PREDICTOR SELF-CHECK SYSTEM FOR ANALOG COMPUTER

Filed Sept. 18, 1963 3 Sheets-Sheet 1

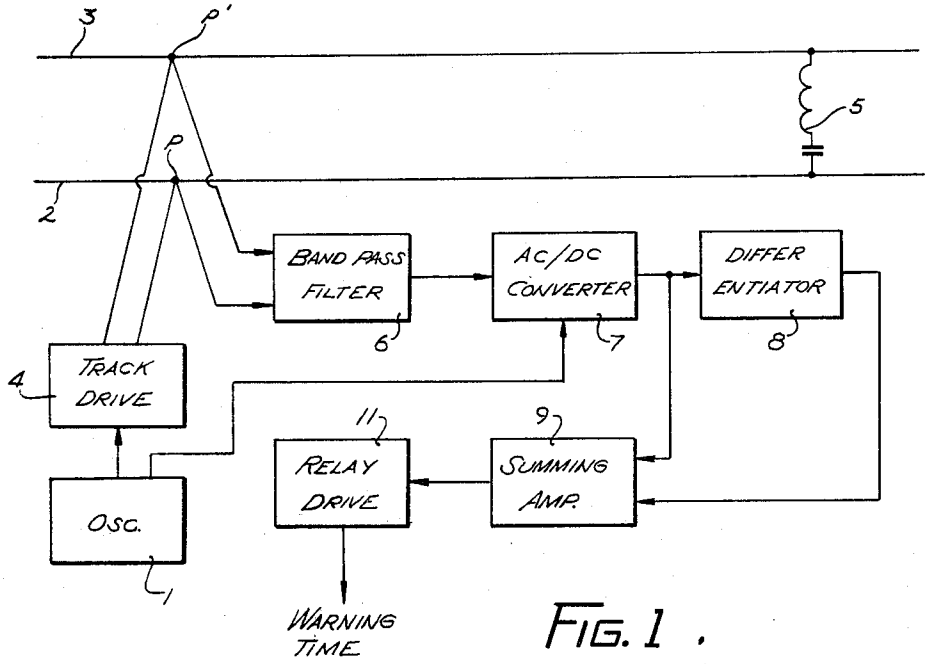


FIG. 1.

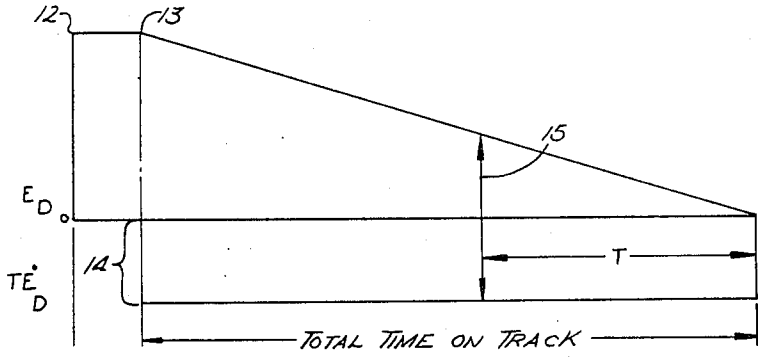
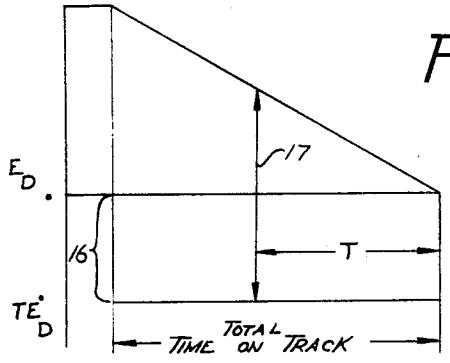


FIG. 2

FIG. 3



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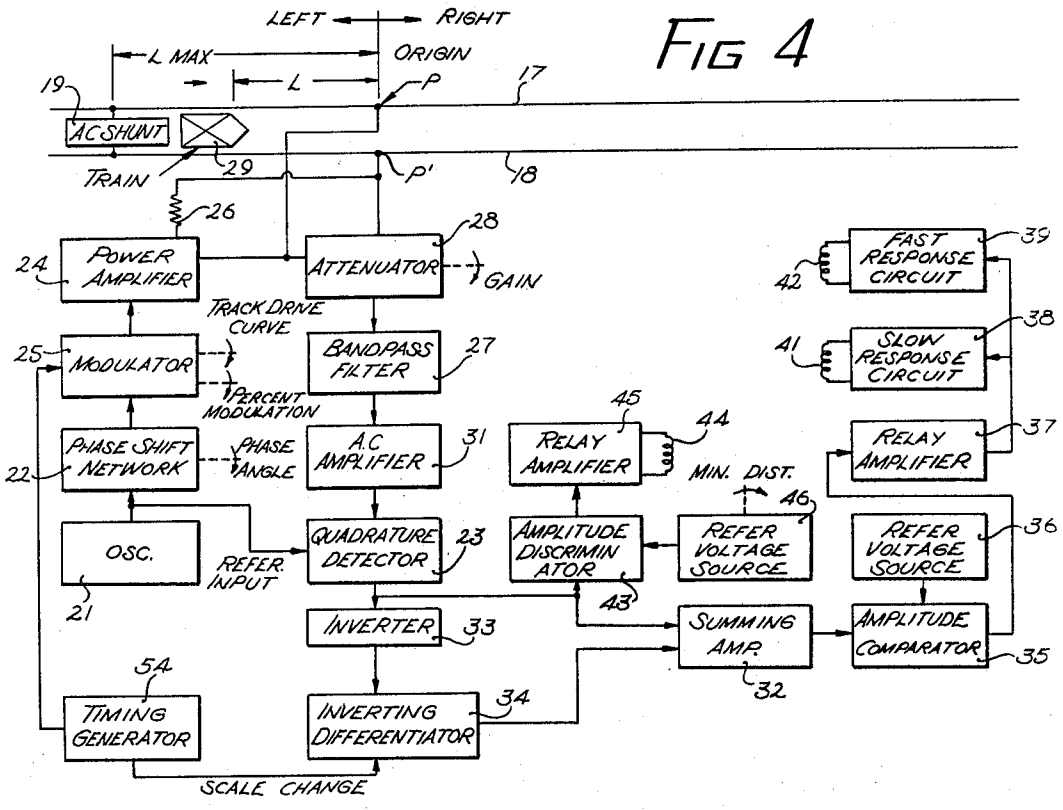
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June 25, 1968 H. M. CLANTON ET AL 3,390,256

PREDICTOR SELF-CHECK SYSTEM FOR ANALOG COMPUTER

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FIG 4



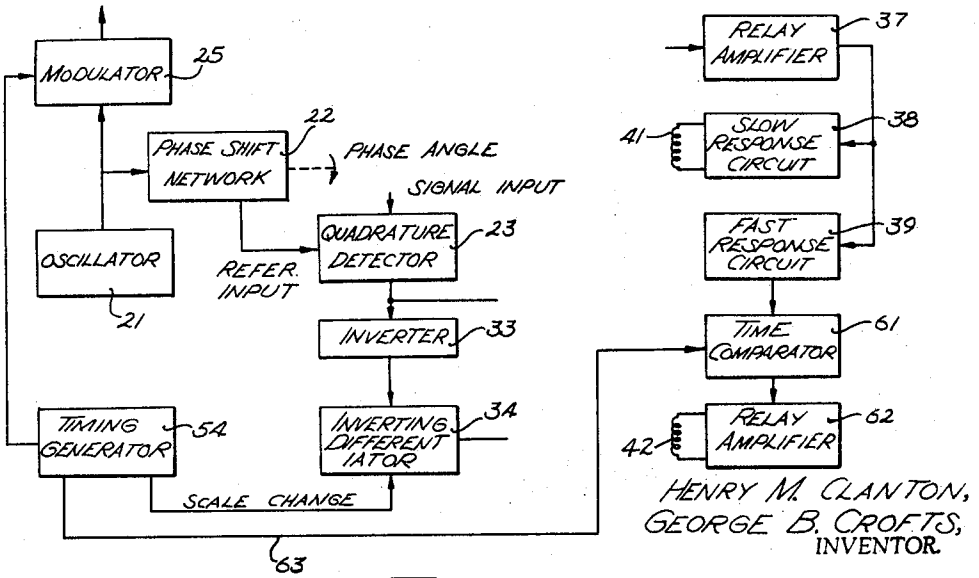


FIG. 5

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PREDICTOR SELF-CHECK SYSTEM FOR ANALOG COMPUTER

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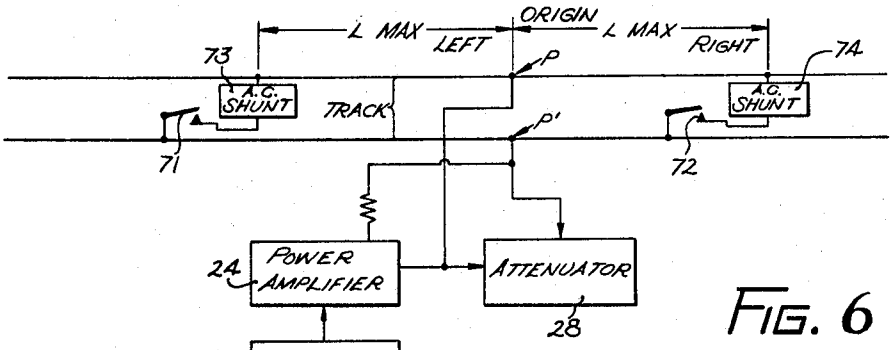


FIG. 6

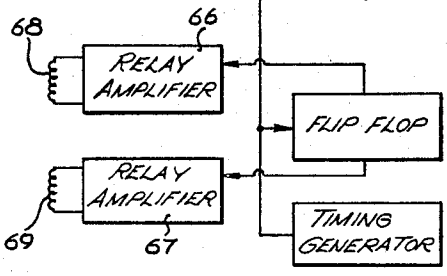
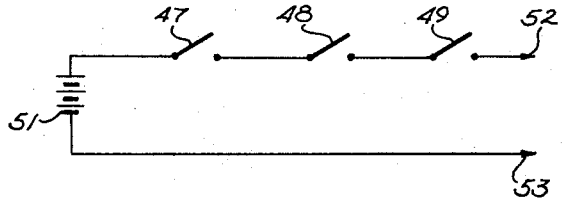


FIG. 7



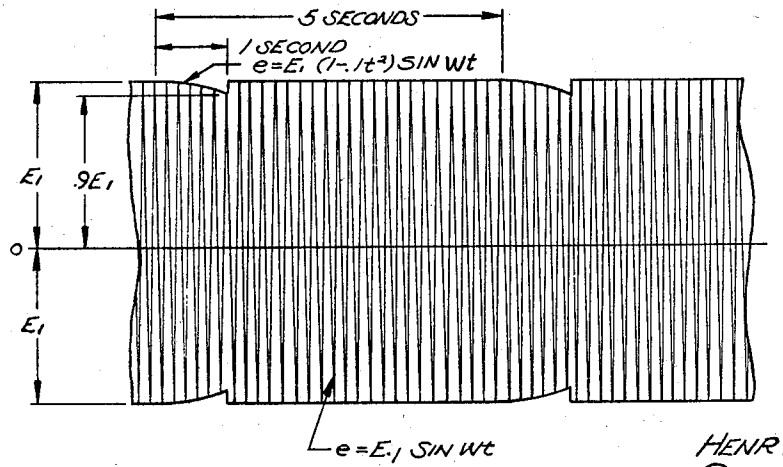


FIG. 8

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United States Patent Office 3,390,256 Patented June 25, 1968

3,390,256

PREDICTOR SELF-CHECK SYSTEM FOR ANALOG COMPUTER

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Filed Sept. 18, 1963, Ser. No. 309,731
7 Claims. (Cl. 235—153)

ABSTRACT OF THE DISCLOSURE

The apparatus simulates, at periodic intervals, a train approaching a grade crossing at a very high rate of speed, higher than any speed attainable by an actual train. This signal actuates the entire crossing predictor system and, if it is not operating properly, a stand-by system is switched into operation.

A timing generator causes a modulated test signal of approximately one second duration to be applied to the system every five seconds. A circuit having one response time responds to the approach of a train, whereas a circuit having another response time responds to the test signal.

This invention relates to predictor systems of the type used for providing a warning of an approaching train at a grade crossing and, more particularly, to a time-sharing, self-check apparatus for such systems which periodically assesses the performance of the entire system to detect possible malfunctions therein and to provide fail-safe protection of the predictor system.

There is shown and described in application Ser. No. 19,747, now abandoned, entitled, Railroad Grade Crossing Protection System, filed Apr. 4, 1960, a grade crossing warning system which operates crossing signals and/or gates at a predetermined time before the train reaches the crossing. The system disclosed therein comprises a grade crossing predictor which excites the track rails with a constant current A-C signal. The rails act as a transmission line which is shorted by the train. A detector connected to the rails is responsive to changes in the A-C excitation signal resulting from the approach of a train to continuously monitor the speed and position of the approaching train. Regardless of the speed of the approaching train, the grade crossing predictor computes when the train is at a predetermined time from the crossing and triggers the crossing warning devices. Any desired time interval between the approach of an oncoming train and the activation of the warning signals may be selected. If an approaching train halts before reaching the crossing, the predictor stops the warning signals and allows cross traffic to proceed. If the train again starts toward the crossing, the grade crossing predictor immediately reactivates the warning signals. By this means, cross traffic is provided with ample warning time, whether a fast moving mainliner or a slow moving freight is approaching the crossing.

While the grade crossing predictor shown and described in the aforementioned application represents a significant advancement in the state of the art, the apparatus of the present invention enhances the operation and further assures safety of the grade crossing predictor by providing an automatic self-check of the system's reliability.

The self-check apparatus of the present invention simulates a train approaching at a very high speed at periodic intervals. This simulated signal activates the entire grade crossing predictor system and causes it to respond in a normal manner with the exception that the operation of the crossing signals and/or gates is inhibited during the self-check cycle. If, for any reason, the self-check cycle is not satisfactorily completed, a stand-by system is switched

into operation and activates the crossing signals. Since the apparent velocity of the simulated train is very high, the duration of the predicted arrival time is very short. For this reason, the time required to check the functioning of the system is brief, typically being of the order of a fraction of a second. In a preferred embodiment, the self-check cycle is automatically repeated every few seconds. In this way, the performance of the system is, for all practical purposes, continuously monitored.

While the invention is hereinafter described in terms of its application to a railroad grade crossing predictor system, it should be understood that the novel and improved self-check apparatus of the invention may also be applied to other types of predictor apparatus such as automatic time-to-target navigation computers, and/or time-of-arrival predictors, and analog computing devices for solving equations of the form:

$$T\frac{dL}{dt}+L=0$$

or

$$aT^2+2VT-2L=0$$

where:

T=time required for moving object to arrive at given point

L=distance of moving object from given point

V=velocity of moving object toward given point=

$$-\frac{dL}{dt}$$

a=acceleration of moving object toward given point=

$$-\frac{d^2L}{dt^2}$$

It is therefore an object of this invention to provide a novel and improved predictor system having greater reliability than systems proposed heretofore.

Another object of the present invention is to provide a novel and improved self-check system for use in the predictor systems.

Yet another object of the invention is to provide a railroad grade crossing predictor system having improved reliability.

Still another object of the present invention is to provide a novel and improved self-check apparatus in a railroad grade crossing warning system for the purposes of enhancing its reliability.

It is another object of the invention to provide novel self-check apparatus for analog computing circuits in which the time scale of the checking or testing input signals is substantially reduced as compared with the normal or real-time input signals to the computing circuits, thereby permitting frequent or cyclical checking of the apparatus without significantly reducing the availability of the apparatus to receive normal input signals.

Another object of the invention is the improvement of predictor systems, generally.

A general object of this invention is to provide novel and improved grade crossing predictor apparatus which overcomes disadvantages of previous means and methods heretofore intended to accomplish generally similar purposes.

The features of this invention which are believed to be novel are set forth with particularity in the appended claims. The present invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference characters refer to similar parts and in which:

FIGURE 1 is a simplified block diagram of a grade-

crossing predictor of the type to which the invention applies;

FIGURE 2 is a graphic plot showing total-time-on-track versus distance-voltage for a slow speed train;

FIGURE 3 is a graphic plot showing total-time-on-track versus distance-voltage for a high speed train;

FIGURE 4 is an expanded block diagram of a grade crossing predictor system incorporating the self-check apparatus of the invention;

FIGURE 5 is a block diagram of an alternative embodiment of the invention;

FIGURE 6 is a block diagram of yet another embodiment of the invention;

FIGURE 7 is a switching circuit diagram useful in explaining the invention;

FIGURE 8 is a waveform diagram showing the modulation envelope of the simulated input signal and is of assistance in the exposition of the invention.

Reference will now be made to FIGURE 1 of the drawings which is a simplified block diagram of a grade-crossing predictor system of the type to which the present invention relates. It is to be understood that inasmuch as the grade crossing predictor system itself does not constitute part of the instant invention, only so much of the structural details and operation thereof considered to be essential for a complete understanding of this invention will be described herein. A complete description of a grade crossing predictor is disclosed in the aforementioned copending application Ser. No. 19,747, filed Apr. 4, 1960.

The predictor circuit includes an oscillator **1**, the output of which is applied to the rails **2** and **3** via track drive power amplifier **4**. The power amplifier circuit comprises a constant current generator which delivers the A–C input to the track at substantially a constant current. In a typical construction, the A-C excitation signal is at a frequency between 86 and 645 cycles and at a current of 200 milliamperes. The system transmits and receives at the same point utilizing the track as an impedance. The points of connection are identified as P and P'. The receiver senses the voltage developed across the tracks by the constant current generator (oscillator **1** and amplifier **4**). For an unoccupied track, the A-C shunt **5** between the rails **2** and **3** at a distance from P and P' equal to L_{MAX} provides a low impedance across the track representative of a train standing still at a maximum distance. The received signal is filtered via band pass filter **6** to eliminate noise or extraneous signals. The filtered voltage is composed of resistive and reactive components. Only the reactive component is sensed. This eliminates errors due to high rail bond resistance. This reactive or quadrature component is converted to a D-C voltage, E_D, by means of AC/DC converter **7**. This voltage (E_D) is a D-C voltage proportional to the reactive component of the received A-C voltage at points P–P'. The D-C voltage is then differentiated via differentiator **8** to obtain a voltage proportional to train speed ($\dot{E}_D$). The train speed voltage ($\dot{E}_D$) is then multiplied by warning time T, and summed in summing amplifier **9** with the distance voltage, E_D. The distance voltage E_D is supplied to summing amplifier **9** directly from AC/DC converter **7**. When $T\dot{E}_D$ is equal to or greater than E_D, then the relay drive circuit **11** is energized, which in turn activates the signals or gate at the crossing.

When no train is on the track, the received signal is maximum and constant; therefore, $\dot{E}_D$ is zero and no warning will occur. When the train approaches points P–P' on the track, E_D decreases and $\dot{E}_D$ increases to a level determined by the train speed.

The two above-mentioned conditions are graphically illustrated in FIGURES 2 and 3. Looking first at FIGURE 2, the D-C voltage E_D, which represents the distance of the train from points P–P', is plotted along the axis of the ordinate; the total time period during which

the train shorts the transmission line (tracks) is plotted along the axis of the abscissa. When the train is remote from the crossing, the distance voltage E_D will be at a maximum value as indicated at **12**. When the train passes over the track shunt the distance voltage begins to decrease. The point at which this occurs is indicated at **13** on the graph. The differentiated distance voltage ($\dot{E}_D$), multiplied by the fixed warning time T is indicated at **14** and corresponds to $T\dot{E}_D$. When this value equals the distance voltage (E_D) as indicated at **15**, the crossing signals will be activated. This gives a fixed warning time T.

As can be seen in FIGURE 3, a faster train than that depicted by FIGURE 2, will generate a greater relative velocity signal **16**; thus, the point **17** at which $E_D = T\dot{E}_D$ occurs sooner than similar point **15** in FIGURE 2, and the warning time T remains the same.

Summarizing, as the train approaches the points P–P' on the tracks to which the constant current excitation is applied, the impedance of the tracks looking toward the train from these points is continuously diminished. This follows by reason of the fact that the train comprises a short across the tracks which is moved toward point P–P'. The moving short continuously changes the reactance of the circuit as the train approaches the point P–P'. Therefore, by measuring the voltage across the tracks, an indication is obtained of the distance of the train from the points at which the voltage is impressed. The change, with respect to time, of the phase of the voltage provides velocity information, and the second derivatives of this voltage information provides information as to the acceleration of the train. There is shown in FIGURE 4 a block diagram of a practical predictor system into which is incorporated the self-check apparatus of the invention. Inasmuch as each of the functional units represented by a block in FIGURE 4 may be any one of the numerous devices for each respective function, well known in the art, it is deemed unnecessary to show circuit details.

The track, comprised of two rails **17–18** and the ballast, may be considered a transmission line. It is terminated with a narrow-band A-C shunt **19** at a predetermined distance from the point of excitation (P–P'). As stated previously, the distance at which the shunt **19** is placed from the crossing is indicated as "L_{MAX}" and is dependent upon the maximum speed of the train and the desired crossing warning time. The distributed impedance of rails **17** and **18** includes both resistive and inductive components. The relationship between the total impedance and the resistive components determines the phase angle and in a typical rail transmission line is of the order of 70 degrees. Being responsive to changes in phase, the system may be made immune to changes in resistive components, which—in practice—vary significantly with environmental changes. The A-C excitation signal is derived from oscillator **21**, the output of which is connected to phase shift network **22**. This network introduces a compensating phase shift equal and opposite to that introduced by the other elements of the signal path between the oscillator output and the input to the quadrature detector **23**, when a pure resistance load is substituted for the track impedance at points P–P'. The output from network **22** is supplied to power amplifier **24** via modulator **25**, the operation of which will be described hereinafter in connection with the functioning of the self-check apparatus. A resistor **26** connects one side of power amplifier **24** to one rail (e.g. rail **18**) at point P'. The other side of power amplifier **24** is connected to the other rail at P. The power amplifier **24** together with resistor **26** comprises a constant current generator. The output of the constant current generator is used to develop a voltage proportional to the distance of the train from points P–P'. As the train approaches the crossing the impedance of the tracks looking towards

the train is continuously being diminished. Since the current is maintained constant, the voltage decreases. By measuring the changing voltage across the tracks an indication is obtained of the distance of the train from points P–P'. The change with respect to time of this voltage provides velocity information, and the second derivative of this voltage information provides information as to the acceleration of the train.

Bandpass filter **27** has its narrow pass band centered at the oscillator frequency and is connected via attenuator **28** to the same points on the track as the constant current generator. The received signal is modulated by the motion of the train **29** towards points P–P'. The output of the narrow bandpass filter **27** is applied to amplifier **31** and detector **23** which demodulates the received A-C signal and applies it to one input of summing amplifier **32**. The output from detector **23** is a voltage representative of the distance L.

The detector output is also applied to a differentiator circuit comprising inverter **33** and differentiator **34**. The output of the differentiator circuit will be a voltage representative of the velocity V of the train. This voltage is applied to another input of summing amplifier **32**. The output of summing amplifier **32** is connected to amplitude comparator **35**.

Voltage from reference source **36** is also applied to comparator **35** to be compared with the output from summing amplifier **32**. The output from comparator **35** is applied to relay amplifier **37** whose output is divided into "warning" and "self-check" components by the slow and fast response circuits **38** and **39**, respectively. The outputs of the slow and fast response circuits operate the respective relays **41** and **42** for warning and self-check. One of the two inputs to the summing amplifier **32** is representative of the distance L between the train and the excitation points P–P', and the other is proportional to the derivative of the first which is then representative of the train's velocity. The output of the summing amplifier can be represented by:

$$-\left(L+K\frac{dL}{dt}\right)=f(t)$$

where K is the product of the differentiator scale factor and the ratio of the summing amplifier input resistor for the distance signal to that for the velocity signal. The initial negative sign is the result of the summing amplifier inversion, and dL/dt is negative for an approaching train. If it is desired to have a warning time of 30 seconds, for example, then K is set to 30 and the following equation results:

$$-\left(L+30\frac{dL}{dt}\right)=f(t)$$

Consider now a train at a distance L greater than 30 dL/dt; under these conditions, $f(t)$ will be negative and the train will take longer than 30 seconds to arrive at the excitation point (P–P'). If the train proceeds at constant speed, there will be a time when L equals 30 dL/dt and $f(t)$ will be zero. At this distance, the train will arrive at the excitation point in exactly 30 seconds if it does not change its speed. A short time later the instantaneous value of L will be less than 30 dL/dt and $f(t)$ will be positive. Therefore, the amplitude comparator **35** monitors $f(t)$ and causes the warning relay **41** to be energized through the relay amplifier **37** and the slow response circuit **38** when $f(t)$ is negative; on the other hand, relay **41** will be de-energized when $f(t)$ is zero or positive.

Having described the basic predictor system, the self-check portion of the apparatus will now be considered.

The self-check feature comprises a self-generating signal fed into the track which is changing in amplitude at a very rapid rate. This signal, which is superimposed on the transmitted current, is received and used to drive a holding circuit. This self-check feature operates every five seconds when the train is not on the track. It takes 1.5 seconds to complete the self-check cycle. Should a self-check cycle not be completed for any reason, this holding circuit drops out and the warning lights are operated. An indicator light may be employed to indicate proper operation of the equipment. During the self-check cycle, the differentiator **34** scale factor is switched to a suitable value such that, with proper adjustment of the percent modulation, a solution of the prediction equation will be obtained, $f(t)=0$, during the self-check cycle. This will be detected by the amplitude comparator **35** which will cause the self-check relay **42** to be energized through the relay amplifier **37** and the fast response circuit **39**. The self-check relay **42** is of the slow-release type (or it may be made to function as such with the addition of proper ancillary circuits) which will remain energized slightly longer than the period between self-check cycles. The slow-response circuit **38** between the relay amplifier **37** and the warning relay **41** prevents the warning relay **41** from responding to the self-check solution of the prediction equation.

Amplitude discriminator **43** monitors the distance representative output of the quadrature detector **23** and energizes the minimum distance relay **44** through the relay amplifier **45** when the distance to the train L is greater than that value represented by the setting of the reference voltage source **46**. Timing generator **54** initiates self-check cycles at an optimum repetition rate. This rate must be low enough to provide adequate time between self-check cycles for prediction of train arrival time. The repetition rate must also be high enough to provide a short enough time between self-check cycles to give a reasonably short detection time for a condition which causes the warning system to operate improperly. The timing generator **54** controls modulator **25** to which is applied the output of the phase shift network **22**. The output of the modulator **25** will be a carrier voltage at the oscillator frequency which is amplitude-modulated by the self-check wave form at intervals determined by the timing generator **54**.

As has been stated hereinbefore, the self-check modulating waveform is designed to represent a very high speed train so that the self-check response of the system will be affected to a relatively small degree by an actual train on the track. Several different waveforms can be used, but those which result in a rapidly changing velocity signal are preferred since they give best results. One such waveform, when used at a modulation factor of 10%, will give a velocity signal which varies linearly from 0 to 800 feet per second (assuming a track length of 4,000 feet) during the one second duration of the self-check cycle and may be repeated at 5 second intervals. The corresponding modulator output may be represented by

$$e=E_1(1-.1t^2)\Big]_{t=0\text{ sec}}^{t=1\text{ sec}}$$

during the self-check cycles and by $e=E_1$ between self-check cycles. This waveform is shown in FIGURE 8.

FIGURE 7 shows the normally-open contacts **47–49** of each of the three relays **41, 42,** and **44** connected in series between a power source **51** and terminals **52** and **53** for controlling a relay (not shown) in the crossing protection device (barrier gate and/or flashing lights). When any one or more of the three relays (warning **41**, self-check **42** or minimum distance **44**) is de-energized, the power to the relay in the crossing protection device will be interrupted and the crossing protection device will begin operation.

For an unoccupied track, the A-C shunt **19** between the rails **17–18** at a distance from P and P' equal to L_{MAX} provides a low impedance across the track representative of a train standing still at maximum distance. If no D-C track circuits are in use, the A-C shunt **19** may be a wire jumper. The self-check modulation of the track drive current will therefore give a voltage across the feed

points P–P' which represents a train moving very rapidly from L_{MAX} to $0.9L_{MAX}$ during the typical one second self-check cycle previously described.

With the train 29 on the track at distance L, the voltage across the feed points P–P' will represent a train moving from L to $(0.9L-Vt)$ or $(0.9L-V)$ during the typical one second self-check cycle where V is the velocity of the train and $Vt=V$, since $t=1$ second. Normally, the apparent motion of the train 29 due to the self-check modulation will be much greater than the actual train motion during the one second self-check cycle, and the self-check response will be primarily determined by the self-check modulation except when the train is close to the feed point P–P'. When the approaching train 29 is close to the points P–P', however, the warning device at the railroad grade crossing will already be actuated and performance of the self-check subsystem is of little concern.

The self-check circuit assures the complete system is intact and proper warning time will be provided. In a typical construction, the simulated train traverses the track in 0.6 second giving warnings for approximately 0.25 second. The slow response circuit 38 inhibits the operation of the warning devices via relay 41 for the quarter of a second which corresponds to the artificially generated warning time.

FIGURE 5 illustrates another embodiment of this invention which includes a time comparator 61 circuit and relay amplifier 62 between the fast response circuit 39 and the self-check relay 42. Line 63 connects the timing generator 54 to time comparator 61. All other blocks in FIGURE 5 correspond to like parts of FIGURE 4. This addition of time comparator 61 causes the self-check subsystem to operate in the same manner as that shown in FIGURE 4 except that the time comparator 61 now requires that the self-check response pulse must occur only during the preset time represented by the time sample pulse. This added restriction in the self-check gives a more stringent test of the complete grade crossing system.

Summarizing, the operation of the circuit of FIGURE 5, the self-check cycle is initiated by timing generator 54. This circuit 54 causes an additional step signal to occur at the time the simulated high-speed train is expected to cause the one-quarter second warning. These two signals, warning and the pulse from the timing circuit, must appear at time comparator 61 simultaneously. If, for any reason, coincidence is not achieved, the self-check system will cause the warning system to operate.

Another possible modification of FIGURE 4 is illustrated in FIGURE 5, though it is not necessarily related to the illustrated self-check modification. The phase shift network 22 can be equally well placed in the reference path between the oscillator 21 and the quadrature detector 23 reference input (64) rather than between the oscillator 21 and the modulator 25. With this alternative placement, the phase shift will be set equal to that in the signal path instead of equal and opposite.

An embodiment of the invention adapted to a grade crossing protection system which operates for trains approaching center feedpoints from either direction is shown diagrammatically in FIGURE 6. The operation of this system is the same as that shown in FIGURE 1 except that with the insulated joints omitted some provision must be made for checking both left and right tracks from the excitation points P–P'. This is accomplished by adding flip-flop 65, two relay amplifiers 66–67, and two relays 68–69 whose contacts 71 and 72, respectively, alternately connect A-C shunts 73 and 74 across the left and right ends of the track for the duration of alternate self-check cycles.

Although the basis of the grade crossing predictor is motion on the track, it is necessary to protect the crossing when the train is on the crossing, but not moving. This has been accomplished heretofore by means of an "island" or "street" circuit. The apparatus of the present invention, however, takes advantage of the distance voltage to accommodate this exigency. As long as the distance E_D voltage is greater than a predetermined value, the system operates in response to motion. When the voltage E_D corresponds to a distance less than this predetermined value, the system provides protection independent of motion. This feature is called "minimum distance" and is typically adjustable from 40 to 500 feet on a 4,000-foot track. It is less for shorter distances.

The self-check operation is responsive to broken rails, open rail bonds, and failure of system components.

The two controllers required to protect a crossing for single track operation each has the three controlling contacts, shown in FIGURE 7, in series with the crossing relay. These contacts are minimum distance 47, self-check 48 and warning or prediction time 49. Any of the three contacts (47–49) can cause operation of the crossing warning device. As can be seen, the invention is inherently failsafe and any failure causes operation of the crossing warning system.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to preferred embodiments, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated and in their operation may be made by those skilled in the art, without departing from the spirit of the invention; therefore, it is intended that the invention be limited only as indicated by the scope of the following claims.

What is claimed is:

1. Self-checking apparatus for an analog computing circuit having an alternating current input normally modulated at less than a given rate, comprising:
   - a timing generator for generating a timing pulse;
   - modulator means connected to said generator and responsive to said timing pulse for modulating said alternating current input at a rate exceeding said given rate;
   - first control means comprising a relay amplifier connected to said computing circuit and responsive to the output therefrom and a fast response relay connected to said relay amplifier to detect the functioning of said computing circuit; and
   - second control means comprising a slow response relay connected to said relay amplifier and responsive to the output therefrom whenever said given rate is exceeded to inhibit the output of said computing circuit.

2. Self-check apparatus as defined in claim 1 including
   - a time comparator connected to said timing generator and to said first control means, and responsive to said timing pulse, for comparing the response of said first control means with the time of occurrence of said timing pulse to check the functioning of said computing circuit.

3. Apparatus for self-checking an analog predictor circuit of the type including a differentiator having an input signal thereto variable at less than a given rate, comprising:
   - a timing generator for generating a timing pulse;
   - modulator means connected to said generator and responsive to said timing pulse for modulating said input signal to said predictor circuit at a rate exceeding said given rate;
   - scale change means connected to said generator and to said differentiator, responsive to said pulse to change the time scale of said differentiator whereby said differentiator is made responsive to said modulated input signal; and
   - control means connected to said differentiator and responsive to the output therefrom to detect the functioning of said predictor circuit and to inhibit the output from said predictor circuit in response to said modulated input.

4. Apparatus as defined in claim 3 including:
means for activating said timing generator at recurring intervals;
time comparator means connected to said timing generator and to said control means for detecting coincidence between the response of said control means and the time of occurrence of said timing pulse and thereby detect the functioning of said predictor circuit.

5. In a railroad grade-crossing predictor system having an analog computing circuit responsive to the speed of an approaching train to generate a fixed warning interval, a self-check system comprising:
means connected to the input of said computing circuit for generating an input signal simulating an approaching abnormally high speed train;
timing means connected to said generating means for periodically activating said generating means and thereby generate said simulated input signal;
scale change means connected to said computing circuit and to said timing means for adjusting the scale factor of said computing circuit so as to be responsive to said simulated input signal; and
control means connected to said computing circuit and responsive to the output therefrom during activation of said generating means for checking the operation of said predictor system.

6. In a railroad grade-crossing predictor self-check system as defined in claim 5 wherein said control means comprises:
a first relay circuit responsive to the output of said computing circuit when activated by a signal corresponding to a train approaching in a first direction;
a second relay circuit responsive to the output of said computing circuit when activated by a signal corresponding to a train approaching in a direction opposite said first direction; and
switching means connected to said timing means and to said first and second relay circuits for alternately activating said relay circuits in response to successive ones of said input signals.

7. Apparatus for self-checking a predictor system of the type including a first computing circuit for producing a first signal representative of distance in response to a variable input signal, a second computing circuit for deriving a second signal from said first signal representative of instantaneous velocity and a third computing circuit for combining said first and second signals to provide a third signal representative of arrival time, comprising:
timing means for cyclically applying a simulated signal to said first computing circuit, said simulated signal being varied at a rate exceeding the rate at which said variable input signal is normally varied;
scale change means connected to said timing means and to said second computing circuit, and responsive to said simulated signal to change the time scale of said second computing circuit whereby said second computing circuit is made responsive to said simulated signal to produce a velocity signal having a normal rate;
a reference source for providing a fixed amplitude output; and
comparator means connected to said reference source and to said third computing circuit for comparing said third signal with the output of said source to detect the functioning of said predictor system.

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