided with means for detecting the presence of a train occupying that section, and a crossing protection device selectively activated for warning highway traffic of a train approach, comprising in combination,

- a. static relay means associated with each track section detection means and controlled thereby for registering the absence or presence of a train occupying the section,
- b. a pair of static relay means for selectively registering the direction of travel of a train while approaching and receding from said crossing, one relay of said pair activated for each direction of travel,
- c. each static relay means having a solid state coil circuit portion and a plurality of contact circuits each comprising an illumination emitting diode and an illumination responsive semiconductor,
- d. the contact circuits of each detection relay mean selectively activated by the associated coil circuit, some to indicate the corresponding section unoccupied and others to indicate the presence of a train occupying the corresponding section,
- e. the contact circuits of each direction registry relay means also selectively activated by the associated coil circuit, some to register a train movement in the corresponding direction and others to indicate absence of any movement direction registry,
- f. a control circuit network for activating each direction relay means to register a train approaching in the corresponding direction and for holding that relay activated until that train clears the opposite direction approach section, including,
 1. a contact circuit activated by the detection relay for the opposite direction approach section when a train is detected occupying that section,
 2. a contact circuit of the other direction relay means activated when no train direction is registered,
 3. a contact circuit of the corresponding direction relay means activated when a train direction is registered, and
 4. a contact circuit of the detection relay means of the corresponding approach section activated when a train is detected occupying that section,
- g. a modulation switching means coupled to each detection relay coil circuit and to the control circuit network of each direction relay means for providing the modulated switching input upon which relay activation depends, and
- h. a control circuit network for said crossing device, controlled by first, second, and third circuit paths and connected for normally holding said device inactivated and for activating said device only when all said circuit paths are simultaneously incomplete,
 1. said first circuit path completed when both detection relay means detect the corresponding approach sections unoccupied,
 2. said second circuit path completed when one detection relay means detects the corresponding one approach section unoccupied and said direction relays register a train receding from said crossing through the other approach section,
 3. said third circuit path completed when the other detection relay means detects said other ap-

proach section unoccupied and said direction relays register a train receding from said crossing through said one approach section.

11. Control logic circuitry for a highway crossing protection system including an approach warning track section for each direction of train movement, each section provided with track circuit means for detecting the presence of a train occupying that section, and a crossing protection device activated at times for warning highway traffic of an approaching train, comprising in combination,
 - a. a modulation switching means operable to provide a modulated switching signal,
 - b. a detector means associated with each track circuit means and operable to a first and a second condition or detecting the presence or absence, respectively, of a train occupying the corresponding section,
 - c. an AND circuit network for each detector means, controlled by the associated track circuit means and by said switching means, and connected for operating the corresponding detector means to its second condition only when the corresponding approach section is unoccupied by a train and a switching signal is present,
 1. each detector means otherwise operating to its first condition,
 - d. a train direction registry means associated with each detector means for registering the direction of movement of trains which approach said crossing through the track section with which the other detector circuit means is associated,
 1. each registry means normally in a first condition when no train direction is registered and operable when actuated to a second condition to register a train movement in the corresponding direction,
 - e. a first AND circuit network for each direction registry means, controlled by the opposite direction registry means and the other detector means and coupled to said switching means, connected for actuating the associated direction registry means when an approaching train is detected in the other approach section and no opposite direction train is registered, only if a switching signal modulates the network,
 - f. a second AND circuit network for each direction registry means; controlled by the corresponding direction registry means, the opposite direction registry means, and the associated detector means, and coupled to said switching means; connected for retaining actuated the previously actuated corresponding direction registry means when the train occupies the associated track section and no opposite direction train is registered, only if a switching signal modulates the network, and
 - g. an OR circuit network for said crossing protection device, controlled jointly by both detector means and both direction registry means, and coupled to said switching means, and connected for holding said crossing device inactive only when both approach sections are unoccupied, or when one approach section is unoccupied and the other section is occupied by a train receding from said crossing, or when said other approach section is unoccupied and said one section is occupied by a train receding

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from said crossing, only if a switching signal modulates the active portion of said OR network.

12. Control logic circuitry as defined in claim 11 in which,

- a. said AND circuit network for each detector means 5 includes a first insulated signal coupler controlled by said switching means and a second insulated signal coupler connected for coupling the modulated switching signal and a section unoccupied signal from the corresponding track circuit means to that detector means, 10
- b. each detector means controls a plurality of other insulated signal couplers for activating some couplers when in its first condition and the remaining couplers when in its second condition, 15
- c. each direction registry means controls still another plurality of insulated signal couplers for activating some couplers when in its first condition and the remaining couplers when in its second condition,
- d. each first and second AND circuit network is coupled to said switching means by an insulated signal 20

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coupler for receiving a network modulating signal and further includes signal couplers of the controlling detector and registry means for performing AND logic functions to determine the existence of the required conditions for operating the associated direction registry means to its second condition, and

- e. said OR circuit network includes insulated signal couplers controlled by each detector means and each direction registry means for performing AND logic functions to determine the existence of at least one set of the required conditions for holding said crossing device inactive, and is coupled to said switching means by selected ones of the included couplers for receiving a network modulating signal.

13. Control logic circuitry as defined in claim 12 in which each insulated signal coupler comprises a light emitting diode and an associated light responsive transistor.

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