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MOVABLE CORE TRANSFORMER TRANSDUCER WITH
COMPENSATED PRIMARY WINDING

3,555,405

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2 Sheets-Sheet 1

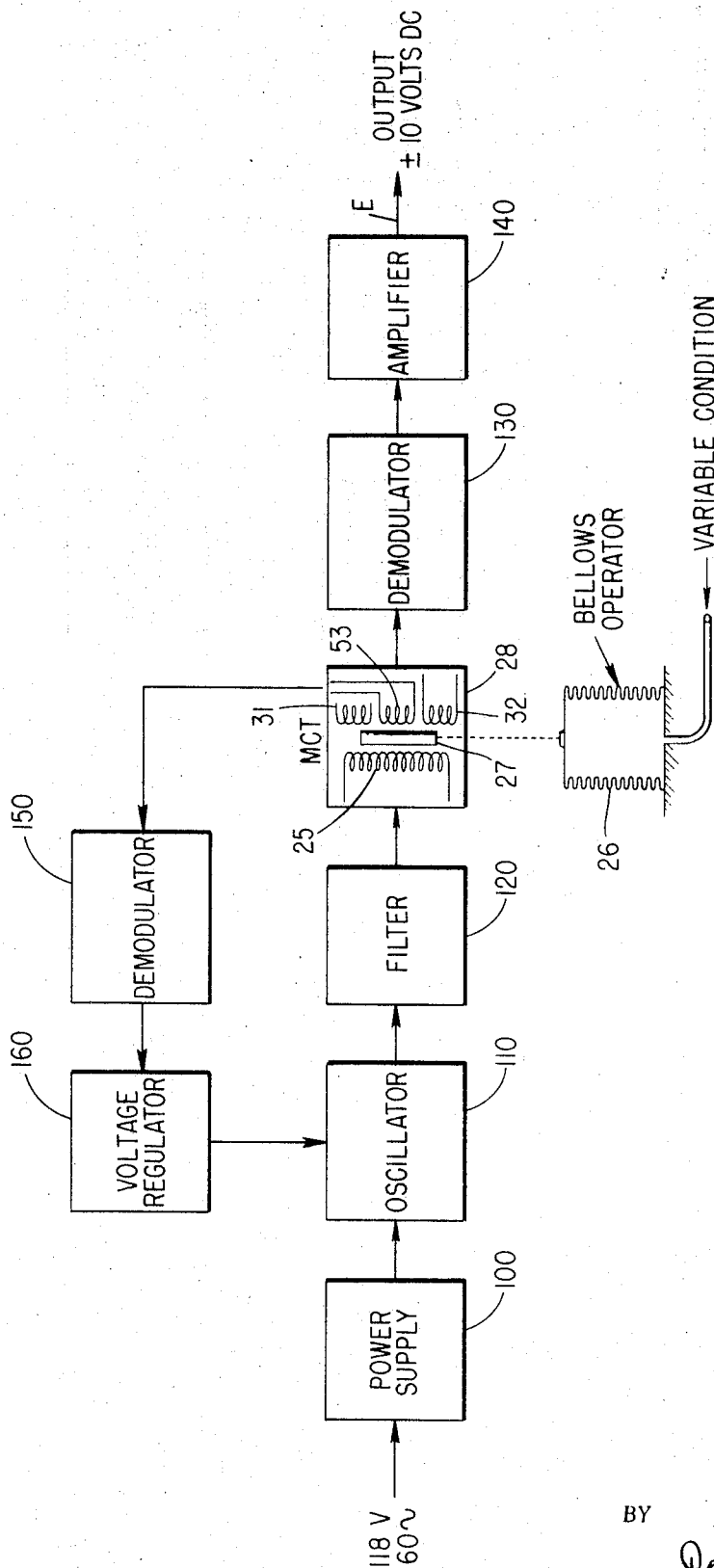


FIG. 1

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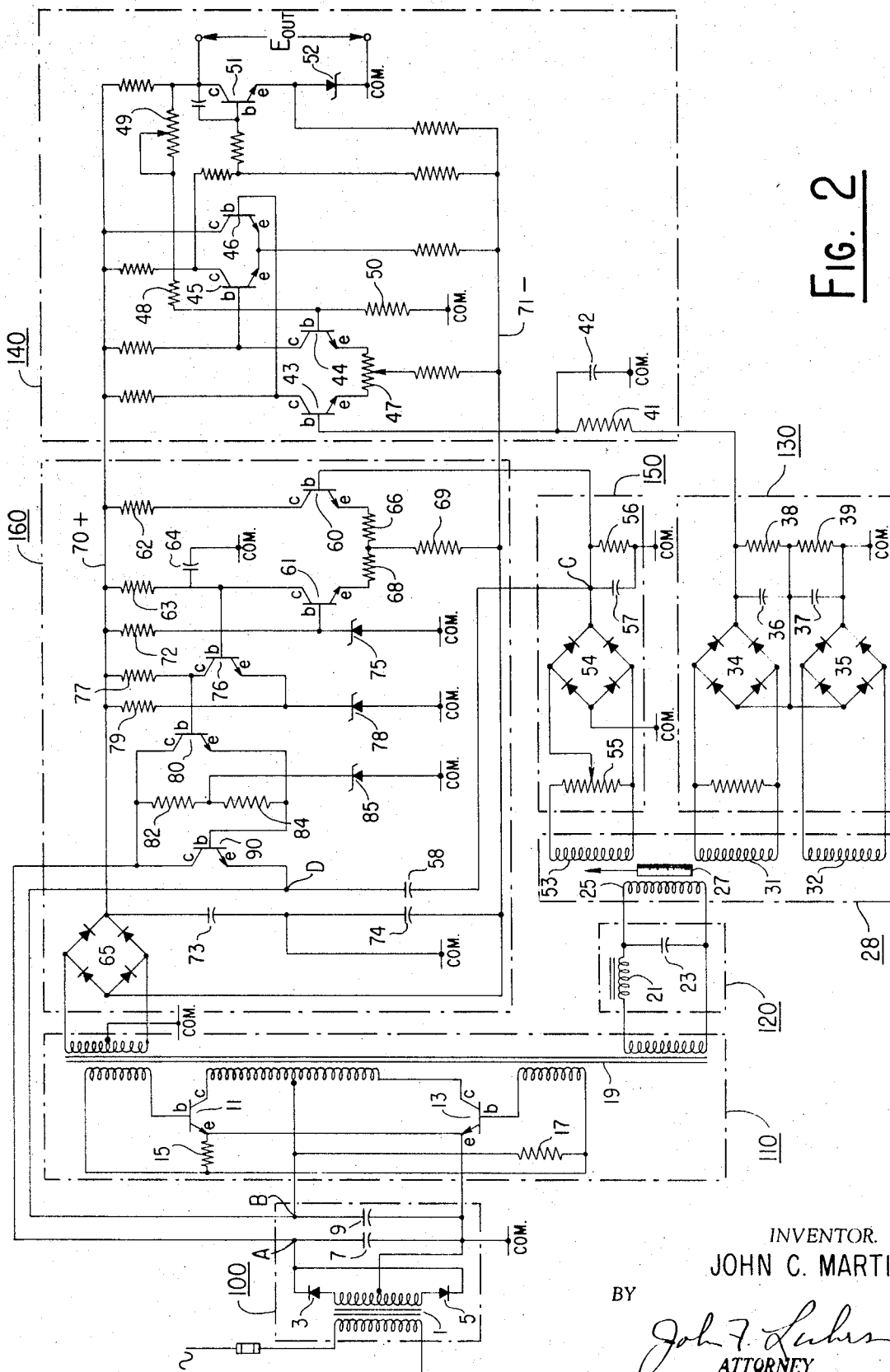


FIG. 2

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1

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MOVABLE CORE TRANSFORMER TRANSDUCER WITH COMPENSATED PRIMARY WINDING

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4 Claims

ABSTRACT OF THE DISCLOSURE

An MCT measuring circuit which includes a voltage regulator circuit forming a feedback path from an independent auxiliary secondary winding of the movable core transformer to an oscillator circuit which generates a square wave energization signal. This energization signal is applied to a filter circuit which is magnetically interposed between the oscillator circuit and the primary winding of the movable core transformer in order to attenuate the odd harmonic sinusoidal frequency components of the square wave signal while passing a substantial portion of its fundamental frequency component to the primary winding so as to enhance the operational characteristics of the transducer.

BACKGROUND OF THE INVENTION

This invention relates to transmitting devices and more particularly to a transmitter utilizing a movable core transformer for producing an electrical output signal representative of a variable condition.

Field of the invention

The movable core transformer has been heretofore employed as a transmitting device to establish an electrical output signal representative of a condition. Such transmitting devices produce an alternating voltage across a secondary winding dependent on the position of the core which establishes the inductive coupling between the primary and secondary windings.

In many electrical instrumentation systems, and particularly those employed in process control, it is desired to use D-C voltage signals for transmission between remote locations. Accordingly, when a movable core transmitter is used to derive a signal representative of a variable, the A-C output signal is usually converted into a D-C voltage signal variable in a desired positive and negative range. In a typical system, the D-C voltage signal range may be, for example, +10 to -10 volts.

Description of the prior art

The major causes of fluctuation in signal output are variations in supply voltage and ambient temperature. Secondary causes are changes in core permeability and the like.

It has been customary to compensate for fluctuations in supply voltage by incorporating a voltage regulator in the movable core transformer primary circuit. Conventional voltage regulators, both the saturable transformer type and the electronic type, furnish a distorted output wave shape as well as being sensitive to variation in supply voltage frequency. Yet another disadvantage of conventional devices is the narrow input voltage range for which the regulator will produce a constant output.

A rise in transformer temperature results in an increase in the resistance of the copper wire ordinarily used in

2

the primary and secondary coils. The most direct consequence of this resistance increase is an increase in primary impedance with an associated reduction in primary current which, in turn, affects the magnetic flux. The ambient temperature compensation device commonly used in the movable core transformer circuit is a thermistor. The thermistor, having a negative temperature coefficient, responds to an increase in ambient temperature by a decrease in resistance. Such a device, matched for a given circuit application, is inserted in series with the primary winding of the transformer, said winding having a positive temperature coefficient. A change in ambient temperature affecting the resistance of the primary coil winding, thus varying the voltage across the primary, is compensated by the thermistor changing resistance an amount equal to the resistance change of the primary but in opposite direction. The primary disadvantages of the thermistor are the temperature range limitations of the device and its inherent inaccuracy resulting from its inability to compensate for circuit component deterioration over an extended period of time.

The compact, solid-state circuit which is the subject of my invention increases the accuracy and the range of compensation over that attainable with the devices previously described.

SUMMARY OF THE INVENTION

The movable core transformer measuring circuit includes a voltage regulator circuit comprising a feedback circuit which monitors the voltage across an independent auxiliary secondary winding and compares this voltage to an established reference voltage. A deviation from the reference voltage produces an error signal which, when amplified, regulates the voltage drop across a control transistor. The control transistor is inserted in series in the supply voltage circuit thus varying the voltage to the primary winding of the movable core transformer such that the voltage across the auxiliary winding is maintained at a predetermined level.

The control transistor varies the voltage to the primary winding of the movable core transformer through an oscillator means for generating a square wave energization signal and a filter means is magnetically coupled between the oscillator means and the primary winding of the movable core transformer. The filter means attenuates the odd harmonic sinusoidal frequency components of the square wave energization signal while passing a substantial portion of its fundamental frequency component to the primary winding to enhance the operational characteristics of the movable core transformer transducer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration in functional block diagram of the basic operation of the disclosed embodiment of the invention.

FIG. 2 is a schematic illustration of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is depicted in block form, a network for measuring and transmitting an electrical signal representative of an input variable condition. This figure shows bellows 26 as responsive to a pressure signal representing a variable condition such as temperature, pressure, etc. The movement of bellows 26 positions core 27 of movable core transformer 28. The movable

3

core transformer consists of core 27, primary winding 25 and secondary windings 31, 32 and 53.

The alternating current excitation voltage applied to primary 25 is a high frequency voltage developed by power supply 100, oscillator 110 and filter 120. Power supply 100 rectifies the input power supply, usually 118 volts, 60 Hz. and applies the resultant direct current voltage to oscillator 110. The oscillator circuit 110 is a square wave inverter which converts the direct current voltage from power supply 100 into a square wave output at a frequency of 1000 Hz. The use of a high frequency excitation voltage improves the efficiency and resolution of the movable core transformer as well as reducing the physical dimensions thereof.

As a result of the increase in primary inductance and a coincidental decrease in primary current due to the increase in excitation frequency, the primary voltage level may be increased to a safe insulation limit thereby increasing the output signal range and sensitivity of the movable core transformer.

The square wave output of oscillator 110 is applied to filter 120. The filter circuit 120 allows the greater part of the fundamental frequency, approximately 1000 Hz., to pass while attenuating the higher odd harmonics of the input square wave. As a result, the movable core transformer 28 is excited by a 1000 Hz. sine wave with very little harmonic distortion. Two outputs are taken from the movable core transformer. One output signal is produced by signal windings 31 and 32 and a second signal is produced by auxiliary winding 53. The output signal windings 31 and 32 may be connected in series opposition so that the two voltages across the signal windings are opposite in phase, the net output of the signal windings being the difference of these voltages. When the core 27 is moved from a central position between secondary windings 31 and 32, an electrical unbalance is developed. When the core is moved from this balance point, the voltage induced in the coil toward which the core is moved increases, while the voltage induced in the opposite coil decreases. This differential output, which varies linearly with change in core position, is applied to demodulator circuit 130 which converts the alternating current output signal into a proportional direct current signal. The level of the direct current signal from demodulator 130 is then amplified by amplifier 140 to a desired level, such as ± 10 volts D-C and is available at output terminal E for transmission to remote measuring or controlling stations.

The second output from movable core transformer 28 is provided by auxiliary winding 53 which is so arranged on the transformer 28 that the voltage induced therein by primary winding 25 is independent of core position and provides a means of monitoring fluctuations in total magnetic flux caused by variation, for example, in supply voltage and ambient temperature. This feedback signal from secondary winding 53 is converted into a proportional direct current signal by demodulator 150 and applied to voltage regulator circuit 160 where it is compared with a Zener diode regulated reference voltage. Any error voltage developed between the reference voltage and the signal from demodulator 150 is amplified in circuit 160 and applied to the base of a regulating transistor. This regulating transistor adjusts the input voltage to oscillator 110 from power supply 100 to correct for any changes in transformer excitation.

Referring now to FIG. 2, there is depicted in schematic form, a voltage regulator circuit 160, shown in combination with movable core transformer 28, power supply 100, oscillator 110, filter 120, demodulators 130 and 150 and amplifier 140; said combination comprising the measuring network depicted in block form in FIG. 1.

Suitable alternating current voltage provided by a transformer 1 is converted to direct current voltage by a rectifier circuit in power supply 100 consisting of diodes 3 and 5 and filter capacitors 7 and 9. The direct current output voltage of power supply 100 appearing across capacitor 7

4

is subsequently modified by the operation of transistor 90 of regulator 160 such that a desired voltage input to oscillator 110 across capacitor 9 is maintained. The operation of oscillator 110 is initiated by the voltage present at point B.

The power supply 100 output voltage appearing across capacitor 7 produces a bias voltage across collector 90c and base 90b of transistor 90 by means of regulating Zener diode 85 and resistors 82 and 84. The bias thus established produces a base current to base 90b of transistor 90 causing transistor 90 to conduct in its linear region such that a voltage is established across capacitor 9 sufficient to trigger oscillator 110 through bias resistors 15 and 17. The operation of oscillator transistors 11 and 13 in conjunction with toroidal transformer 19 establishes an inverter circuit producing a square wave output signal at a frequency of 1000 Hz. The amplitude of the alternating current square wave output is a function of the direct current voltage supplied to the input of oscillator 110. It will become apparent in a subsequent discussion of voltage regulator circuit 160 that the voltage applied to the oscillator will be regulated by transistor 90 of voltage regulator 160.

Oscillator 110 provides two output potentials, one of which is converted by bridge rectifier circuit 65 of voltage regulator 160 to provide a voltage supply for regulator 160 and amplifier 140. The second output potential from oscillator 110 is applied to filter circuit 120 which consists of inductance 21 and capacitance 23.

The effect of filter 120 is to attenuate odd harmonics of the square wave output of oscillator 110 and provide a fundamental 1000 Hz. sine wave excitation voltage to primary winding 25 of movable core transformer 28.

The secondary signal windings 31 and 32 of movable core transformer 28, the operation of which was discussed in reference to FIG. 1, establish signal inputs to a pair of full wave bridge rectifier circuits 34 and 35 respectively of demodulator 130.

The direct voltage output signal from bridge rectifier 34 is filtered by capacitor 36 and applied across resistor 38, while the direct voltage signal from bridge rectifier 35 is filtered by capacitor 37 and applied across resistor 39. The net potential appearing across resistors 38 and 39 represents the value of the measured variable input signal to bellows 26 of FIG. 1.

This net output signal from demodulator 130 is applied to amplifier 140 where the signal is initially filtered by an R-C network consisting of resistor 41 and capacitor 42 and then applied to the base 43b of transistor 43, of a differential amplifier. The signal is further amplified by transistors 45, 46 and 51 to an output voltage E of suitable magnitude and range for operation of conventional indicators, recorders, controllers and the like. The amplifier gain and linearity is controlled by the feedback loop consisting of resistors 48 and 50 and range potentiometer 49 connected to the base circuit of transistor 44 of the differential amplifier. The zero adjustment for amplifier 140 is provided by potentiometer 47 which is common to emitters 43e and 44e of differential amplifier transistors 43 and 44 respectively.

As described in reference to FIG. 1, movable core transformer 28 includes a third secondary winding 53, the output of which is independent of core position. The alternating current voltage induced in winding 53 is reduced to a predetermined level by potentiometer 55 of demodulator 150 and converted to a proportional direct current feedback signal by full wave bridge rectifier 54.

The feedback signal from bridge rectifier 54, filtered by capacitor 57, appears across resistor 56 and is applied as one input to a differential amplifier consisting of transistors 60 and 61 of voltage regulator 160. A stable reference voltage, established by Zener diode 75, is applied to the base 61b of transistor 61 and comprises the second input to the differential amplifier.

The Zener diode 75 voltage is established by bridge rectifier 65 which establishes a supply voltage to leads 70 (+) and 71 (-). Resistor 72 connects Zener diode 75 to lead 70.

Resistors 62 and 63 connecting collectors 60c and 61c of transistors 60 and 61 respectively to lead 70 serve both as collector load resistors and bias resistors for transistors 60 and 61. Likewise, emitter resistors 66 and 68 of transistors 60 and 61 respectively perform as bias resistors through resistor 69 to lead 71.

The output signal from the differential amplifier represents an unbalance between the input signal to base 60b of transistor 60 and the stable reference voltage present at base 61b of transistor 61.

A preset unbalance may be maintained at differential amplifier inputs 60b and 61b such that an output signal, representing the net difference between Zener 75 reference voltage and demodulator 150 output voltage, is amplified by transistors 76 and 80 and fed into the base of regulating transistor 90. The second amplification stage consists of transistor 76, collector load resistor 77, which connects collector electrode 76c to lead 70, and Zener diode 78 which establishes the operating voltage level at emitter electrode 76e by means of current limiting resistor 79 which connects Zener diode 78 to lead 70. The third stage of amplification consists of transistor 80, the base electrode of which is connected to collector 76c of transistor 76. The collector electrode 80c is connected to power supply output voltage at point A and the emitter electrode 80e is connected to the base electrode 90b of regulating transistor 90. As mentioned in the prior discussion with regard to operation of oscillator 110, the base potential of transistor 90 obtained from emitter electrode 80e of transistor 80 will determine the voltage present at point B and thus the operating level of oscillator 110. It is by means of adjusting potentiometer 55 of demodulator 150 that a feedback signal is produced which is sufficient to establish the desired operating level of oscillator 110 and thus the excitation of transformer 28. Temperature compensation for circuit components having a negative temperature coefficient is provided by reference supply Zener diode 75 which exhibits a positive temperature coefficient at its established operating level.

Stabilization for high gain voltage regulator 160 is provided by feedback capacitor 58 which is connected between the input to voltage regulator 160 as represented by point C and regulator output as represented by point D.

The feedback signal generated by secondary winding 53 as modified by potentiometer 55, is initially preset to produce the correct transformer magnetic flux and will fluctuate as supply voltage and ambient temperature change. The voltage regulator 160 senses such deviations from the preset conditions and produces an error signal which regulates the voltage drop across collector 90c and emitter 90e of transistor 90. The polarity of said error signal will determine whether the potential of base 90b of transistor 90 will be increased or decreased, likewise whether the voltage drop across transistor 90 will increase or decrease.

The compensation provided by my novel feedback circuit for changes in supply voltage and ambient temperature is illustrated in the following examples.

Assume for the purpose of discussion that the excitation voltage to primary 25 of movable core transformer 28 decreases as a result of a decrease in supply voltage to power supply 100. The control signal appearing across resistor 56 will indicate that the potential at point B is below a desired value and cause a deviation from the preset unbalance existing at bases 60b and 61b of differential amplifier transistors 60 and 61. The output signal from the differential amplifier, amplified by transistors 76 and 80, will cause an increase in potential of base 90b of transistor 90 thus causing the drop across transistor 90 to

decrease resulting in an increase in voltage at point B, the input to oscillator 110.

The compensation provided by voltage regulator 160 for changes in primary excitation due to variation in ambient temperature is similar. As pointed out in the discussion with reference to FIG. 1, an increase in ambient temperature will increase the resistance of the windings of the movable core transformer 28 resulting in a decrease in secondary output as sensed by control winding 53. Once again a deviation signal is superimposed on the preset unbalance signal from the differential amplifier of voltage regulator 160 causing a variation in base potential to transistor 90. This variation will cause a decrease in voltage drop across transistor 90 such that the voltage at point B will increase sufficiently to compensate for the increase in resistance of the transformer windings.

It will be apparent to those skilled in the art that I have, for simplicity of illustration, shown the secondary windings 31, 32 and 53 opened out and removed from their true positions relative to core 27 and primary 25. As customary in the art, windings 31 and 32 are, in practice, wound about a nonmagnetic sleeve and symmetrical about the mid-position of core 27, so that as the core moves in one direction, the voltage induced in winding 31 increases, whereas that induced in winding 32 decreases, and vice versa. Feedback coil 53 is also wound about the non-magnetic sleeve, symmetrical with reference to the mid-position of core 27 but such that it embraces the core throughout its range of movement; and, hence, the voltage induced therein is not affected by core movements.

While I have illustrated and described my invention by means of one embodiment, it will be understood that this is by way of explanation only and not by way of limitation.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a movable core transformer transducer comprised of:

a movable core transformer having a movable core, a primary winding, a pair of secondary windings effectively connected to be series opposing and an auxiliary secondary winding inductively coupled to said primary winding for producing a feedback signal representative of the total magnetic flux generated in said transformer, said feedback signal being independent of core position; means demodulating said feedback signal, means generating a reference signal and for comparing it with said demodulated feedback signal to produce an error signal; and, means, responsive to said error signal, controlling the energization of said primary winding to maintain said feedback signal at a predetermined value, the improvement comprising;

said controlling means responsive to said error signal includes oscillator means for generating a square wave energization signal and filter means, magnetically interposed between said oscillator means and said primary winding of said movable core transformer, for attenuating the odd harmonic sinusoidal frequency components of said square wave energization signal while passing a substantial portion of its fundamental frequency component to enhance the operational characteristics of said movable core transformer transducer.

2. The movable core transformer transducer of claim 1 wherein said controlling means also includes means for voltage regulating and for amplifying the error signal, said regulating and amplifying means being interposed between said demodulating means and said oscillating means.

3. The movable core transformer transducer of claim 2 wherein said oscillating means generates a square wave energization signal in the kilocycle range in order to increase the inductance of said primary winding beyond its

7

value at power frequencies, with a coincident decrease in primary current, so that the output signal range and sensitivity of said movable core transformer transducer is correspondingly increased.

4. The movable core transformer transducer of claim 2 wherein said demodulating means includes means for setting said oscillating means to generate a preselected amplitude square wave signal.

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