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[54] **BALLAST RESISTANCE AND TRACK CONTINUITY INDICATING CIRCUIT**

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[52] **U.S. Cl.** .... **324/65 R,** 246/28 F, 324/51

[51] **Int. Cl.** **G01r 27/02**

[58] **Field of Search** .... 324/65 R, 51; 246/34 CT, 246/34 R, 128, 126, 182 A, 28 F

[56] **References Cited**

UNITED STATES PATENTS

2,930,888	3/1960	Crawford et al.	246/34 CT X
2,985,752	5/1961	Fines, et al.	246/34 R
3,387,064	6/1968	Joy et al.	246/34 R X
3,553,481	1/1971	Hasenbeck	324/65 R X

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[57] **ABSTRACT**

A track quality meter for determing ballast resistance of a track section, regardless of whether or not the track section is insulated. An oscillator produces a signal at an appropriate frequency which is applied to the track section. Detector means, connected across the track section, is responsive to the voltage across the track section. From this voltage the characteristic impedance of the track section can be determined in a number of ways. In a preferred embodiment, the signal applied across the track section is also applied across a variable resistor. By adjusting the variable resistor so that the voltage across it equals the voltage across the track section, the resistor value is a measure of the characteristic impedance of the track section at the frequency produced by the oscillator. The characteristic impedance of the track section has a number of parameters, but only the ballast resistance in the track section is variable. As a result, the ballast resistance for the track section can be read off a calibration table.

5 Claims, 9 Drawing Figures

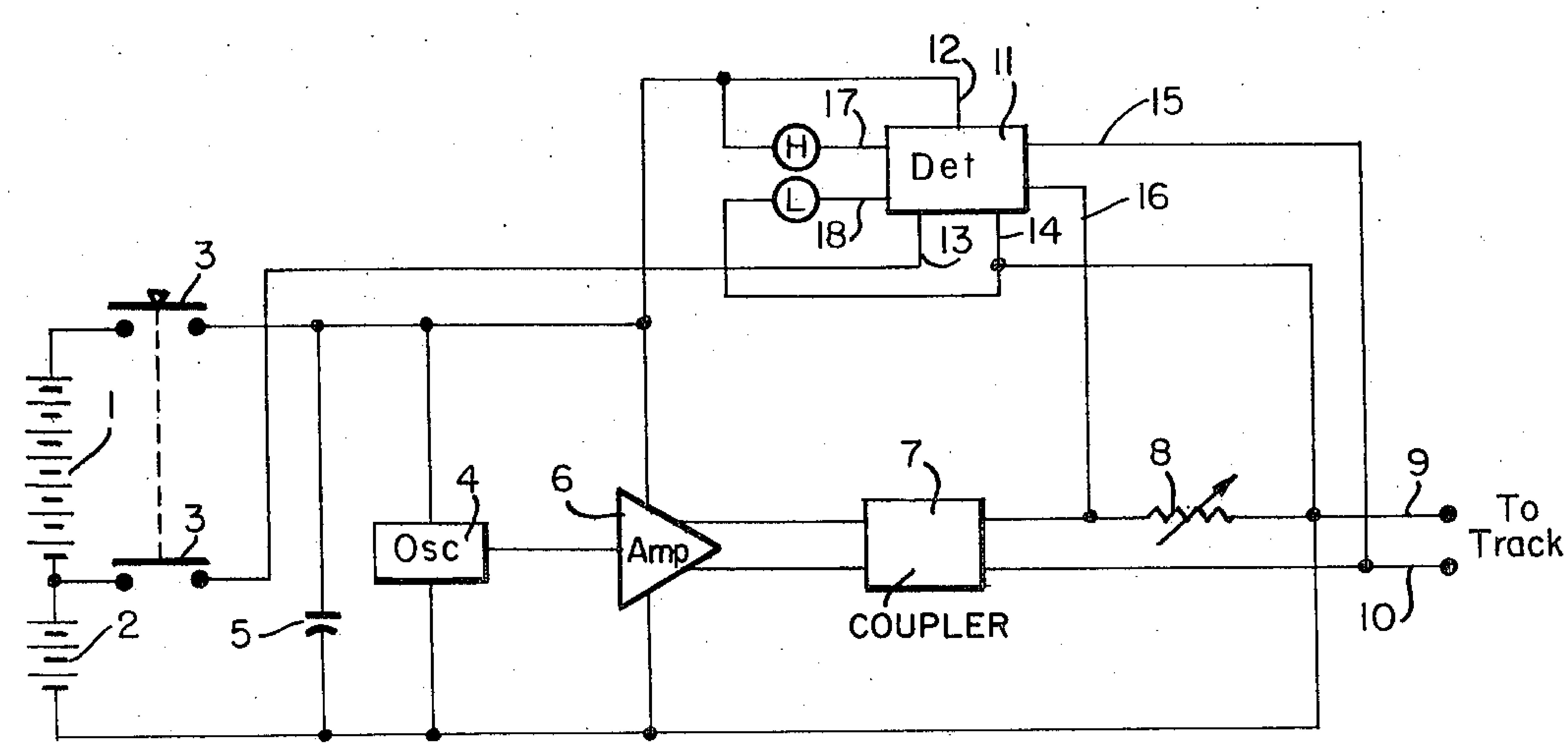


FIG. 1.

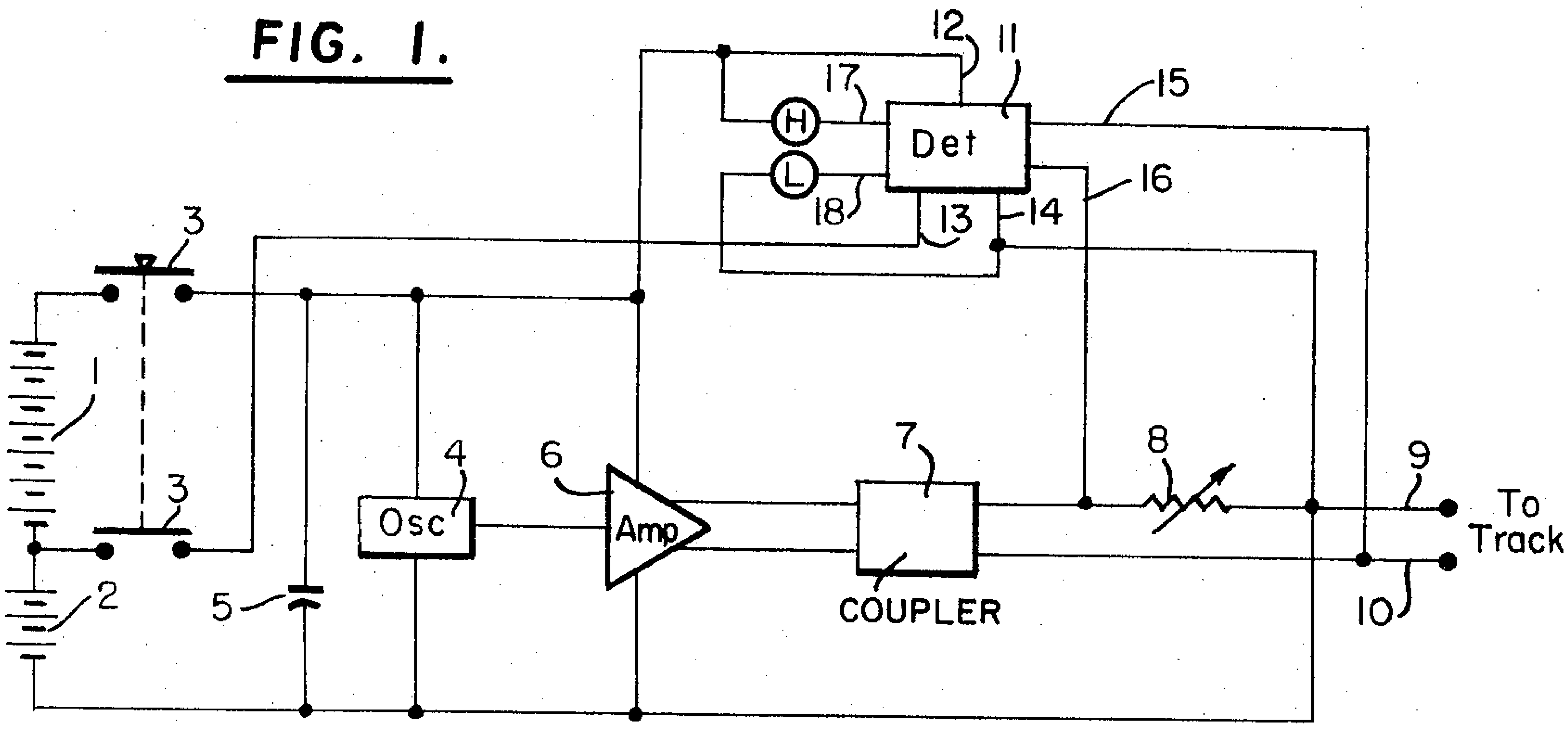


FIG. 2.

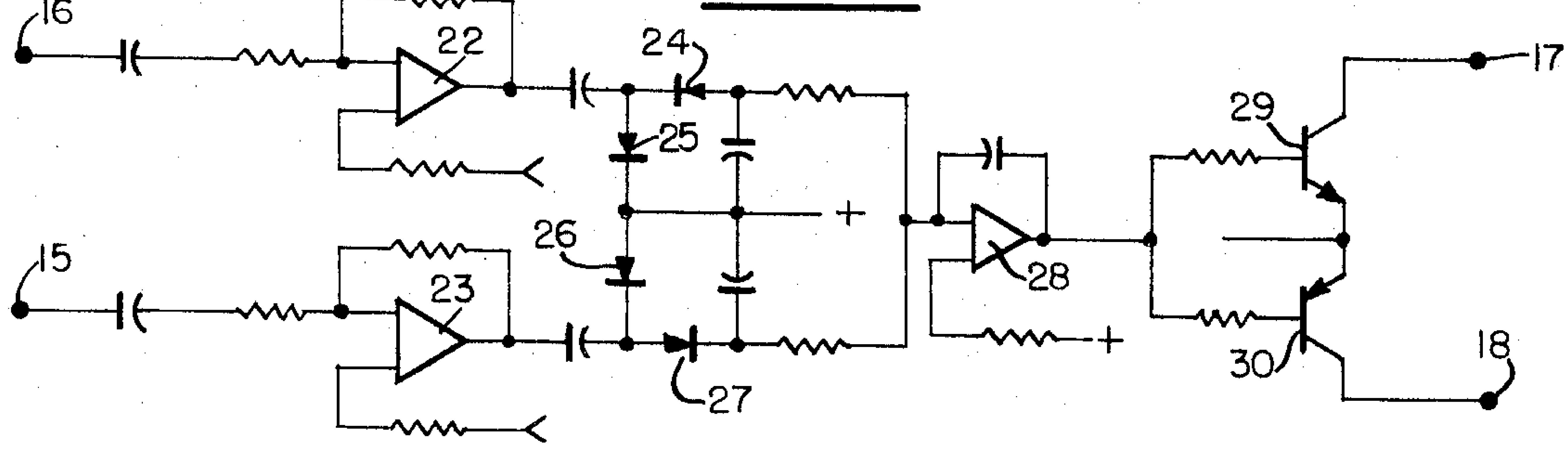


FIG. 3.

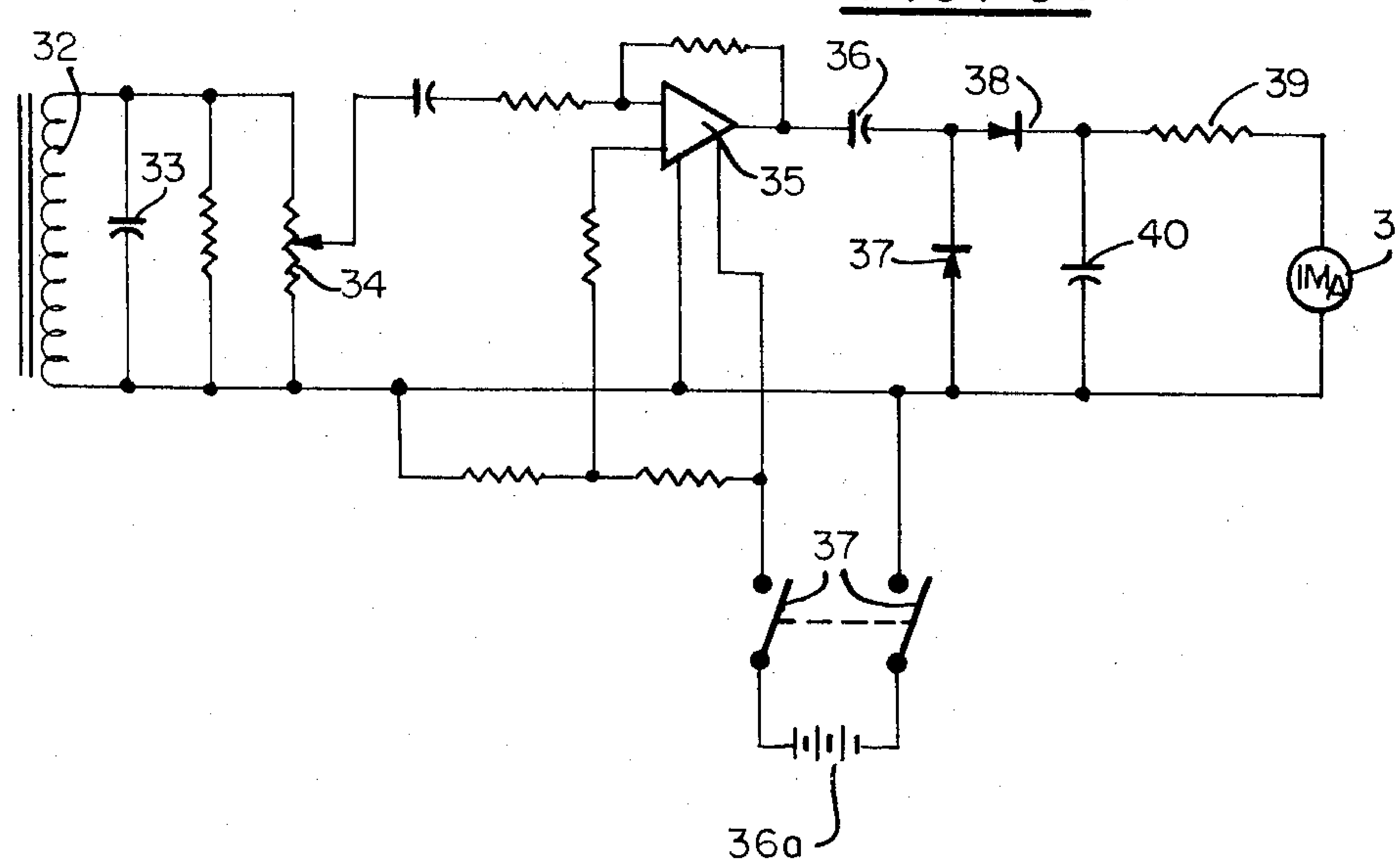


FIG. 4.

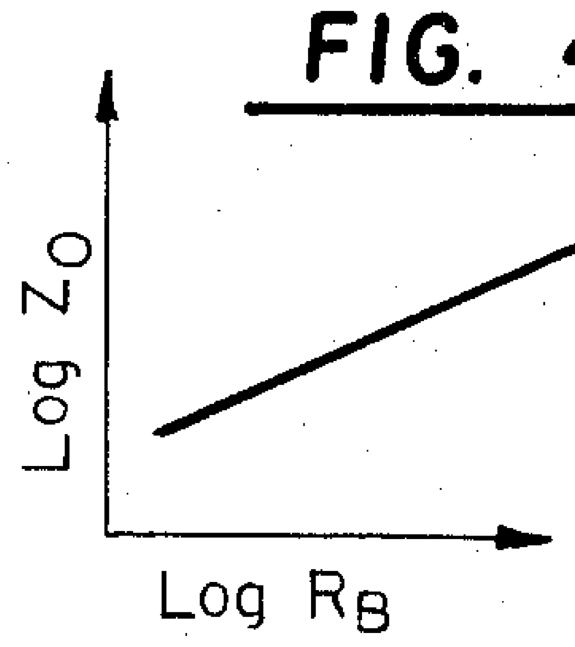


FIG. 5.

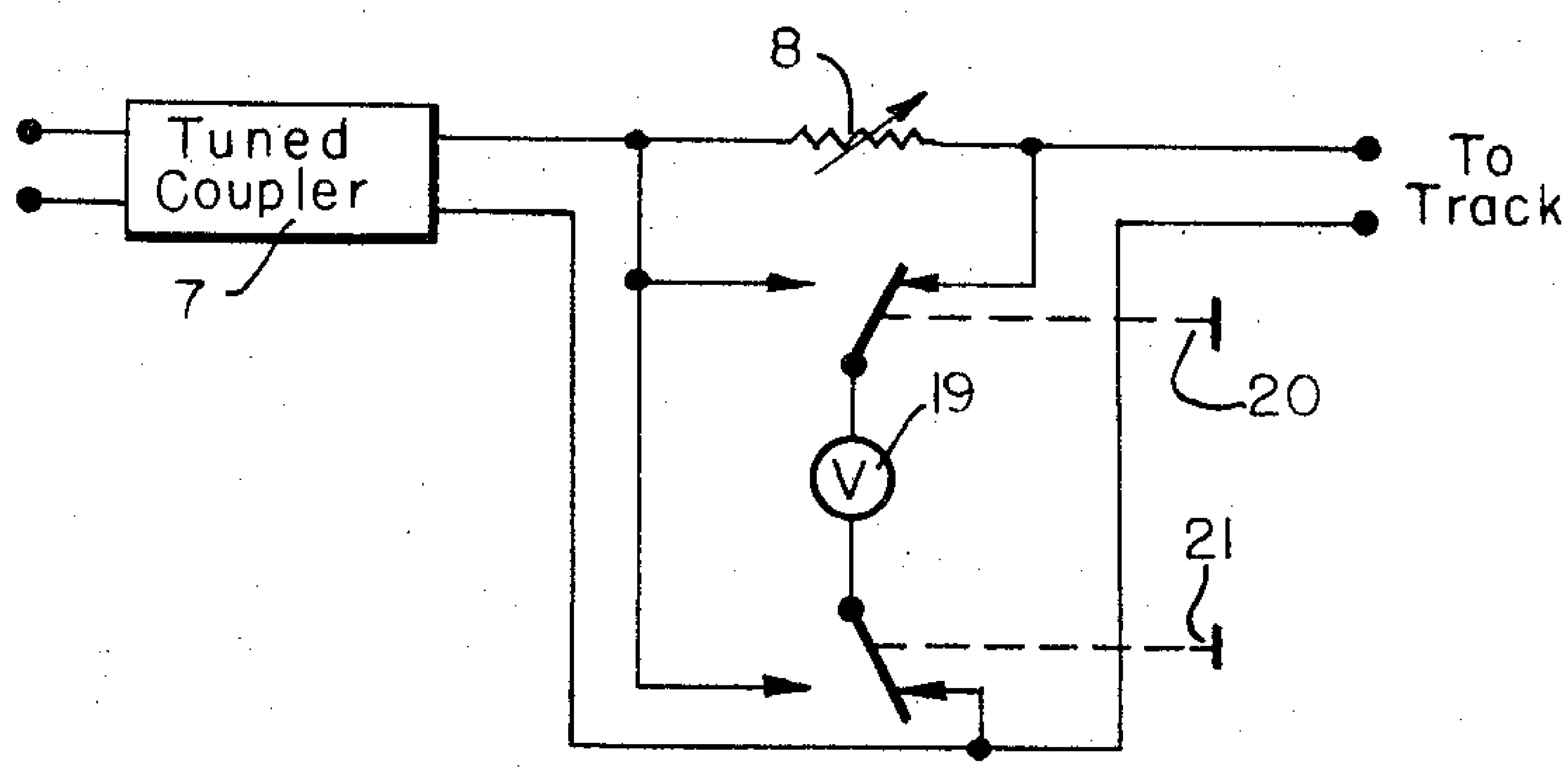


FIG. 6A.

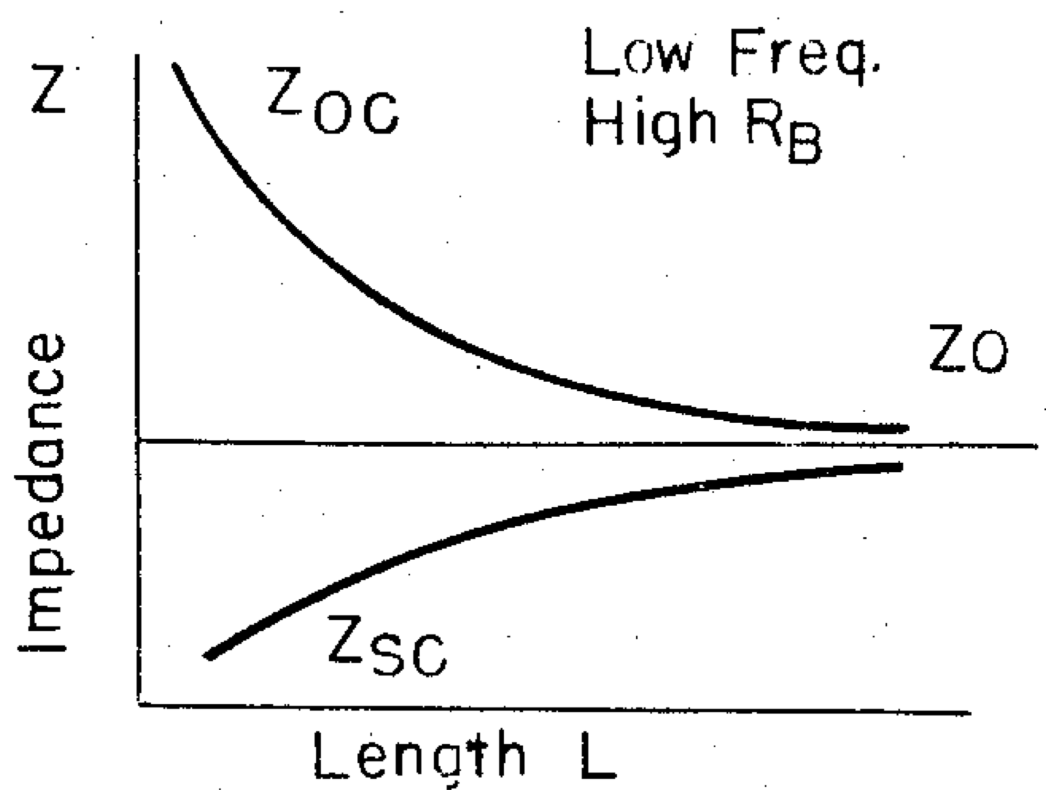


FIG. 6B.

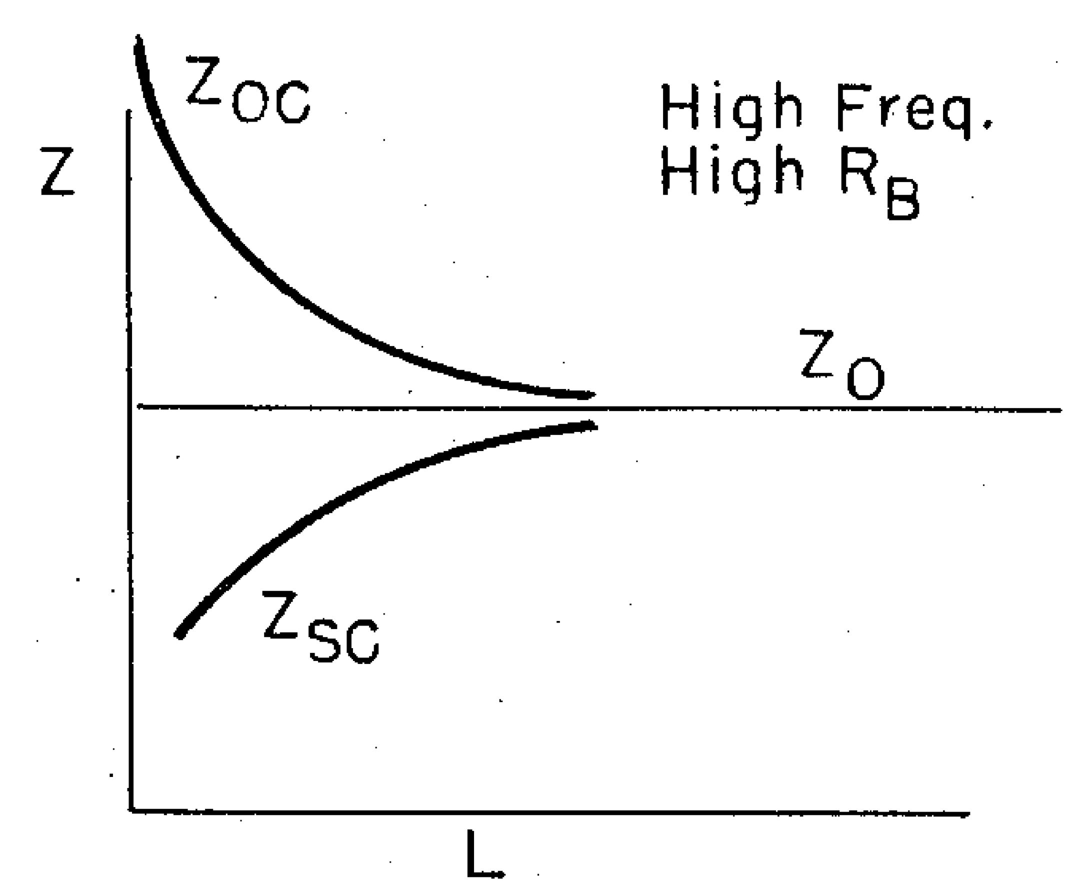


FIG. 6C.

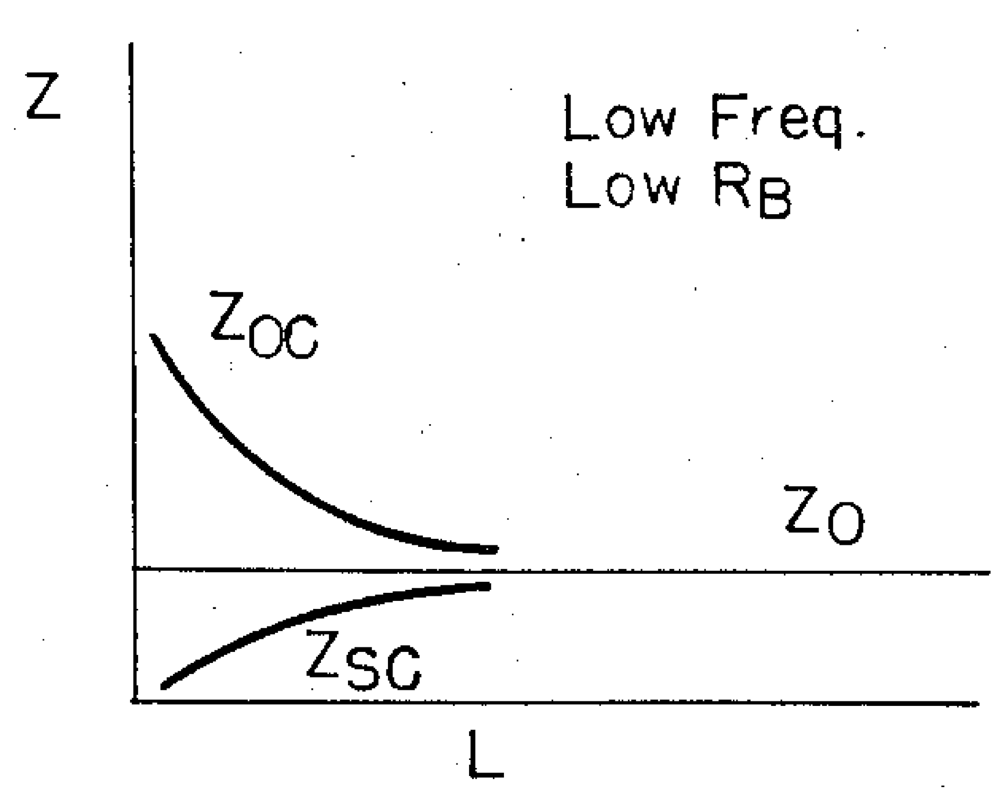
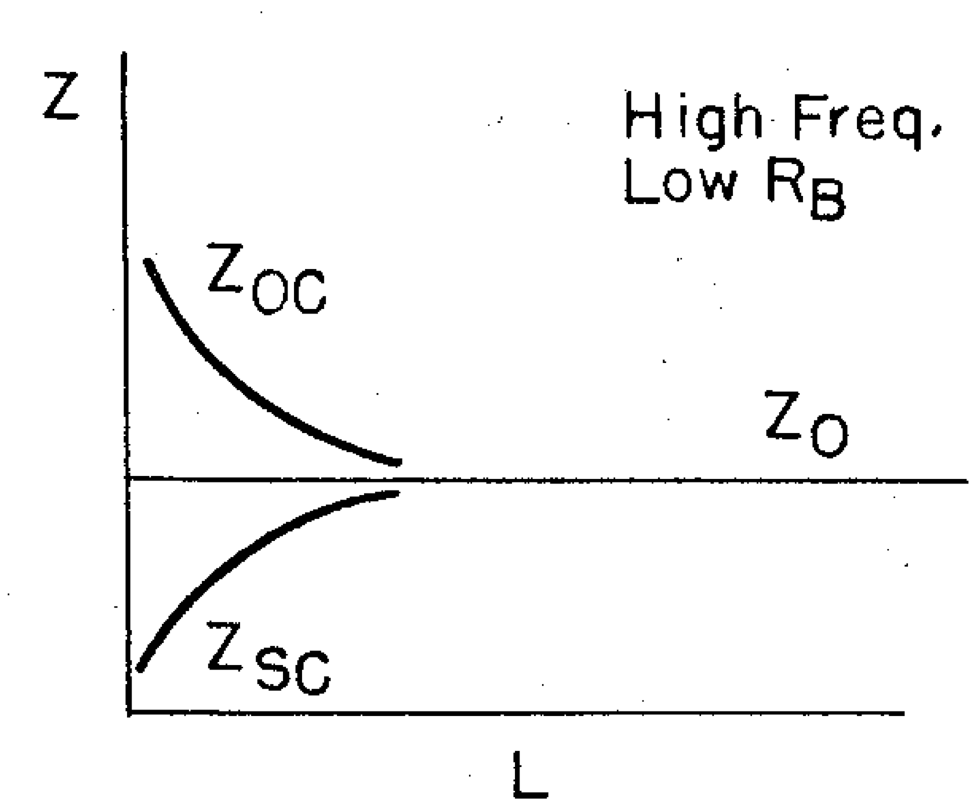


FIG. 6D.



BALLAST RESISTANCE AND TRACK CONTINUITY INDICATING CIRCUIT

FIELD OF THE INVENTION

The invention relates to measuring devices and more particularly a device for determining the ballast resistance in a section of track regardless of whether or not the track section in question is insulated or uninsulated.

BACKGROUND OF THE INVENTION

A keystone of railroad signaling and control is the well-known track circuit which is used for detecting the presence or absence of a train in a particular section of track. In the well-known track circuit, a voltage is impressed across the track rails at one end of a section of track, sometimes referred to as the feed end of the section. The resulting voltage produced at the other end of the track section (sometimes referred to as the receiving end) is monitored. The decrease in this voltage, at the receiving end of the track circuit, when a train is present in the track section, is used to signal the presence of the train in the section. The voltage normally produced at the receiving end of a track section is dependent, of course, upon the resistance presented to the current flowing in the track circuit. This resistance undergoes an abrupt decrease when the steel wheels and axle enter the section and shunt the circuit.

For many years, one method utilized to define the extent of a track circuit was to insulate each rail at both ends of the circuit. Thus, the voltage impressed at one end of the track circuit will produce a current flowing only toward the receiving end of the track circuit by reason of the insulated joints immediately adjacent the point at which the voltage is impressed. More recently, however, railroads have begun to use what is known as welded rail for the vast majority of their trackway. In this application, the sections of rail, as they are laid, are welded together so that the rail forms a continuous conductor. In this type of application, the track circuit is defined by the points at which voltage is impressed and the point at which it is received. In order to segregate these voltages, the frequencies of the voltages in adjacent track circuits are different and the receiving apparatus is tuned to the frequency of interest.

Unfortunately, however, there is at least one other parameter which enters into determining the voltage at the receiving end of a track circuit other than the presence or absence of the wheels and axles of a train shorting out the track circuit. This other factor is the effect of current leaking from one rail to the other through the ballast on which the rails are laid. The particular complicating factor of this ballast resistance is the fact that it is variable with weather conditions and other factors. When the track is relatively dry, the ballast resistance is relatively high, and conversely in humid or rainy weather, when the ballast is wet, the ballast resistance is relatively low. As a consequence, the parameters in the track circuit must be adjusted so that there is sufficient voltage at the receiving end when the ballast resistance is low and no train is present to indicate the absence of a train. By the same token it is necessary that when the ballast resistance is high and a train is present in the track section, that the voltage be reduced sufficiently at the receiving end of the track circuit so that the presence of the train will be recognized.

Thus, it is apparent that for the track circuit to operate properly, the parameters of the circuit must be adjusted in accordance with the ballast resistance in that circuit. Thus, it is necessary for measurements to be made of the ballast resistance in each section of track so as to properly adjust the parameters of the track circuit.

The prior art exclusively used DC measuring techniques for making ballast resistance measurements. In the case of welded rail applications, this measurement is obviously highly inaccurate as there are no readily available means for determining the length of track over which the measurement has been made. This particular disadvantage is not applicable to insulated rail track section measurements. However the art has found that in making DC measurements of ballast resistance, the indicated value varies appreciably with current level. This leaves the operator in doubt as to the ballast resistance value that should be used in adjusting the parameters of the track circuit. Also, using a DC measurement technique does not allow for indication of non-uniform ballast characteristics. Thus, if there is a portion of the section in which the ballast is non-uniform in resistance, this effect will be averaged in with the ballast resistance of other portions of the track section which will result in an inaccurate measurement. If the parameters of the track circuit are adjusted in accordance with that reading, the track section will exhibit poor shunting sensitivity adjacent the feed end of the track circuit.

To overcome these difficulties and to obtain an accurate reading of ballast resistance, I employ a high-frequency oscillator to generate the voltage applied to the track section in question. For high frequency throughout this application, I mean high audio frequency extending up from about 10 khz to the order of 50 khz. At frequencies in this range the track section can be analyzed as a transmission line. As is well known, the impedance of an infinite transmission line is known as the characteristic impedance of that line. Departing upon the frequency of measurement, the length of the track section which is necessary to appear as infinite can vary from some 400 to 2,000 feet. Using a high frequency voltage for measurement effectively isolates a section of track for the measurement. The length of the track section isolated depends upon the frequency utilized.

A number of different detectors can be used in order to make the characteristic impedance measurement. In the preferred embodiment, the track section is fed through a variable precision resistor. The resistor is adjusted in value so that the voltage across the track rails equals the voltage across the resistor. This can be indicated either by a meter arrangement or a differential amplifier. In any case, the value of resistance is then equal to the magnitude of the characteristic impedance. An alternative detecting arrangement would be to provide a constant current source power supply. Thus merely measuring the voltage across the track rails would give an indication of the track characteristic impedance. In a further elaboration of this arrangement, an analog multiplier could be so connected that by manipulating the voltage and current applied to the track rails, a signal will be obtained proportional to the characteristic impedance. Regardless of the detecting arrangement used, the result is a value for the characteristic impedance of the track section.

Knowing the characteristic impedance of the track section and the frequency of measurement, one can, from a calibration curve, read off the value of the ballast resistance.

The factors that dictate the characteristic impedance of a section of track are all fixed except for the ballast resistance, that is, the cross-sectional area and shape of the rails, spacing between rails, material of the rails, etc. Furthermore, the variation of log Z_o (where Z_o is the characteristic impedance) with log R_B (where R_B is the ballast resistance) is essentially linear as shown in FIG. 4. Therefore, construction of a calibration curve or table to relate characteristic impedance to ballast resistance at a particular frequency with specified rail materials, shape and spacing can be performed by insulating a section and making two DC measurements of ballast resistance under different conditions. At the time of each DC measurement, another measurement is made with the apparatus disclosed herein. Since the logarithmic relationship is linear, from these two points a calibration curve or table can be constructed.

I also provide an accessory to determine whether or not the characteristic impedance value determined by the meter is or is not meaningful. Discontinuities of lack of uniformity in the track section can result in a characteristic impedance value which is inaccurate. A current probe is provided which is capable of measuring the current in the track rails. Assuming a measurement is made at a location where it is reasonable to assume the current flow equally in opposite directions from the point of voltage application, the current in two directions in both track rails should be approximately equal if there is a lack of discontinuities. Nonuniform current would indicate the presence of a discontinuity. Discontinuities can occur by reason of faulty insulation adjacent track switches, faulty insulation in insulated rail, nonuniform ballast resistance, or metallic masses whose location is not symmetric with respect to the two rails in the track section. These masses could be adjacent tracks or bridges or the like. Nonuniform current values where there is no obvious explanation for the nonuniformity are a signal to the operator that before he can accept the impedance measurement as being valid, he must locate the cause of the nonuniformity and determine if it is affecting the characteristic impedance measurement.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings of this application, when taken in conjunction with the descriptive portion of this specification, provide a description of applicant's invention. In the drawings,

FIG. 1 is a block diagram schematic of the track quality meter,

FIG. 2 is a circuit diagram of the preferred embodiment detector arrangement,

FIG. 3 is a circuit diagram for the accessory current probe,

FIG. 4 is a graphical representation of the variation of characteristic impedance with ballast resistance at a constant frequency,

FIG. 5 is a schematic diagram of another embodiment of a detector arrangement, and

FIGS. *6a–6d* show the variations of track length measured with frequency and ballast resistance.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a block schematic diagram of the track quality meter of the instant invention. The power supply comprises DC voltage sources **1** and **2** which are connected to the rest of the circuit through on-off switch **3**. An oscillator **4** is connected across the power supply and provides a high frequency signal to amplifier **6**. The range of usable frequencies lies between 10 khz to 50 khz. At 10 khz the length of track which is measured becomes too long to obtain the advantages of the invention and above 50 khz the effective track length measured becomes too short for practical use. Preferably a frequency in the range 30–40 khz is employed. In this range the effective length of the measurement is a few thousand feet with high ballast resistance and three to four hundred feet with low ballast resistance. The effective length over which the measurement is made is that length of track which appears infinite, under the measurement conditions. This length is qualitatively shown in FIGS. *6a–6d*. The output of amplifier **6** is fed to tuned coupler **7**. The coupler is tuned to the frequency of oscillator **4** and ensures that it presents a low impedance to the track rails only at the frequency of oscillator **4**. Thus, the track quality meter can be connected to a track section and it will not affect the operation of the associated track circuit, assuming the track circuit operates on a frequency different than that produced by oscillator **4**. The output of tuned coupler **7** is fed to the track section through terminals **9** and **10**. Terminal **9** is connected to the output of the tuned coupler **7** through a precision decade resistor **8**. The decade resistor is an operator-controlled resistor whose controls indicate the resistance actually in the circuit. Power is supplied to detector **11** through its terminals **12** and **13** from the power source. The detector **11** is connected to the circuit ground through terminal **14**. The voltage across the precision decade resistor **8** is provided to the detector **11** through its terminal **16**. The voltage appearing across the track section is provided to the detector **11** through its terminal **15**. The two outputs of detector **11** appear at terminals **17** and **18** and are respectively connected to indicator lights H and L.

In operation, when it is desired to make a characteristic impedance check upon a particular track section, it is only necessary to connect terminals **9** and **10** to the track section by conventional clamps (not shown). Closing on-off switch **3** energizes the track quality meter and supplies a high frequency signal to the track rails. Depending upon the setting of precision decade resistor **8**, one or the other of the indicator lamps H and L will be lit. Manipulation of the precision decade resistor **8** will allow it to be adjusted so that the voltage provided detector **11** at terminal **15** is equal to the voltage provided detector **11** at terminal **16**. When this condition is achieved, the characteristic impedance can be read off the controls of decade resistor **8**. Assuming that the track quality meter had been connected to a section of welded rail, the length of track whose characteristic impedance has been measured is determined by the frequency of oscillator **4**. The higher the frequency of the oscillator, the shorter the length of track whose characteristic impedance has been measured. In practice measurements are made at periodic intervals along the track section. The intervals are between 400 and 1,000 feet depending on the frequency of the oscillator. When making measurements on welded rail the characteristic impedance read from the controls of resistor **8** will be one-half of the characteristic impedance of the track. The voltage provided to the track produces current flowing in both directions from the connection from the connection point. As a result the impedance presented by the track is actually a parallel combination of two impedances, each equal to the characteristic impedance of the track.

When making measurements far from insulated joints the same considerations apply. However, when making measurements close to an insulated joint the setting of decade resistor **8** will equal the characteristic impedance of the track. In order to determine the actual ballast resistance that has been measured, it is necessary to refer to a calibration curve such as the one shown in FIG. **4.** The calibration curve shown in FIG. **4** must be one for the frequency at which the oscillator **4** is tuned. Entering the graphical representation at the value of characteristic impedance Z_0 equal to that measured, one can read from a horizontal scale the value of ballast resistance corresponding thereto.

FIG. **2** shows a detailed schematic of the detector **11** wherein like reference numerals identify identical apparatus. Thus, terminal **16,** shown in FIG. **2,** is the same as terminal **16,** shown in FIG. **1,** etc. The voltage input signal from the precision decade resistor **8** is provided to input terminal **16** and it is amplified by operational amplifier **22.** The voltage provided detector **11** from the track rails is introduced to terminal **15** and it is amplified by operational amplifier **23.** These voltages are then compared one with the other in a diode network comprising diodes **24** through **27.** The difference between these voltages provides an input signal to operational amplifier **28** whose output is fed to the bases of transistors **29** and **30.** The emitter of transistor **29** is connected to the emitter of transistor **30** which are both connected to a positive source of potential. The collector of transistor **29** is connected to terminal **17** and the collector of transistor **30** is connected to terminal **18.** Depending upon the relative magnitude of the potentials applied to terminals **16** and **15,** the voltage provided to the bases of transistors **29** and **30** will be either above or below the bias potential applied to the emitters of these transistors. Assuming that the potential applied to the bases of transistors **29** and **30** is above the bias potential, then transistor **29** will conduct which will cause the H indicator lamp connected to terminal **17** to be lit. On the other hand, if the voltage provided to the bases of transistors **29** and **30** is less than the bias potential, then transistor **30** will conduct energizing the L indicator lamp connected to terminal **18.** This informs the operator of the direction in which the value of precision decade resistor **8** should be changed so as to equalize the voltages across the decade resistor and across the track rails.

An alternate embodiment of a detector arrangement is shown in FIG. **5** again where like reference numerals indicate identical apparatus. FIG. **5** shows the tuned coupler **7** and omits the power supply, oscillator and amplifier. The output of the tuned coupler is fed through the decade precision resistor **8** to the track rails. A volt meter **19** is connected between the poles of single pole double throw switches **20** and **21.** In the position shown, the volt meter **19** would indicate the voltage across the track rails. When pushbutton switch **21** is depressed, the volt meter **19** will read the voltage across the precision decade resistor **8.** By manipulating pushbutton switch **21** and the controls of the precision variable decade resistor **8,** the operator can adjust the resistor **8** so that the voltage read by volt meter **19** does not change when pushbutton switch **21** is depressed. This is the equivalent condition indicating that the controls of decade resistor **8** read the characteristic impedance of the track section.

As a further alternative to the detector means arrangement illustrated in FIGS. **2** and **5,** the oscillator **4** and amplifier **6** (shown in FIG. **1**) are arranged to act as a constant current source at the frequency of oscillator **4,** by means well known in the art. In order to obtain a measure of the characteristic impedance of the track to which the tuned coupler **7** is connected, it is then only necessary to measure the voltage across the track rails. Since the current supplied the track rails is constant, the volt meter could be calibrated in terms of characteristic impedance. In further elaboration of this embodiment, the voltage across the track rails could be fed to a multiplying circuit, such as an integrated circuit solid state multiplier. A second input to this multiplier would comprise a signal proportional to the inverse of the current supplied by the constant current source. The resulting output voltage from the multiplier would then be directly proportional to the characteristic impedance of the track rails.

The foregoing portion of the specification demonstrates the manner in which the track quality meter can determine the characteristic impedance of a section of track. However, as has been explained above, before the operator can rely upon this value of characteristic impedance in determining the actual ballast resistance of the section of track, it is necessary for the operator to be informed as to whether or not the reading he has obtained is an accurate one, that is, whether or not any discontinuities or nonuniformities have entered into this value. As an aid to making this determination, the current probe, illustrated in FIG. **3,** can be utilized. The operating principle of the current probe illustrated in FIG. **3** is as follows. When the track quality meter is connected across a section of track which is uniform and exhibits no discontinuities, the current in both rails of the track will be equal. Furthermore, the current proceeding away from the connection point in one direction in one rail will equal the current proceeding in the opposite direction from the same connection point of that rail. A discontinuity or nonuniformity in the track section will cause the currents to be nonuniform. The coil of the current probe shown in FIG. **3** is placed adjacent each rail, on each side of the connection point of the track quality meter. The ammeter **31** will provide a value for the current flowing in the rail adjacent the coil. If the current values are substantially equal, the operator is assured that there are not discontinuities or nonuniformities. On the other hand, if the values of current are unequal, the operator is informed that he must examine the track section, either visually or otherwise to determine the cause for the nonuniform current readings.

The current probe comprises a coil **32** connected across a capacitor **33.** The combination of these elements is tuned to the frequency of oscillator **4.** A calibration potentiometer **34** is in parallel with the coil **32** and capacitor **33** to provide a scale adjustment for the meter **31.** The signal from potentiometer **34** is provided to an operational amplifier **35** which is powered by a DC source of potential **36***a*. Power is applied to the current probe through on-off switch **37.** The signal from the operational amplifier **34** is fed through a capacitor diode network comprising capacitors **36** and diodes **37** and **38**. A protective resistor **39** provides a current path from the diode **38** through the meter **31**. A capacitor **40** is connected in parallel with the resistor **39** and meter **31** to shunt any higher frequency signals.

When making measurements adjacent insulated joints, of course, the current probe should measure equal currents in the two track rails flowing away from the joints and little or no current flowing towards the joints. If there is an appreciable amount of current flowing towards the insulated joints, then a defective insulated joint or joints has been located.

What is claimed is:

1. A measuring device for measurement of ballast resistance in a section of track comprising,

an oscillator producing a high frequency signal,

coupling means connected to said oscillator,

a variable resistor connecting said coupling means to said track, and

detector means connected to said track and to said variable resistor including further means to indicate, as the variable resistor is varied in value, when the voltage across said resistor is equal to the voltage across said track.

2. The device of claim **1** wherein said further means comprises a meter selectively connectable across either said track or said variable resistor.

3. The device of claim **1** wherein said further means comprises comparison means producing a signal whose magnitude is indicative of whether or not said voltage across said track is greater or less than said voltage across said resistor,

and indicating means connected to said comparison means for indicating whether the voltage across said track is greater or less than the voltage across said resistor.

4. The device of claim **3** wherein said indicating means includes a pair of indicating lamps, each of said lamps being connected to the collector of a pair of complementary transistors,

the emitters of said complementary transistors being connected together and connected to a bias potential,

the bases of said complementary transistors being connected to said comparison means.

5. A method of determining ballast resistance of a section of track comprising the steps of,

injecting a high frequency signal in both rails of said track,

determining the impedance presented to said signal by said track,

determining whether the currents flowing in each of the rails of said track are uniform,

and determining, if said currents are uniform, from the characteristic impedance the ballast resistance presented by said track.

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