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Darrow et al.

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[54] **FAIL-SAFE RAILROAD-HIGHWAY GRADE CROSSING PROTECTION SYSTEM**

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[51] **Int. Cl.** **B61l 1/18**
[58] **Field of Search** 248/125, 162, 128, 248/130

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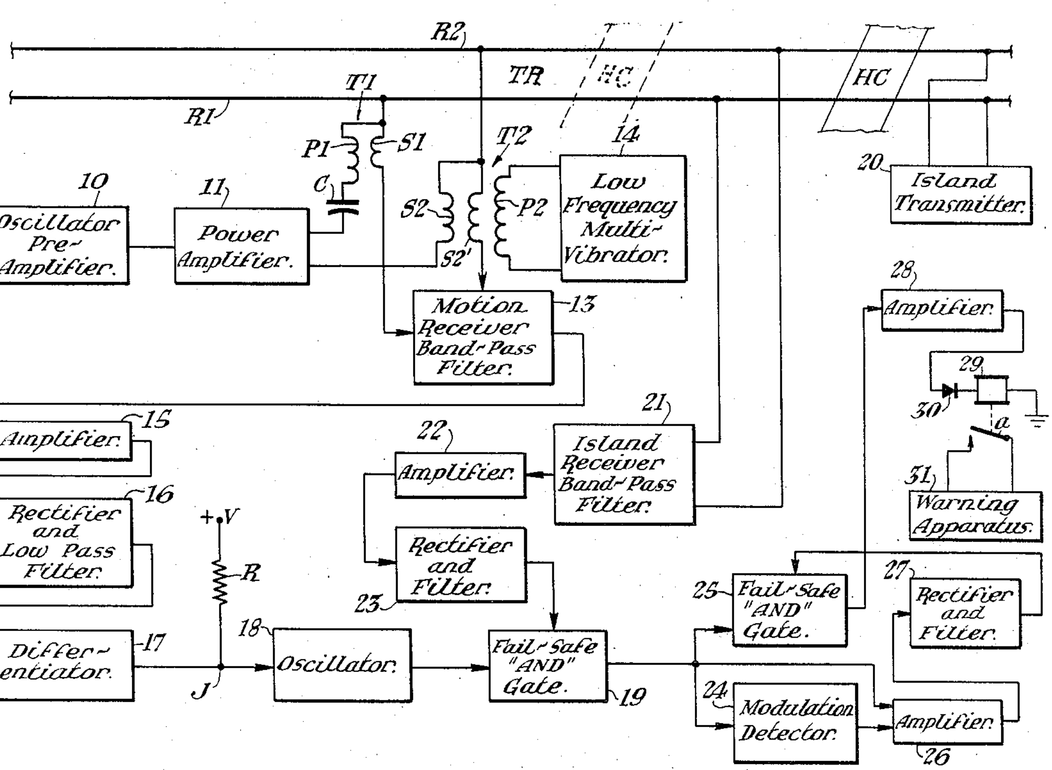
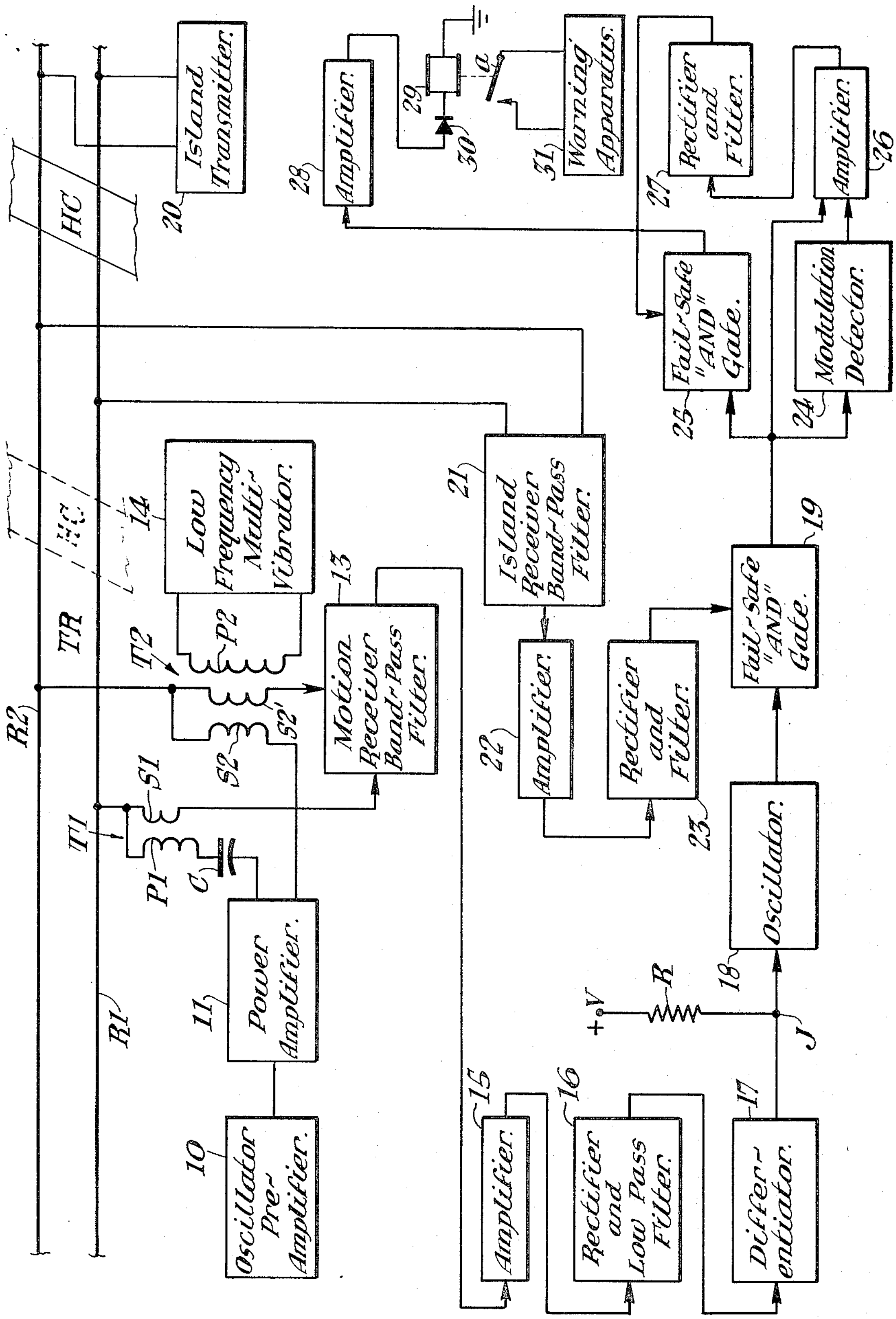
[57] **ABSTRACT**

This disclosure relates to a fail-safe electronic system for protecting a railroad-highway grade crossing. The system includes a solid state transmitter for applying a constant current to the track and a solid-state receiver for obtaining a voltage signal from the track. A differentiating circuit senses any differential change between the track voltage and an opposing voltage in order to distinguish an approaching train from a receding train so as to appropriately control the warning apparatus. The integrity of the system is constantly monitored by modulating the track voltage signal so that the absence of the modulating signal activates the warning apparatus to ensure the highest degree of safety to pedestrians and motorists.

14 Claims, 1 Drawing Figure




Island Transmitter.
20
HC
R1
R2
TR
T1
T2
P1
P2
S1
S2
S2'
C
Oscillator Pre-Amplifier.
10
Power Amplifier.
11
Motion Receiver Band-Pass Filter.
13
Low Frequency Multi-Vibrator.
14
Amplifier.
15
Rectifier and Low Pass Filter.
16
Differ-entiator.
17
+V
R
J
Oscillator.
18
Fail-Safe "AND" Gate.
19
Island Receiver Band-Pass Filter.
21
Amplifier.
22
Rectifier and Filter.
23
Modulation Detector.
24
Fail-Safe "AND" Gate.
25
Amplifier.
26
Rectifier and Filter.
27
Amplifier.
28
29
30
a
Warning Apparatus.
31

FAIL-SAFE RAILROAD-HIGHWAY GRADE CROSSING PROTECTION SYSTEM

This invention relates to a fail-safe railroad-highway grade crossing protection arrangement, and more particularly to a vital type of warning system which effectively alerts and forewarns pedestrians and motorists of an approaching train.

The perils connected with the intersection of a roadway and railroad crossing are universally known to the general public. It is common practice to provide a suitable warning to pedestrians and motorists by activating an alarm circuit for indicating that a train or transit vehicle is approaching the grade crossing intersection. There are approximately 232,000 railroad-highway grade crossings of which only about 47,000 crossings have been equipped with protective warning devices, such as, audible, visible, or barrier mechanisms to forewarn pedestrians and motorists of an approaching train or transit vehicle. Each year there are between 1,500 to 1,800 deaths and between 3,500 to 4,000 injuries caused by accidents at crossings. In addition to the human anguish involved, there is an annual economic loss well in excess of 300 million dollars due to the accidents at the crossings. Experience has shown that the accident rate at protected crossings is equal to and in some cases greater than that at unprotected crossings. In protected areas, a few accidents result from a system failure; however, most mishaps are the result of human failings. For example, people become irritable and impatient at the crossings when the warning devices, such as the flashing of the lights, the sounding of the gongs, or the lowering of the gate arms, are operated for a substantially long period of time due to a slow approaching train or due to the train stopping in advance of the crossing. Thus, many individuals fail to heed the warning after an extended period of time and in numerous cases are clobbered by the oncoming train in their vain attempt to move across the intersection. In order to prevent or at least reduce the number of such needless accidents, it has been found to be advisable to deactivate the warning devices when the train stops at some point in advance of the grade crossing. It will be appreciated that a non-approaching train or vehicle presents no danger to pedestrians or motorists at the crossing and, therefore, it is advantageous to allow the traffic to pass over the crossing when the train is stopped in advance of a given point from the crossing. Like a non-approaching train, a receding train or vehicle, namely, one moving away from the grade crossing, presents no peril to pedestrians or motorists attempting to cross the intersection. Thus, in addition to deactivating the warning devices for a train stopped ahead of the grade crossing, it is highly desirable to effectively deactivate the warning devices as soon as the last vehicle of a train passes a given safe point beyond the grade crossing. In addition, any proposed railroad-highway grade crossing monitoring system should effectively and efficiently control the warning devices in a manner that would provide the highest degree of safety yet would result in the lowest degree of inconvenience and aggravation to the general public. Hence, the Department of Transportation has requested that grade crossing protection be given the highest priority by all the parties involved and that the industrial and governmental groups pursue the matter in all haste. Further, the monitoring apparatus must operate in a vital or fail-safe manner in order to prevent costly damage to equipment as well as to avert serious injury and possible death to individuals due to unsafe failures.

Hence, it is an object of this invention to provide a new and improved vehicle motion monitoring system for use in railroad-highway grade crossings.

A further object of this invention is to provide a unique fail-safe electronic system for monitoring the motion of a vehicle and for actuating warning devices when a vehicle approaches a grade crossing.

Another object of this invention is to provide a vital type of motion monitoring arrangement which activates grade crossing warning equipment when a vehicle is approaching the crossing and deactivates the grade crossing warning equipment when the vehicle stops in advance of the grade crossing or when the vehicle recedes from the grade crossing.

Still a further object of this invention is to provide a fail-safe monitoring arrangement for a railroad-highway grade crossing protection system which initiates warning devices when a moving vehicle approaches in a given distance from the grade crossing.

Still another object of this invention is to provide an improved railroad-highway grade crossing warning system which forewarns pedestrains and motorists of an oncoming train by sensing a change in the electrical impedance characteristic of the railroad track.

A still further object of this invention is to provide a unique automatic crossing protection arrangement which alleviates undue delays to the general public by only actuating the warning devices at a grade crossing when a vehicle moves toward the crossing.

Yet another object of this invention is to provide a novel railroad-highway grade crossing protection arrangement which does not normally perturb or irritate pedestrians and motorists in that the flashing lights, sounding bells, or the barrier gates are not activated except when a train is moving toward the grade crossing.

Yet a further object of my invention is to provide a fail-safe grade crossing warning arrangement for sensing the motion of railway vehicles.

In addition, it is a further object of this invention to provide a vital railroad-highway grade crossing protection system which is reliable in operation, durable in use, and efficient in service.

In accordance with the present invention, the fail-safe railroad-highway grade crossing protection system includes a transmitter and a motion receiver connected to the railroad track. The transmitter includes a fail-safe constant amplitude signal generator having a shunt regulator which supplies a substantially constant d.c. operating potential to a free-running transistor oscillator and preamplifier circuit. The a.c. output of the oscillator preamplifier circuit is applied to a power amplifier composed of a plurality of cascaded transistor amplifying stages which provides a constant current output signal. The plurality of stages ensure that sufficient amplification or gain is present for efficiently driving the load. The power amplifier is designed to have an exceptionally high negative feedback signal or large degeneration so that the output of the amplifier is effectively a constant current sources. One output terminal of the power amplifier is coupled to one rail of the track through a series resonant L-C network, the L parameter of which is formed by a primary winding of a voltage bucking transformer, while the other output terminal of the power amplifier is coupled to the other rail of the track through a low impedance winding of a suitable modulating transformer. Thus, it will be appreciated that the voltage that appears across the track will also remain substantially constant when no railway vehicle is within the detection region of the grade crossing protection system. The input terminals of the motion receiver are coupled to the track rails by separate inductors, namely, the secondary windings of the voltage bucking and the modulation transformer, respectively. The primary winding of the modulation transformer is connected to an amplitude modulating circuit which includes a suitable type of oscillator, such as, a conventional low frequency multivibrator so that the integrity of the system may be constantly monitored against component and circuit failures which could result in an unsafe condition. The primary winding of the bucking transformer supplies a large fixed voltage across the secondary winding which is effectively connected in series with the voltage developed across the track rails. Thus, the algebraic sum of the track voltage, the bucking voltage and the modulating voltage is applied to the motion receiver. The motion receiver includes a band-pass filter which passes the desired frequency signals and substantially reduces or eliminates spurious noise and other undesirable frequency signals. The output from the motion receiver is applied to a multistage transistor amplifier, and then the a.c. voltage is stepped up and rectified into a d.c. voltage. The d.c. voltage in turn is applied to a differentiating circuit which produces an output signal which is substantially in proportion to the rate of change of the input voltage. The differentiator is coupled to the input of a fail-safe oscillator which is normally powered by operating voltage supplied from the shunt regulator of the track transmitter. The differentiator output is arranged to buck or oppose the normal operating power of the oscillator so that the oscillations will cease when a train approaches the grade crossing, as will be described in detail hereinafter. However, when no train is approaching the grade crossing, the oscillator is powered by the voltage of the shunt regulator and produces a.c. oscillations which are supplied to a subsequent circuit. That is, the output of the fail-safe oscillator is coupled to the a.c. input terminal of a two-input fail-safe "AND" gate. In order to provide the highest degree of safety to the public, it is preferable to supplement the motion monitor with a positive protection type of track circuit in the vicinity of the grade crossing. In the present case, a positive crossing protection area is achieved by employing an island track circuit which is coupled to the track rails at a given safe distance from the highway crossing. The island track circuit may consist of an AFO transmitter which is located at a select distance on one side of the highway crossing. An island receiver is situated at a suitable location on the other side of the highway crossing. The island track receiver includes a band-pass filter which eliminates noise and any other extraneous signals. AFter amplification, rectification and filtration, the received island signal is employed to power the d.c. input terminal of the two-input fail-safe "AND" logic gate. Thus, the lack of a non-approaching vehicle and the absence of a vehicle within the positive protection island track area cause both the a.c. and the d.c. voltages to be applied to the input of the "AND" logic gate so that an a.c. output signal is available at the output terminal of the "AND" logic gate. The output of the "AND" gate is connected to the input of a modulation detector, a subsequent "AND" gate, and a wide-band amplifier. The output of the wide-band amplifier is rectified and filtered and provides d.c. operating potential for the d.c. input terminal of the subsequent "AND" gate. It will be seen that the d.c. operating potential will be present only when the modulation is detected or when the output of the fail-safe oscillator is above a predetermined level. The presence of both the d.c. operating potential from the wide-band amplifier and the a.c. output from the preceding "AND" logic gate causes an a.c. signal to be passed by the second or subsequent "AND" gate. After amplification, the a.c. signal of the second "AND" gate is rectified and is employed to energize a polar sensitive type of relay which normally opens a back contact and interrupts the warning equipment. Thus, the warning equipment will remain deactivated so long as the polar relay continues to be energized. As mentioned above, when an approaching train enters the detection zone, the polar relay will become deenerzied so that its back contact will become closed. The closing of the back contact will cause the warning equipment to be activated, thereby alerting pedestrians and motorists of the impending danger.

The above, as well as other feature and objects of the present invention will be understood by reference to the following detailed description when considered with the drawing in which the single FIGURE represents a simplified functional block diagram in the preferred embodiment of the present invention.

Referring now to the single FIGURE of the drawing, there is illustrated a simplified functional block diagram of a fail-safe railroad-highway grade crossing protection system of a type which preferably constitutes the present invention.

As mentioned above, a highway grade crossing protection system is actuated when a moving train enters the motion detector zone. Normally, the train detection zone is between 1,500 and 2,500 feet in advance of the crossing which is generally a safe distance from the highway crossing even when a train is traveling at its maximum speed. Under certain circumstances, it is desirable to deactivate the highway crossing protection devices in cases where the train stops before it enters the positive protection area of the crossing in order that vehicular traffic and pedestrians will not be needlessly inconvenienced by the stopped train. That is, in cases where a railway train stops before a preselected minimum point in advance of the crossing, the warning devices should be quickly deactivated so that the awaiting public may go over the crossing without undue delay to themselves. However, if the vehicle or train is restarted and again approaches the crossing, it is absolutely necessary to promptly reactivate the warning devices in order to protect persons attempting to go over the crossing. However, if, upon restart, the vehicle or train recedes or moves away from the crossing, it is desirable to forego activating the warning devices in that the receding train presents no danger to people attempting to cross the grade crossing. In order to achieve a high degree of effectiveness, the warning devices should be extinguished or deactivated as soon as the train clears the crossing in order to readily permit motorists and pedestrians to pass over the trackway. The warning system must operate in a vital manner in that no circuit or component failure should be capable of erroneously deactivating the warning devices when an oncoming vehicle is approaching the crossing. Thus, each and every component and portion of the system must be analyzed in a fail-safe manner so that each and every precautionary measure may be taken to avert an unsafe condition.

Hence, the presently described invention is a fail-safe railroad-highway grade crossing protection system which includes a track transmitter having an oscillator-preamplifier circuit 10 and a power output amplifier 11. The circuit 10 may take the form of a fail-safe constant amplitude signal generator, as shown and described in my copending application for letters Patent of the United States, Ser. No. 108,264, filed Jan. 21, 1971, for A Fail-Safe Constant Amplitude Signal Generator, which is assigned to the assignee of the present application. The oscillator-preampifier or fail-safe constant amplitude signal generator 10 includes a shunt regulator for supplying d.c. operating potential to a free-running transistor or oscillator as well as for controlling the quality factor of the resonant tuned circuit and, in turn, the oscillator so that an a.c. output signal is capable of being produced with a known amplitude which cannot be changed by a critical circuit or component failure. The oscillator includes a transistor amplifying stage having a tickler coil for providing regenerative feedback and having a resonant circuit for determing the frequency of oscillation. The shunt regulator includes a pair of series connected resistors one of which is connected to one terminal of a d.c. supply source and the other terminal of which is connected to the cathode of a Zener diode. The anode of the Zener diode is connected to the other terminal of the d.c. source. Thus, constant a.c. amplitude signals are derived from the output of the amplifying transistor when and only when no critical circuit or component failure is present. Now the preamplifier of circuit 10 includes a series of transistor amplifier stages which are conventional and well known in the art except for the fact that the input to the preamplifier is safely filtered by a four-terminal capacitor. The gain of the preamplifier is extremely stable and independent of power supply changes due to a relatively high amount of degenerated feedback. The power amplifier circuit 11 includes a plurality of cascaded transistor amplifying stages, the output stage of which may take the form of a class B push-pull amplifier in order to produce high power output and efficiency. Further, since the supply voltage to the power amplifier circuit 11 is also supplied by the shunt regulator of the oscilaltor circuit, the output of the power amplifier will remain constant as long as the oscillator is working at all. Like the oscillator-preamplifier, the power amplifier uses emitter degeneration to make it independent of power supply, and thus it supplies a constant current to the rails. The independence of power supply ensures that pulsations or ripples possible present in the power source cannot result in a false amplitude modulation of the transmitter output which could invalidate the system check performed by the internal modulator. One output terminal of the power amplifier 11 is coupled to one of the rails R1 of the track TR via a series tuned resonant circuit made up of capacitor C and a primary winding P1 of a voltage bucking transformer T1. The other output terminal of the power amplifier 11 is coupled to rail R2 of the trackway TR via a low impedance secondary winding S2 of a modulation transformer T2. The series tuned resonant circuit including capacitor C and inductor winding P1 isolates the circuit from other a.c. frequency signals as well as any d.c. signals which may be present on rails R1 and R2. Thus, the constant current is impressed upon the track rails, and assuming a normal 3 ohm ballast resistance, a train detection distance of approximately 2,500 feet is obtained with a 200 Hz signal, and a detection distance of approximately 1,500 feet is achieved with a 600 Hz signal. Thus, a train entering the detection zone will vary the rail impedance so that a resulting voltage change will occur due to the shunting effect of the train wheels and axle.

As shown, the track voltage is constantly monitored by a motion receiver 13. The motion receiver 13 is connected to the rail R1 through the secondary winding S1 of the voltage bucking transformer T1 and is connected to rail R2 through secondary winding S2' of the modulation tranformer T2. It has been found that the directional movement of the train must be sensed by subtracting the track voltage from a given fixed voltage so that the voltage input to the differentiating capactor is decreased as a train recedes. This ensures that normally an output voltage from the differentiator should always be opposite in polarity to the voltage polarity resulting when possible leakage occurs in the differentiating capacitor. Thus, transformer T2 is employed to provide a large fixed voltage in series opposing relationship with the received track voltage. That is, primary winding P1 induces a large constant voltage which is in opposition to the track voltage developed across the track TR so that an approaching train may be distinguished from a receding train, as will be more readily described hereinafter. It has been found that in order to attain fail-safe operation at the grade crossing, it is also necessary to provide some means of checking the system against failures. This type of vitalness is accomplished by a modulating scheme which induces a low frequency signal upon the substantially high frequency track voltage. As shown, a low frequency multivibrator 14 is connected to primary winding P2 of modulating transformer T2. Thus, a modulating signal is impressed upon the track voltage and is also fed to the motion receiver 13. The motion receiver 13 includes a band-pass filter section which is tuned to the appropriate frequency of the track voltage. The receiver also includes a surge diode network which protects the circuit against high voltage transients, such as, the spikes and transitory voltages which are produced by lightning and the like.

The output from the motion receiver 13 is fed to the input of amplifier 15 which preferably includes a plurality of cascaded transistor amplifier stages. The output of amplifier 15 is transformer-coupled to a rectifier and low pass filter 16. The filter 16 includes a voltage transformer which steps up and increases the level of the a.c. signal and provides d.c. isolation. The rectification is accomplished by a voltage doubler network which again increases the level of the receiver voltage signal. It will be understood that the rectified voltage is negative with respect to the supply voltage so that leakage through the differentiating capacitor would ensure the turn off of oscillator 18. The operation of the low pass filter is accomplished by a pair of four-terminal capacitors which ensure that a loss of a conductive lead or the opening of the capacitor will not result in the passing of other spurious frequency signals. The d.c. signals along with the low frequency modulating signal are fed to the input of a differentiating circuit 17. The differentiating circuit 17 includes an R-C circuit for producing an output which is substantially proportional to the rate of change of the applied input signal. The capacitance value of differentiator **17** is such that it readily allows passage of the low frequency modulating signal. As shown, the output of the differentiator **17** is fed to the input of an oscillator **18.** It will be noted that the ouptut of the differentiator **17** is in fact fed to a junction point J which effectively is the power supply source terminal for the oscillator **18.** That is, the operating potential for the oscillator **18** is supplied from a suitable supply source +V through a substantially larg resistance R so that a substantially constant current is normally applied to the oscillator **18.** The terminal +V, in fact, is tied to the shunt regulator of the oscillator-preamplifier circuit **10** so that a stable constant current supply is available for oscillator **18.** The output of the oscillator **18** is supplied to the input of a first fail-safe "AND" gate **19.**

It will be appreciated that in order to provide the highest degree of safety to pedestrians and motorists using the railroad-highway grade crossing, it is necessary to provide a positive protection area or section on either side of the crossing. In the instant case, the positive protection area is provided by an audio frequency overlay (AFO) island track circuit arrangement. However, it is understood that other types of track circuits, both a.c. and d.c., may also be employed for detecting when a vehicle or train is within bounds of the positive detection area. The AFO track circuit includes an island transmitter located on one side of the crossing, namely, on the right-hand side of the highway which is the safe minimum distance from the near edge of the highway. The island track circuit also includes an island receiver **21** which is connected to the opposite side of the highway, namely, on the left-hand side as viewed in the drawing. Thus, the island track circuit is connected to the rails at a point which is the minimum distance from the crossing to alert motorists and pedestrians that a train is within the positive detection zone. Under certain circumstances it may be possible to dispense with the island transmitter **20** and have the highway crossing HC located in the position as shown in phantom in the drawing. Under such a condition, the island receiver **21** would obviously be tuned to the frequency of the oscillation signals produced by oscillator circuit **10.**

It will be appreciated that the island receiver **21** preferably includes a band-pass filter network which eliminates various noise and other extraneous signals which may appear on the rails. The filtered output voltage of the island receiver **21** is applied to the input of a multistage transistor amplifier **22.** The amplified AFO signals, in turn, are applied to the input of a rectifier-filter network **23.** The rectifier and filter network **23** includes an initial voltage doubling circuit and a subsequent four-terminal capacitor for rectifying and filtering the AFO input signals. The filtered d.c. output of the rectifier-filter circuit **23** is applied to the d.c. input of the first fail-safe "AND" gate **19.** The fail-safe "AND" logic circuit **19** is preferably of the type generally described and disclosed in letters Patent of the United States No. 3,430,066, issued Feb. 25, 1969, to Donald B. Marsh and Walter W. Sanville, for a Fail-Safe "AND" Logic Circuit, which is assigned to the assignee of the present application. The "AND" gate **19** includes an active network in the form of an a.c. transistor amplifier which produces a logical assertion, namely, an a.c. output, during the presence of a pair of input signals and which produces a logical negation, namely, no output, during the absence of either or both of the input signals. For example, during the presence of both the a.c. and the d.c. input, the logic circuit functions as a signal passing gate so that a.c. signals are readily available at the amplifier output terminals. Alternatively, during the absence of either or both of the a.c. and the d.c. input signals the logic circuit **19** functions as a signal blocking gate so that no output signal is available at the output terminals. Further, the "AND" gate **19** operates in a fail-safe manner in that any critical component or circuit failure will not erroneously produce an a.c. output signal. Thus, an a.c. output signal is available from the first "AND" gate **19** only when both modulation from the differentiator **17** and a signal from the island receiver are present.

As shown, the output from the first "AND" gate logic circuit **19** is connected to the input of a modulation detector **24**, a ssecond or subsequent fail-safe "AND" logic gating circuit **25**, and a modulation amplifier **26.** The modulation detector **24** detects the presence or absence of the modulating signal produced by the low frequency multivibrator **14** and thereby provides a self-checking effect on the electrical condition and behavior of the oscillator **18** and on the integrity of the differentiator **17.** This constant checking or examination procedure is necessary in order to ensure that the capacitor of the differentiator **17** has not become open-circuited whereby the oscillator **18** would continually oscillate irrespective of whether or not a train or vehicle was approaching or was within the detection zone of the highway crossing. As shown, the output of the modulation detector **24** is coupled to the input of the amplifier **26.** Thus, since the failure, namely, opening of the capacitor of differentiator **17**, would result in the disappearance of the low frequency modulating signal, the modulation detector **24** would be unable to provide an input to the amplifier **26**, and therefore a circuit failure would be readily detected. It will be appreciated that the circuit failure immediately causes the activation of the warning apparatus so that traffic is obstructed until a maintainer or other responsible person can correct the situation. Under certain conditions a rapidly receding train tends to cause the oscillator **18** to obliterate the low frequency modulating signals. However, as shown, the amplifier **26** is also indirectly coupled to the oscillator **18** via "AND" gate **19** so that when the output signal of the oscillator is sufficiently or relatively high, due to a rapidly receding train, the amplifier **26** will be driven by this relatively high oscillator signal in that the modulating signal falls off and tends to effectively disappear due to the rapidly receding train.

As mentioned above, the first fail-safe "AND" gate **19** provides an a.c. input to the second fail-safe "AND" gate **25.** It will be appreciated that the second fail-safe "AND" gate may also be of the type shown and disclosed in the above-mentioned U.S. Pat. No. 3,430,066. As shown, the d.c. input of the fail-safe "AND" gate **25** is derived from a rectifier and filter network **27** which is similar to circuits **16** and **23** and is composed of a voltage doubler network and a filtering circuit. The input to the rectifier and filter circuit **27** is derived from the amplifier **26.** As mentioned, the output from the rectifier and filter circuit **27** is coupled to the d.c. input of the fail-safe "AND" gate **25.** Thus, the d.c. input to gate **25** will exist only when modulation is detected by modulation detector **24** or when the oscillator level is sufficiently high due to a receding train. The a.c. input to gate **25**, which must also exist for producing an a.c. output, will only be present when the island circuit is not occupied or when a.c. oscillations are not produced by oscillator **18** due to an approaching train. All of these circuit functions are performed in such a manner that no failure can result in a less restrictive condition with regard to the main function of detecting an approaching train. The output of the fail-safe "AND" gate **25** is applied to a multistage solid-stage amplifier **28**. The amplifier **28** includes a plurality of transistor stages which have sufficient gain to power a vital type of electromagnetic relay **29**. In the present instance, the output of the power amplifier **28** is rectified by diode **30** which provides a d.c. power to the electromagnetic relay **29**. As shown, the relay is mechanically coupled to a contact a which completes or interrupts the circuit to suitable warning apparatus **31**, which obviously may take the form of appropriate lights, bells, barrier gates, or any combination thereof.

Turning now to the operation of the described railraod-highway grade crossing warning system, it will be initially assumed that either no railway vehicle is approaching the highway crossing or, at least, that no railway vehicle is within the detection area of the system. It will be appreciated that under this condition the protective devices controlled by warning apparatus **31** should be deactivated if no circuit or component failure is present and the system is operating properly. As previously mentioned, the track transmitter continuously supplies a constant current to the track TR and, in the absence of an approaching vehicle, the voltage drop across the rails remains substantially constant. The constant current flowing through the primary winding **P1** of transformer **T1** also induces a substantially large constant voltage into the secondary winding **S1** of transformer **T1**. It will be recalled that the motion receiver **13** is connected to the track rails **R1** and **R2** through the secondary windings **S1** and **S2'**, respectively. Thus, in addition to receiving the track voltage signal, the motion receiver **13** is supplied with the bucking voltage developed across secondary winding **S1** and also the modulating signal induced into the secondary winding **S2'** by the multivibrator **14**. Thus, the algebraic sum of the track voltage, the bucking voltage, and the modulating voltage is applied to the motion receiver **13**. As shown, the bucking voltage is induced into a relatively small secondary winding of the transformer **T1** and any failure which eliminates the bucking voltage causes the removal of input voltage to the receiver **13**. In addition, any detuning effect will greatly increase the impedance of the series resonance circuit formed by the primary winding **P1** and capacitor **C1** so that such an adverse condition will result in the reduction of the amount of current that is applied to the rails **R1** and **R2**. It will be appreciated that the amount of modulation is proportional to the amount of current applied to the rails and, therefore, either of the abovementioned adverse conditions will reduce the modulation to the point where it will cause the eventual turning off of "AND" gate **25**.

The output from the motion receiver **13** is amplified and rectified by the circuits **15** and **16**, respectively. The rectified output is applied to the differentiating circuit **17**. It will be appreciated that the differentiating circuit **17** is responsive to the rate of change of the incoming voltage. However, with the lack of an oncoming train, the difference between the bucking voltage and the track voltage remains unchanges so that no differential voltage appears across the resistive capacitive elements of the differentiating circuit **17**. Thus, the power supplied to the oscillator **18** during the absence of a train within the detection zone is in effect +V so that the current I flowing to junction J is equal to V/R. It will be appreciated that the low pass filter of circuit **16** and the capacitor of differentiator **17** freely allow passage of the low frequency modulating signal. The supply current allows the oscillator **18** to go into oscillation and provide an a.c. signal to the a.c. input terminal of the fail-safe "AND" gate **19**. Further, the absence of a train within the positive protection zone of the highway crossing covered by the island track circuit allows the AFO signals emanating from transmitter **20** to be received by the island receiver **21**. The signals of the island receiver **21** are amplified, rectified, and filtered by the circuits **22** and **23**, respectively, and a d.c. output from the rectifier is applied to the d.c. input terminal of the fail-safe "AND" gate **19**. Thus, the a.c. oscillator frequency signals are passed by the first fail-safe "AND" gate and are applied to the a.c. input terminal of the second fail-safe "AND" gate **25**. The output signal of the oscillator **18**, which is passed by the fail-safe "AND" gate, is accompanied by the low frequency modulated signal which is detected by the modulation detector **24**. The modulation detector **24** provides a modulation frequency input signal to the amplifier **26**, the output of which, in turn, is applied to the input of the rectifier and filter **27**. It will be appreciated that an exceedingly rapidly receding train within the detection zone results in the overloading of the modulation detector **24** and, accordingly, the increased amplitude of the oscillator output activates the other input to the amplifier **26**. Thus, the d.c. signal from rectifier-filter **27** is applied to the d.c. input terminal of the second fail-safe "AND" gate **25**. The presence of the a.c. input signal, as well as the d.c. input signal to gate **25**, results in the passage of the a.c. signal which, in turn, is applied to the input of amplifier **28**. The amplified output signal of the amplifier **28** is, in turn, rectified by half-wave diode rectifier **30**. The rectifier signal energizes the electromagnetic relay **29**, so that the front contact *a* is held open. The open contact interrupts the warning circuit so that the warning apparatus **31** is deactivated, and traffic is allowed to pass freely over the highway crossing HC.

Let us now assume that a train enters the detection zone which, as mentioned above, may be between 2,500 and 1,500 feet away from the crossing dependent upon the frequency of the transmitter signal. Upon entering the detection zone, the approaching train begins changing the rail impedance so that the voltage developed across the rails **R1** and **R2** varies in accordance with the change in impedance. As the train approaches the highway crossing the track impedance progressively decreases so that the voltage drop across the track rails **R1** and **R2** decreases proportionately. Accordingly, the voltage applied to the motion receiver, namely, the sum of the track voltage and the bucking voltage, varies so that an increase in voltage occurs at the output of the motion receiver **13**. After amplification and rectification a negative d.c. voltage is applied to the differentiating circuit which produces an output in proportion to the rate of change of the d.c. input voltage. The voltage fed to the motion receiver and hence the voltage applied to the differentiator is arranged to increase as a train approaches so that any differentiator capacitor leakage will appear as an approaching train which would be a safe failure. It can be seen that continuity of the differentiator **17** is checked by its ability to pass the modulating signal. Thus, the output current produced by the differentiator **17** is adjusted to be substantially equal or greater than and opposite to the operating current supplied to the junction J by the voltage source +V. Hence, the sum of the currents at junction J is effectively zero or negative so that the oscillator **18** is effectively without power of the proper polarity. Under this condition, the oscillator **18** reverts to a nonoscillating condition so that oscillator frequency signals are not available at the a.c. input terminal of "AND" gate **19**. Further, the absence of a.c. oscillator frequency signals at the a.c. input terminal of the fail-safe "AND" gate **19** obviously results in no a.c. signal at its output terminal. Therefore, there is no a.c. signal available at the output on the second fail-safe "AND" gate and, in turn, there is no voltage available for energizing the electromagnetic relay **29**. Thus, the relay **29** becomes deenergized and the back contact a releases and closes so that the warning apparatus **31** immediately becomes energized. The relay **29** will remain deenergized so long as the train continues to approach the highway crossing HC. If, for any reason, the train should stop in advance of the highway crossing and outside the bounds of the island track circuit, the rate of change in voltage ceases so that the differentiator **17** will no longer produce a current which opposes the current supplied from the +V terminal of the normal supply source. Accordingly, the oscillator **18** will immediately go into an oscillating condition upon the stopping of a railway vehicle which is in approach of the island track circuit, and thus the warning apparatus **31** will be prompty deactivated.

It will be appreciated that when the train comes within the bounds of the positive protection area, namely, within the island track circuit, the transmitter signals of island transmitter **20** are shunted by the wheels and axle of the train, and, therefore, the island receiver receives no AFO input signal. Thus, there is no d.c. voltage applied to the d.c. terminal of the first fail-safe "AND" gate **19**. Hence, absence of a d.c. input causes the "AND" gate **19** to assume a block mode of operation, namely, a.c. oscillations will not appear on the output of gate **19**.

However, upon restart, an approaching train will again cause the differentiator **17** to supply a current to junction J which is in opposition to the normal supply current which, therefore, will cause the oscillator **18** to stop oscillating again. However, on restart, a receding train causes the differentiator current to enhance the current of the normal supply source so that the oscillator **18** will continue to oscillate and, therfore, there is no change in operation and the warning apparatus will remain deactivated. When the the differentiator current becomes large enough to overload the modulation detector **24**, the output of oscillator **18** will be sufficiently high enough to directly activate amplifier **26**. That is, the warning apparatus will remain deenergized when a stopped train restarts and begins to recede from the highway crossing in the direction it came from. Similarly, when the last vehicle of the train exits the island track circuit, a receding signal will be received by the motion receiver **13** which, in turn, causes the differentiator **17** to supply a current to the junction J which enhances the normal supply current. Thus, a.c. oscillations are produced by the oscillator **18** as soon as the train passes the limits of the island track circuit. Hence, since a receding train does not endanger motorists and pedestrians, it is therefore desirable to deactivate the warning apparatus **31**, such as lights, bells, or barrier, as soon as possible in order not to inconvenience the general public.

As previously mentioned, the modulating signal provides a fail-safe checking arrangement for ensuring that a circuit or component failure will not result in not providing an adequate warning to the public. The use of a bucking voltage allows a more effective and efficient system in that it is readily capable of determing the difference between an approaching and a receding train.

It will be appreciated that various changes, modifications and alterations may be made by persons skilled in the art without departing from the spirit and scope of the present invention. Thus, it will be understood that various modifications may be made in the presently described invention and, therefore, it is realized that all changes, equivalents, and mutations within the spirit and scope of the present invention are herein meant to be covered by the appended claims.

Having thus described my invention, what I claim is:

1. A fail-safe electronic system for protecting a railroad-highway grade crossing comprising, transmitter means for applying a constant current signal to the track, receiver means for receiving a voltage signal from the track, means coupled to said receiver means for producing a voltage potential which is in bucking relationship with said track voltage signal, means coupled to said receiver means for modulating said track voltage signal, differentiator means coupled to said receiving means for producing an output signal substantially proportional to the rate of change of the input signal, oscillator means coupled to said differentiator means, a track circuit coupled to the track and encompassing the grade crossing, and means coupled to said oscillator and said track circuit and responsive to the condition of said oscillator and said track circuit for actuating a protective warning when a train is approaching the grade crossing and is outside the limits of said track circuit or when a train is within the limits of said track circuit or when a critical circuit or component failure occurs within the system.

2. A fail-safe electronic system as defined in claim **1**, wherein a transformer provides said bucking voltage to said receiver means.

3. A fail-safe electronic system as defined in claim **1**, wherein said modulating means is transformer coupled to said receiver means.

4. A fail-safe electronic system as defined in claim **1**, wherein said differentiator means is coupled to the power supply of said oscillator means so that the power supply voltage is opposed by voltage supplied by said differentiator means when a train is approaching the grade crossing.

5. A fail-safe electronic system as defined in claim **1**, wherein said differentiator means is coupled to the power supply of said oscillator means so that the power supply voltage is enhanced by voltage supplied by said differentiator means when a train is receding from the grade crossing.

6. A fail-safe electronic system as defined in claim 1, wherein said responsive means includes a first AND logic gate having two inputs and an output in which one input is connected to said oscillator means and the other input is connected to the track circuit.

7. A fail-safe electronic system as defined in claim 6, wherein said output of said first AND logic gate is connected to a modulation detector for detecting the modulated signal of said modulating means, to a modulating amplifier and to a second AND logic circuit.

8. A fail-safe electronic circuit as defined in claim 6, wherein said second AND logic gate requires an input signal to be applied from said first AND logic gate and an input from said modulation amplifier in order to produce an output.

9. A fail-safe electronic system as defined in claim 1, wherein said track circuit is an island circuit having a transmitter means connected to the track on one side of the grade crossing and a receiver means connected to the track on the other side of the grade crossing.

10. A fail-safe electronic system as defined in claim 6, wherein said track circuit includes a receiver means the output of which is amplified and rectified and then is applied to the other input of said first AND gate.

11. A fail-safe electronic system as defined in claim 1, wherein said transmitter means is connected to the track through a tuned resonant circuit.

12. A fail-safe electronic system as defined in claim 11, wherein said tuned resonant circuit includes the primary winding of a transformer.

13. A fail-safe electronic system as defined in claim 12, wherein said transformer includes a secondary winding which is connected to said receiver means and into which is induced said bucking voltage potential.

14. A fail-safe electronic system as defined in claim 1, wherein said differentiator means opposes the power supply of said oscillator means when a train approaches the grade crossing so that said oscillator means assumes a non-oscillatory condition and said differentiator means enhances the power supply of said oscillator means when a train recedes from the grade crossing so that said oscillator means assumes an oscillatory condition.

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