

Nov. 24, 1959

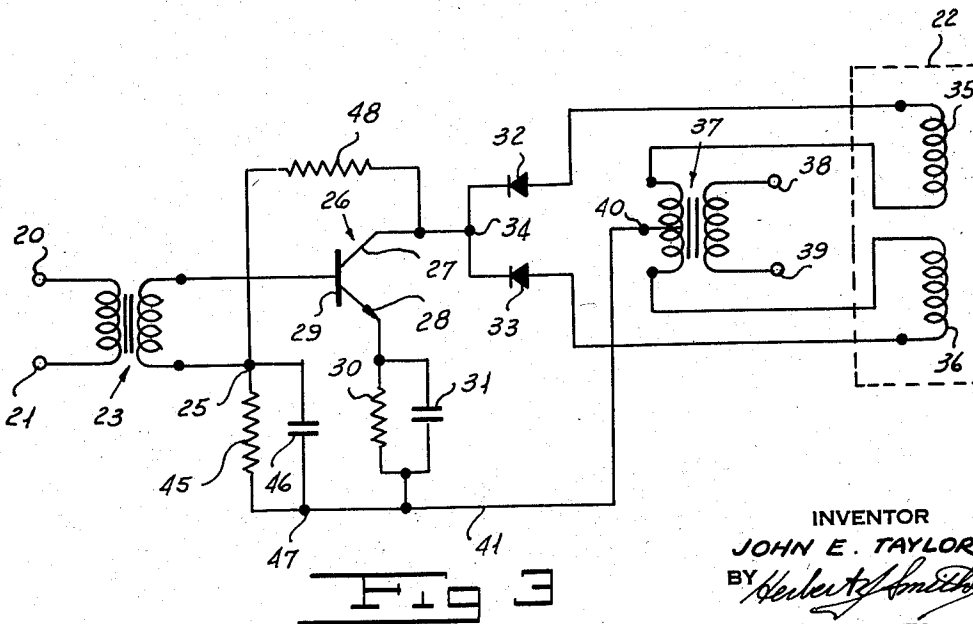
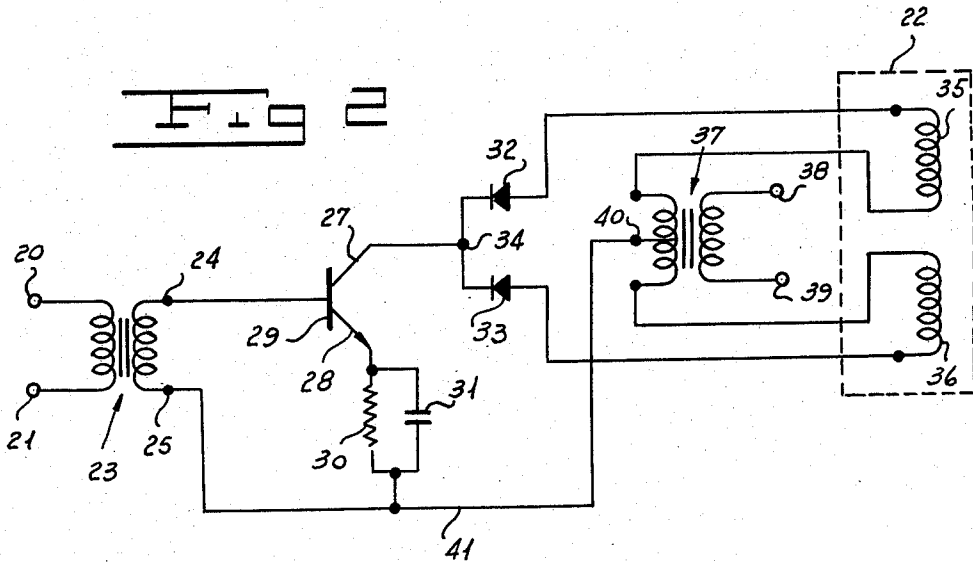
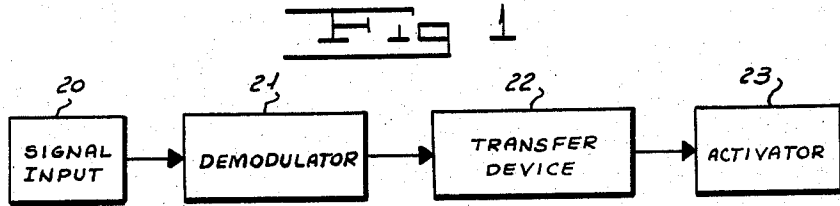
J. E. TAYLOR

2,914,682

DEMODULATOR

Filed Feb. 10, 1955

3 Sheets-Sheet 1



INVENTOR  
JOHN E. TAYLOR  
BY *Hebert Smith*  
ATTORNEY

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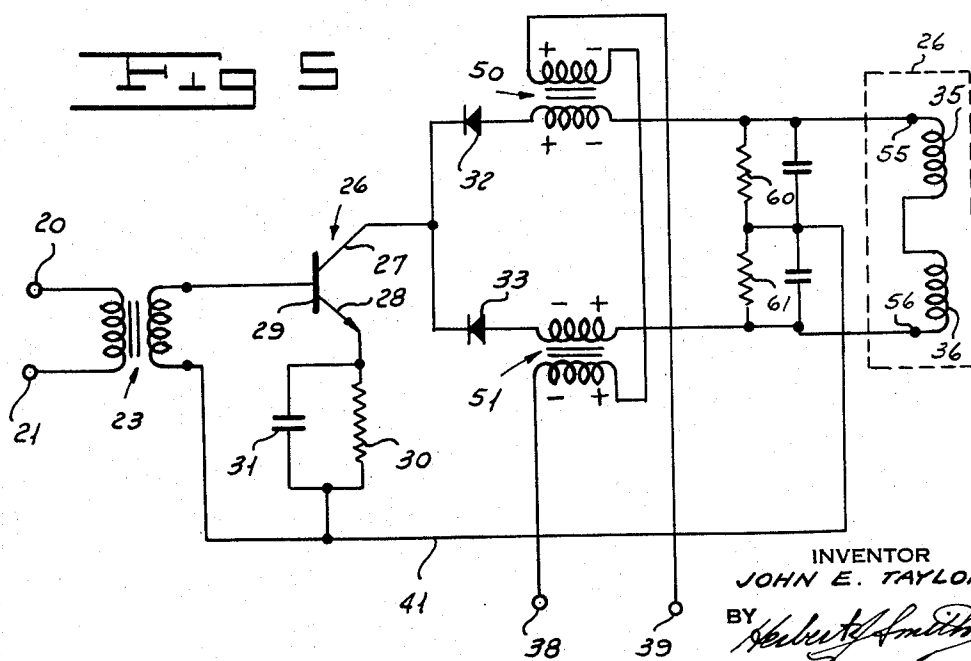
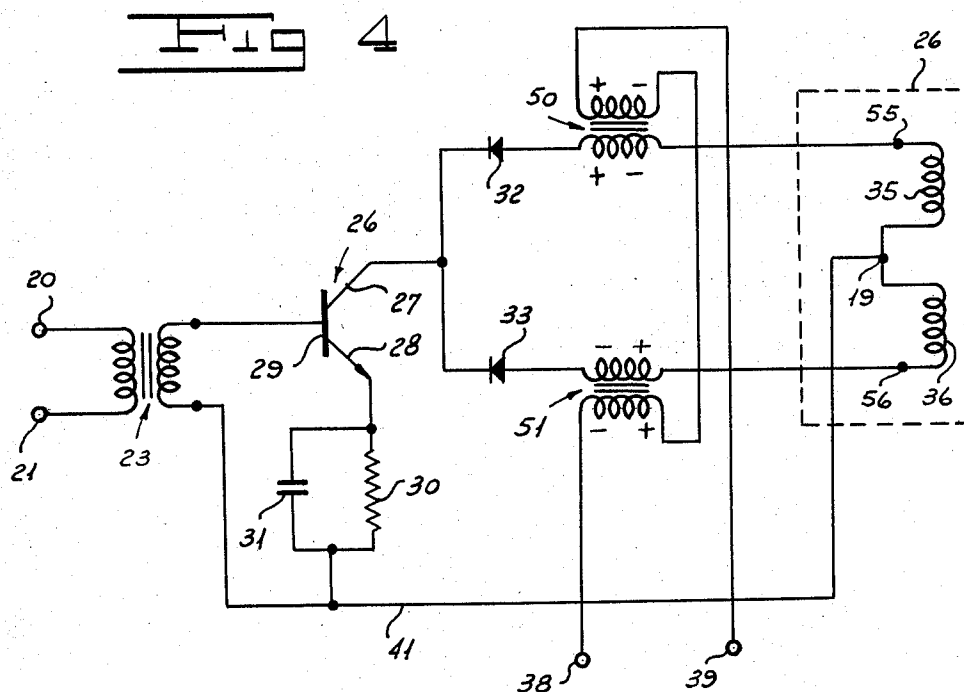
J. E. TAYLOR

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3 Sheets-Sheet 2



INVENTOR  
JOHN E. TAYLOR

BY *Herbert A. Smith*  
ATTORNEY

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J. E. TAYLOR

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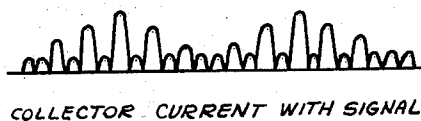
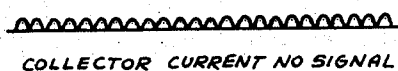
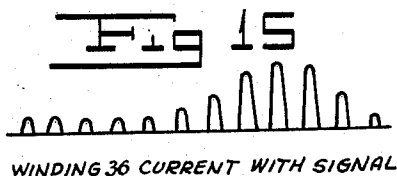
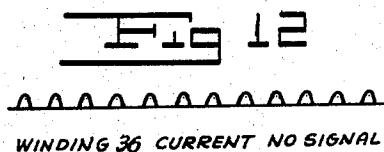
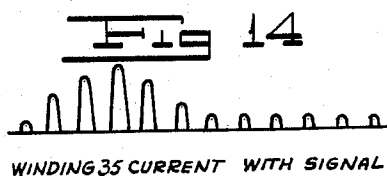
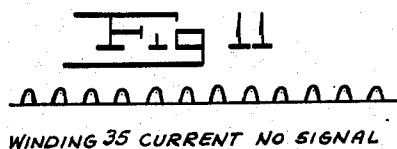
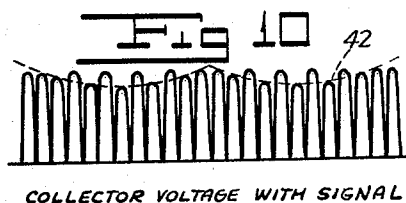
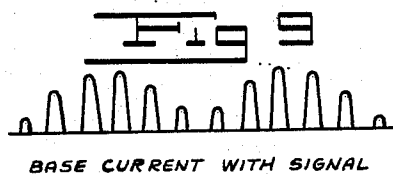
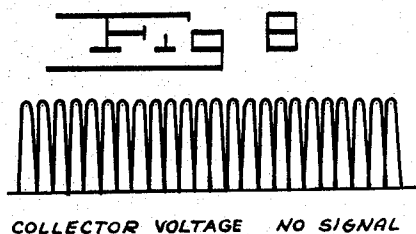
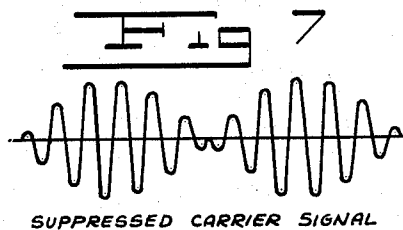
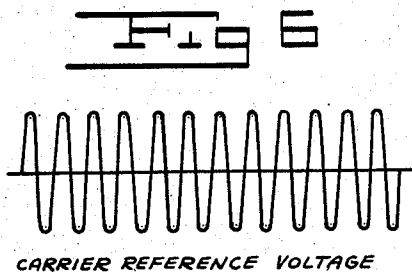


Fig 13

Fig 16

INVENTOR

JOHN E. TAYLOR

BY

*Herbert Smith*  
ATTORNEY

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2,914,682

## DEMODULATOR

John E. Taylor, New Milford, N.J., assignor to Bendix Aviation Corporation, Teterboro, N.J., a corporation of Delaware

Application February 10, 1955, Serial No. 487,258

11 Claims. (Cl. 307—88.5)

This invention relates to control circuits and more particularly to a demodulator which may have an application in servo systems. This invention is an improvement of the co-pending patent application of James Brook, Ser. No. 465,778, now Patent Number 2,802,976.

It is an object of the present invention to provide a novel demodulator employing a single current control means, such as a transistor, coupled with balanced control windings.

Another object of the invention is to provide a novel demodulator employing a transistor arrangement as the single current control means for balanced windings in a transfer device.

A further object is to provide a control circuit for a servo system wherein a transistor is the single current control means coupled to the balance or load windings of a transfer device for operating an actuator.

Another object is the provision of a novel synchronous demodulator employing a transistor as the single current control means and wherein either a two- or a three-terminal output may be provided for a transfer device.

A further object of the invention is to provide a synchronous demodulator having a single current control means such as a transistor, and wherein fixed bias supplies for a single current control means are eliminated.

Another object is to provide a synchronous demodulator employing at least one transistor arrangement which may be connected with various biasing networks to control the null current by establishing suitable operating parameters.

A further object of the invention is to provide a novel demodulator employing a transistor as the current control means, which demodulator is more efficient, requires lower operating voltages, is smaller in size, lighter in weight, generates less heat, has increased operating life, and is extremely robust.

The invention contemplates a synchronous demodulator employing a transistor as the single current control means which feeds a pair of control or load windings of a transfer device. Each of the control windings has rectifying means serially connected therewith and with a transistor having its output element connected to a mid-point of the rectifying means, so that both of the control windings sequentially time share the output of the transistor. Modifications of the invention show various output configurations for reducing the voltage between the control windings. The present arrangement may be employed with a two- or three-terminal output.

The foregoing and other objects and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustration purposes only

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and not to be construed as defining the limits of the invention.

In the drawings:

Fig. 1 is a block diagram of a control circuit utilizing the invention;

Fig. 2 is a schematic diagram of one form of the invention;

Fig. 3 is a modification of Fig. 1 showing a different bias arrangement;

Fig. 4 is a modification of the invention using a three-terminal output;

Fig. 5 is a modification of Fig. 4 showing a two-terminal output;

Figs. 6 to 16 inclusive show representations of various wave forms.

Referring to the drawings, and more particularly to Fig. 1, there is shown a block diagram having a signal input 20 with its output coupled to a demodulator 21, and with the output of the demodulator coupled to a transfer device 22, said transfer device being coupled to an actuator 23. The transfer device may be of any suitable type, such as a differential relay or any control device wherein a two-terminal or a three-terminal output may be required. The load or control windings of the transfer device may be used to operate any of a variety of actuators.

The actuator may be a motor, a piston, a magnetic clutch, lever arrangement or other form of actuator. The actuators may include a phase sensitive magnetic power amplifier for driving a two-phase servo motor, a solenoid clutch-operated servo using a constant speed shaft as a source of energy, a solenoid transfer valve to control hydraulic flow to a power piston, saturable reactor arrangements, a differential direct current relay, or a suitable reactor.

The arrangement shown in Fig. 2 has terminals 20 and 21 which feed the primary of a transformer 23, which transformer has a secondary with output terminals 24 and 25. A transistor 26 has a collector 27, an emitter 28, and a base 29 with said base being connected to terminal 24 of the coupling transformer 23; while the emitter is connected to terminal 25 via a parallel circuit consisting of a resistor 30 and a capacitor 31. A pair of diodes 32 and 33, or switching means, each have cathodes tied to a common terminal 34, which in turn is connected to the collector 27. The plates of said diodes are connected, respectively, to one end of each of said load or control windings 35 and 36, and with the opposite ends of said control windings being connected respectively to the outer terminals of the secondary winding of a transformer 37. Terminals 38 and 39 are connected to a suitable source of reference voltage indicated by legend as Carrier Reference, which reference voltage is supplied to the primary of the transformer 37. The resistor-capacitor network 30—31 has the end thereof opposite the emitter also connected to a mid-tap terminal 40 of the secondary of the transformer 37.

The suppressed carrier modulated signal shown in Fig. 7 is fed into the circuit via terminals 20 and 21 connected to the primary of transformer 23. Transformer 23 may be used for impedance matching between the demodulator circuit and its driving means. The output of transformer 23 is connected to the common conductor 41 and the base 29 of the transistor 26. The action of the diodes 32 and 33, which act as selective switches, is such that during half cycle of the carrier reference, diode 32 presents a very low impedance, while diode 33 presents a very high impedance. Therefore, any current which is drawn during the aforementioned half cycle will be drawn through control winding 35 of the transfer device. On the subsequent half cycle of the carrier refer-

ence, the aforementioned action is reversed, and current will be drawn only through winding 36 of the transfer device.

It will be seen that the diodes act as switches synchronized by the carrier reference to connect windings 35 and 36 of the transfer device in series, sequentially, with the collector 27 of transistor 26. Therefore, the diodes will be conducting on alternate half cycles of the carrier reference voltage. The parallel circuit of resistor 30 and shunt capacitor 31, which is in series with the emitter of the transistor, act to limit the actual current which the transistor will draw. Since the cathodes of both diodes are connected in common and to the collector 27 of the transistor, the current in the transistor is used to control the null currents through the windings and the currents will be balanced independently of the characteristics of the transistor or current control element.

The carrier reference voltage is impressed on the transformer 37, and it is a suitable predetermined frequency having a wave form substantially as shown in Fig. 6. At a no signal condition, the collector circuit of the transistor is a high impedance and only a small current will be drawn. At a no signal condition, the collector voltage may have the wave form substantially as shown in Fig. 8.

At a signal condition, the base current will be substantially as shown in Fig. 9; while the collector voltage may have a wave form substantially as shown in Fig. 10, with an envelope portion as shown by the dotted line 42.

When the input signal is applied to the emitter-base junction of the transistor, the base current will be drawn for only one polarity of the input wave form. This condition is a direct result of the diode characteristics of the emitter-base junction. That half cycle during which the transistor base draws current, and because of the amplifying properties of the transistor, the impedance of the collector will be lowered. This lowered impedance will allow the collector circuit to draw an increased current, thereby increasing the current through the respective winding of the transfer device. During the half cycle in which the base does not draw current, the impedance of the collector circuit remains high. During that half cycle when the impedance is high, the current through the respective transfer device winding is the same as in the absence of signal.

Figs. 11 and 12 represent the current at a no signal condition through winding 35 and 36 respectively; while Fig. 13 shows the combined wave forms of Figs. 11 and 12 representing the collector current at a no signal condition.

Figs. 14 and 15 show current at a signal condition through windings 35 and 36, while Fig. 16 is the combined wave forms shown in Figs. 14 and 15, which represent the collector current at a signal condition.

The action of the diode switch is such that for one half cycle one transfer winding is operatively connected to the collector circuit, and for the next half cycle, the other winding is operatively in the circuit. Therefore, with signal, the current in one winding of the transfer device increases, while the current in the other winding remains at its null value. The amount of additional current which one winding draws is proportional to the amount of base current drawn. The base current, on the conducting half cycle, is proportional to the base-emitter voltage. Therefore, the increase in current in the winding is proportional to the amplitude of the input signal.

Normally, the carrier reference voltage and the suppressed carrier signal are in phase with each other, but they may be 180° out of phase. If the phase of the input signal is changed by 180°, the action of the device is the same as described before except that the additional current will be drawn through the other winding of the transfer device. Consequently, it will be seen that the

device is a phase sensitive synchronous demodulator which compares a modulated alternating input signal with an alternating reference voltage of like periodicity to selectively energize one of a pair of control windings depending on the phase of the input signal which is controlled by a signal source, which source may be an inductive transmitting device.

In Fig. 3, parts similar to those shown in Fig. 2 have like reference numerals. Therefore, the resistor-capacitor network 30—31 is equivalent to the resistor-capacitor network in Fig. 1. However, an additional resistor-capacitor network consisting of a resistor 45 and a capacitor 46 is shown with said resistor and capacitor being connected in parallel, with one end of said parallel circuit being connected to the terminal 25, while the opposite end of said network 45—46 is connected to terminal 47, which terminal is common with conductor 41, so that the network 45—46 is in series with the terminal 25 and the conductor 41.

A resistor 48 is also connected between the collector 27 and the terminal 25. The modification shown in Fig. 3 allows control of the zero signal current in the transfer device windings. The resistors 45 and 48 form a voltage divider from the collector circuit, with capacitor 46 acting as an alternating current by-pass, so that a bias current flows in the base 29. This bias current will cause the zero signal currents in the transfer device windings to increase. The action of the device shown in Fig. 3 is the same as that for the device shown in Fig. 2 for a signal input, except that the current in one winding instead of remaining constant at its null value will decrease from its zero signal value to a smaller value. The transfer device as shown in Fig. 3 will have twice the sensitivity of a device built in accordance with that shown in Fig. 2.

The circuit arrangement shown in Fig. 4 utilizes two separate transformers 50 and 51, each with a primary winding and a secondary winding. The secondaries of transformers 50 and 51 are each serially connected between the plate of a diode and one end of a control coil. Further, the common conductor 41 is connected to the terminal 19, but in this latter showing the terminal provides a mid-tap between ends of the two control windings 35 and 36. Terminals 38 and 39 are connected with the series connected secondaries of the transformers 50 and 51. The remainder of the circuit shown in Fig. 4 is similar to that shown in Fig. 2. With the showing in Fig. 4, the voltage between windings 35 and 36 of the transfer device is reduced by establishing a common return for the control windings of the transfer device. The operation of this device is the same as that explained for Fig. 2. However, the modification of Fig. 3 over Fig. 2 may also be used in relation to Fig. 4 wherein a resistor, such as 48 (Fig. 3) may be used.

The modifications in Fig. 5 over Fig. 4 are concerned in the arrangement of providing a two-terminal output, such as terminals 55 and 56 of Fig. 5, as distinguished from the three terminals 55, 56, and 19 for the output of Fig. 4. The operation of a device built in accordance with the circuitry shown in Fig. 5 is slightly different from that of Fig. 2. For the circuit of Fig. 5 at null, or zero input signal, the voltage  $V-1$  across resistor 60 is equal and opposite to the voltage  $V-2$  across resistor 61. Therefore, there will be no current flowing through windings 35 and 36 of the transfer device at a no signal condition. At a signal condition, the voltage across one resistor will increase, and the voltage across the other resistor will remain constant or decrease according to the method of biasing used, such as shown in Figs. 2 and 3. For a change in signal input of 180°, the polarity of the output voltage will reverse, thereby causing a flow of current through windings 35 and 36 of the transfer device in the opposite direction. The magnitude of the current's flow will be proportionate to the magnitude

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of the input signal. The direction of current will be controlled by the relative phase of the input signal.

The device is current operated with a high output impedance, and, consequently, the device will be suited to drive a current operated transducer.

In both Figs. 4 and 5, as indicated in the drawings, the instantaneous polarity of the primary and secondary windings of transformers 50 and 51 are shown by the plus (+) and minus (-) symbols. It will be noted that diode 32 has its plate connected to one end of the secondary winding of the transformer 50, with the polarity of that particular end of the secondary having a plus (+) sign; while the end of the secondary winding of transformer 51, which is connected to the plate of the diode 33, has a minus (-) indication with the instantaneous polarity indications as shown in Figs. 4 and 5.

It will be seen that at any given instant, while diode 32 is conducting, diode 33 will not be conducting, and while diode 33 is conducting, diode 32 will not be conducting. Depending on the phase of the input signal, one of coils 35 and 36 will conduct more than the other to permit a greater current flow through the respective winding accordingly. Throughout the various circuits, the device produces equal currents in both control windings at quiescent condition. At signal condition, the control windings will have one or the other thereof energized depending on the phase of the modulated input signal. Consequently, the control windings can control operation of a transfer device which may be used in a servo system to drive one element to angular agreement with another element.

Relating to Figs. 4 and 5, the resultant unbalanced voltage across terminals 55 and 56 will cause a flow of current, accordingly, through windings 35 and 36 of the transfer device.

While transformers 50 and 51 are shown in Figs. 4 and 5 as being two separate transformers, it is to be understood that this circuit will operate if only one transformer is used, with said transformer having two isolated secondary windings and only one primary winding, with the secondaries being connected to provide the polarity, as shown in Figs. 4 and 5, which would result in proper operation of the device as explained herein.

While several embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes may also be made in the design and arrangement of the invention as the same will now be understood by those skilled in the art.

What is claimed is:

1. In a control circuit for a transfer device having a pair of control windings, a pair of switching means, said control windings and switching means being connected in a balanced circuit arrangement, a single impedance current control means having its output connected to the balanced circuit arrangement for controlling operation of said switching means, means for connecting an input source to said single impedance current control means, means for connecting a source of reference voltage to said switching means and control windings and arranged to alternately render the switching means conductive during a half cycle, and a direct current biasing arrangement including feed-back means connected to the output of the current control means and to the signal source and input return impedance means connected between the signal source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

2. In a demodulator for a transfer device having a pair of control windings and a pair of switching means operatively connected in a balanced circuit arrangement to periodically energize one or the other of said control windings depending on the phase of a reference voltage connected therewith, an input signal source, current control means having at least a pair of elements with one of said

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elements thereof being connected with said balanced circuit arrangement, means for connecting said input signal source to the other of said elements of said current control means, means for connecting a source of reference voltage to said balanced circuit arrangement and arranged to alternately render the switching means conductive during a half cycle, and a direct current biasing arrangement including feed-back means connected to said one element of the current control means and to the signal source and input return impedance means connected between the signal source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

3. A demodulator as set forth in claim 2 wherein said current control means is a transistor.

4. In a demodulator for a transfer device having a pair of control windings and a pair of switching means operatively connected in a balanced circuit arrangement to periodically energize one or the other of said control windings depending on the phase of a reference voltage connected therewith, an input signal source, current control means having three elements with one of said elements thereof being connected with said balanced circuit arrangement, means for connecting said input signal source to a second of said elements, means for connecting a source of reference voltage to said balanced circuit arrangement and arranged to alternately render the switching means conductive during a half cycle, and a direct current biasing arrangement including feed-back means connected to said one element of the current control means and to the signal source and input return impedance means connected between the signal source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

5. A demodulator as set forth in claim 4 wherein said current control means is a transistor having said three elements, respectively, being a collector electrode, a base electrode and an emitter electrode.

6. In a phase sensitive demodulator for simultaneously selectively increasing energization of one of a pair of control windings and decreasing energization of the other of said pair of control windings of a transfer device depending on the phase of a modulated alternating input signal when compared with an alternating reference voltage of a like periodicity, said demodulator including a pair of switching means, a pair of control windings and windings of a reference voltage source connected in a balanced circuit arrangement and arranged to alternately render the switching means conductive during a half cycle, a current control means having a base, a collector, and an emitter, said collector being connected to a common point of said balanced circuit, and a direct current biasing arrangement including feed-back means connected to the collector and to the signal source and input return impedance means connected between the signal source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

7. A demodulator as set forth in claim 6, wherein said second common point of said balanced arrangement is an electrical mid-point of a source of reference voltage.

8. In a control circuit for a transfer device having a pair of control windings and a pair of switching means connected in a balanced circuit arrangement, a current control means having its output operatively connected with said control windings and switching means for controlling operation of said switching means, means for connecting an input source to said current control means, means for connecting a source of reference voltage to said control windings and switching means and arranged to alternately render the switching means conductive during a half cycle, and a direct current biasing arrangement including feed-back means connected to the output of the current control means and the signal source and input return impedance means connected between the signal

source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

9. In a control circuit for a two terminal transfer device having a pair of control windings and a pair of switching means connected in a balanced circuit arrangement, a current control means having its output operatively connected with said control windings and switching means for controlling operation of said switching means, means for connecting an input source to said current control means, means for connecting a source of reference voltage to said control windings and switching means and arranged to alternately render the switching means conductive during a half cycle, and a direct current biasing arrangement including feed-back means connected to the output of the current control means and to the signal source and input return impedance means connected between the signal source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

10. In a control circuit as set forth in claim 9 and wherein the balanced circuit arrangement produces a magnetic unbalance, and an activator is connected to said transfer device and is operated by the resultant flux of said magnetic unbalance.

11. A control circuit for a transfer device comprising a pair of control windings, a pair of switching means, said control windings and switching means being connected in a balanced circuit arrangement, a current control transistor having a base, a collector and an emitter and having its collector connected to a common point of

the balanced circuit arrangement for controlling the operation of said switching means, means for connecting an input source to the base of said transistor, means for connecting a source of reference voltage to said switching means and control windings and arranged to render each switch means conductive in different alternate half cycles, and a direct current biasing arrangement including feed-back means connected to the collector and to the signal source and input return impedance means connected between the signal source and a common return in the circuit to provide differential energization of the control windings in response to a signal.

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