July 4, 1950 E. R. SHENK ET AL 2,513,525

LOCKING CIRCUIT WITH DOUBLE SIGNAL CONTROL

Filed Dec. 1, 1944 2 Sheets-Sheet 1

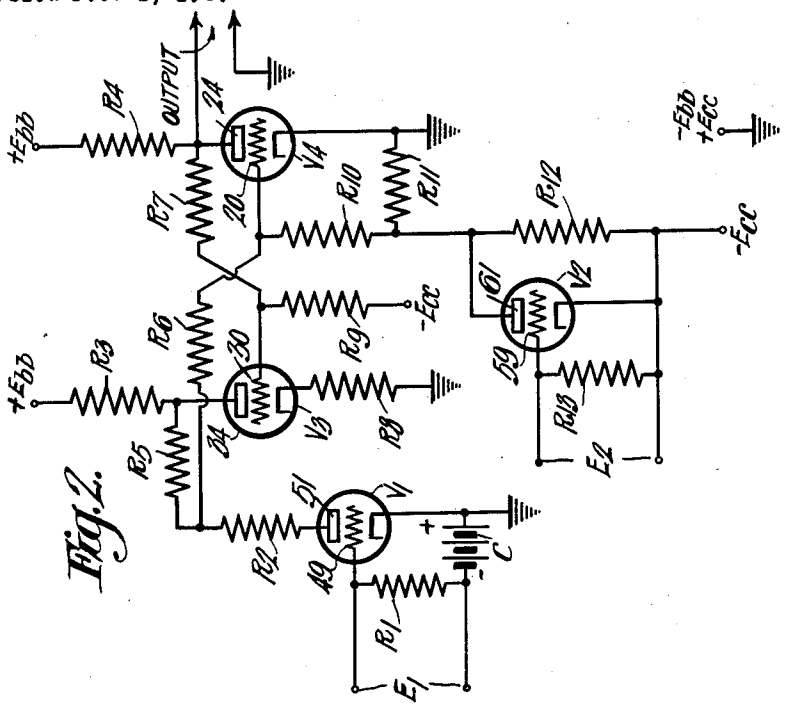


Fig. 2.

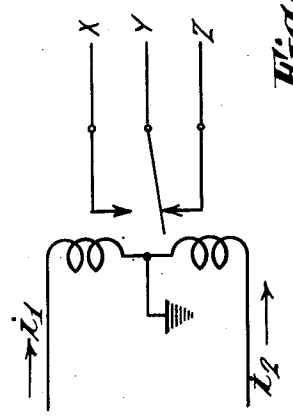


Fig. 1.

	E_1	E_2	V_1	V_2	V_3	V_4
MARK	+	0	ON	ON	ON	OFF
———	0	0	OFF	ON	ON	OFF
SPACE	0	-	OFF	OFF	OFF	ON
———	0	0	OFF	ON	OFF	ON
MARK	+	0	ON	ON	ON	OFF
NOISE ON SPACE MARK ON	+	-	ON	OFF	ON	OFF
NOISE ON MARK SPACE ON	+	-	ON	OFF	OFF	ON

Fig. 2a.

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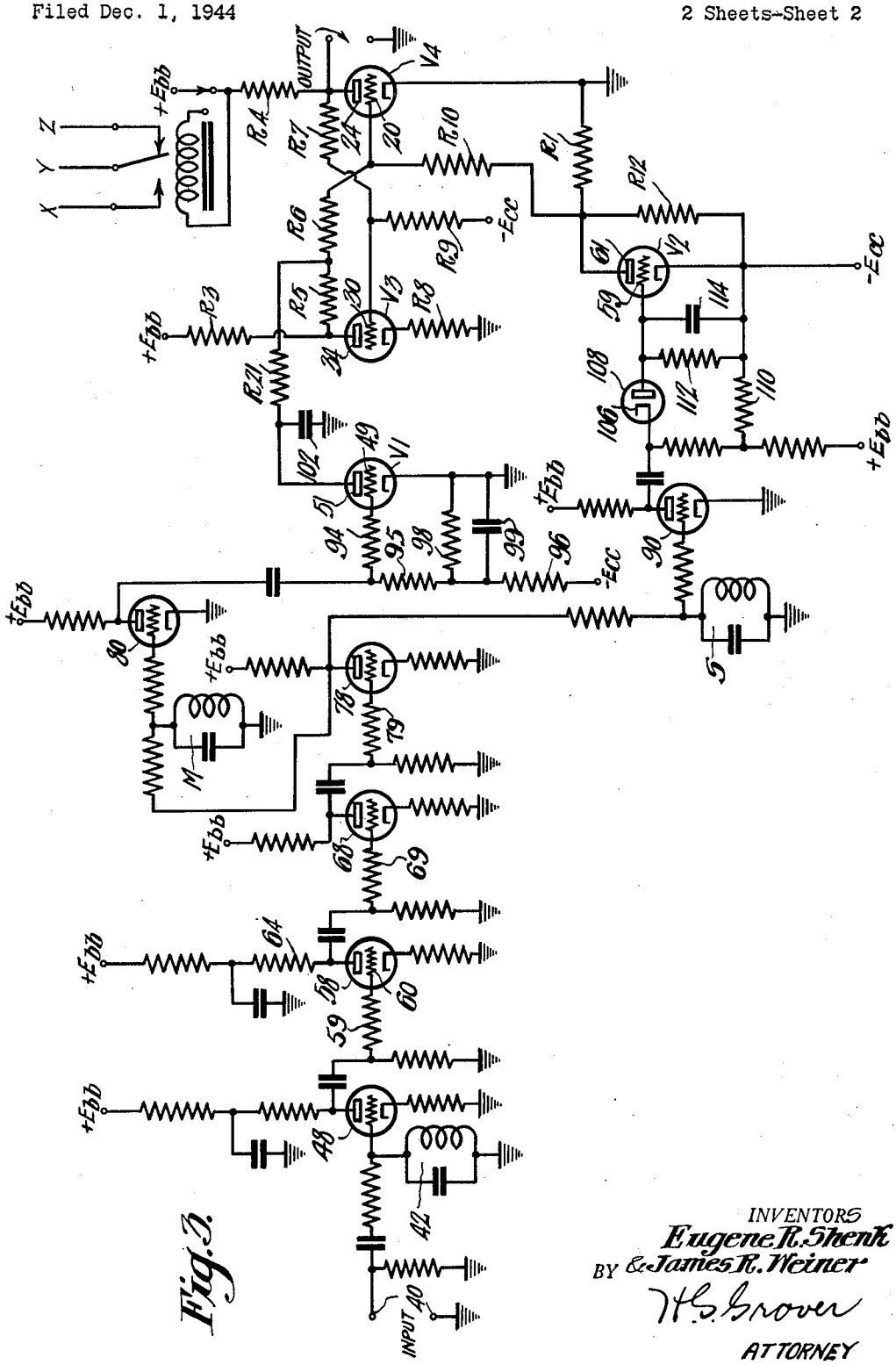


Fig. 3.

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LOCKING CIRCUIT WITH DOUBLE SIGNAL CONTROL

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6 Claims. (Cl. 250—27)

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This application relates to electronic polar relays. Relays of this type have wide application in the radio art. A particular application is use of the same in two-tone telegraph systems. These systems are known also as frequency shift telegraphy systems.

An object of this invention is improved relaying of currents or potentials.

A more specific object of this invention is to provide an electronic equivalent of mechanical polar relay that is capable of much greater operating speeds.

In its broadest aspect this invention comprises a locking circuit somewhat of the type disclosed in Finch U. S. Patent #1,844,950, dated February 16, 1932. Means is provided to subject the control grid of one tube of the locking circuit to a net bias controlled by two independent voltages. Suitable changes are required in these independent voltages to cause an action in the locking circuit.

In accordance with this invention the independent voltages may be or represent two tones, one of which represents mark and the other space in a frequency shift telegraphy system.

In describing this invention in detail, reference will be made to the attached drawings wherein Fig. 1 shows by schematic diagram a mechanical polar relay. This figure is used to make clear the need of this invention, and also to facilitate description of the invention.

Fig. 2 illustrates by schematic diagram the essential elements of the electronic polar relay of this invention.

Fig. 2a is a chart showing the relation between voltages and the conducting conditions of the tubes in the arrangement of Fig. 2 in the presence of certain control potential conditions which in turn may represent certain signalling conditions, the successive rows of this chart representing in general conditions at successive instants of time.

Fig. 3 shows by schematic diagram the essential features of an improved two-tone telegraphy system using my improved high speed electronic polar relay.

The benefits that can be obtained in many applications, for example, in a two-tone telegraph system, through the use of a polar relay are well known.

Heretofore, polar relays have been of the mechanical type. It is a characteristic of such mechanical polar relays that if the electric current through the coils is reduced to zero, the contacts of the relay remain in their last operated

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position. This is usually accomplished through the use of magnetic pole pieces which have sufficient residual magnetism to hold the tongue of the relay in its last operated position in the absence of any electric current through the coils. In order to move the tongue of the relay, it is necessary to reverse the current through the coil or cause current to flow through a different coil.

A two-tone telegraph system will be used to illustrate how a polar relay can be employed to advantage to assist in eliminating errors in transmission. In such a system one tone frequency is transmitted to indicate "marking" intervals, and a different tone frequency is used for "spacing" intervals.

Fig. 1 is a schematic diagram of a mechanical polar relay. When this relay is to be used with a two-tone telegraph system, the circuit is so arranged that current i_1 is controlled by one of the tone frequencies and i_2 is controlled by the other tone frequency. Current can be made to flow either when the tone is present or when it is absent. Suppose current flows during the presence of tone, and let i_1 be controlled by marking tone and i_2 by spacing tone.

Suppose spacing tone is being received. Then i_2 will flow in its portion of the relay coil, but i_1 will be zero, because marking tone is absent. Let i_2 flowing alone cause the relay to operate to the position shown in Fig. 1. If now there should be a momentary (or prolonged) interruption in the transmission circuit such that the spacing tone no longer was received, then i_2 would drop to zero. Under this condition of no current flowing in either portion of the coil, the relay would remain in its last operated position by virtue of the mechanical design of the relay and the residual magnetism in the pole pieces.

Suppose now that instead of the spacing tone dropping out so that neither tone was received, an interfering signal is able to cause i_1 to flow. Now both i_1 and i_2 are flowing simultaneously. If, as is desirable, the magnetizing force produced by i_1 is the same as that produced by i_2, the resultant magnetizing force will become zero. Hence, the net result of both tones present is the same as neither tone present and the operated position of the relay does not change.

Consequently, it is apparent that if the operated position of the relay is to be changed, the spacing tone must go out and the marking tone must come in. This takes place during normal two-tone transmission. However, it is very improbable that spurious conditions and signals would cause one tone to drop out and simul-

taneously cause another different tone of proper frequency to come in. For this reason, a polar relay used in conjunction with a two-tone signalling system provides a very great protection against the recording of false characters.

Among others, it is one purpose of this invention to provide polar operation at much greater speeds than those at which mechanical relays are satisfactory. Fig. 2 is a schematic diagram of a circuit that utilizes the control characteristics of vacuum tubes to simulate the operation of a mechanical polar relay. Since a polar relay must be under control of two separate and independent voltages or currents, two input circuits are provided, one for E_1 and one for E_2. As shown in Fig. 2*a*, E_1 is positive during marking signal and zero during spacing signal, while E_2 is zero during marking signal and negative during spacing signal.

Tubes or electron discharge systems V_3 and V_4 are connected in what basically is the familiar locking circuit. The circuit is so named because of its property of locking into one or the other of its two stable positions, i. e., when the circuit is properly designed, either tube V_3 will be fully conducting and the plate current of tube V_4 will be zero or tube V_4 will be fully conducting and the current through tube V_3 will be zero. This is because when tube V_4 is biased at its grid **20** to cutoff, its anode **24** becomes more positive (potential drop in R_4 is less) as does the grid **30** of tube V_3, so that more current flows in V_3, so that its anode **34** becomes less positive (potential drop in R_3 is more) so that the grid **20** of tube V_4 is made more negative and current is switched through V_3 and cutoff occurs in V_4. When a potential such as to cause V_4 to conduct is applied to the grid **20**, similar action switches the current through tube V_4 and cuts off tube V_3.

In addition to the simple locking circuit, tubes V_1 and V_2 under control of voltages E_1 and E_2 respectively are included. E_1 is applied across a resistance R_1 to the grid **49** of V_1 which is biased by a source —C. The anode **51** of tube V_1 is coupled by resistance R_2 into the anode circuit of V_3 between R_5 and R_6. The voltage E_1 varies from zero (see the chart Fig. 2*a*), at which tube V_1 is biased to cutoff by —C, to a positive value at which —C is overcome and tube V_1 conducts.

The voltage E_2 is applied across R_{13} and to the grid **59** of tube V_2, the anode of which is coupled into the grid circuit of tube V_4 by anode load resistance R_{12}. The voltage E_2 varies from 0 at which tube V_2 is conductive to a negative value at which tube V_2 is cut off.

The plate circuit of tube V_1 is interconnected with the plate circuit of tube V_3 in such a way that it can exercise considerable control over the amount of positive voltage from the source E_{bb} that is available to be coupled into the grid circuit of tube V_4. Tube V_2 together with resistors R_{11} and R_{12} constitute a voltage divider with two possible settings. One setting is that with tube V_2 off. This is the condition of minimum negative bias voltage (magnitude) supplied to V_4. When tube V_2 conducts, it shunts R_{12} with the result that the magnitude of the negative bias coupled into the grid circuit of tube V_4 across R_{11} is increased. Consequently, the net grid-cathode voltage of tube V_4 is ultimately under the control of E_1 and E_2.

During the reception of a marking signal (E_1 positive), tube V_1 will conduct and reduce the amount of positive voltage coupled into the grid circuit of tube V_4. Simultaneously, tube V_2 will be conducting with the result that the magnitude of the negative voltage supplied to the grid circuti of tube V_4 will be a maximum.

If the tubes, circuit components and supply voltages are properly selected, the net negative voltage on the grid **20** of tube V_4 under normal marking condition will be appreciably greater than is required to maintain this tube non-conductive. In fact, it even will be sufficient that if E_1 should fall to zero (due to a fade out, for example) thereby stopping the flow of current in tube V_1 and increasing the positive voltage coupled into the grid **20** of tube V_4, the net bias on the grid of V_4 still would be sufficient to prevent space current in this tube. Or, if instead of E_1 dropping out, E_2 were to come in simultaneously with E_1 thereby reducing the magnitude of negative voltage supplied to the grid of tube V_4 this tube still would not be able to conduct.

In order to change the sense of the output from the locking circuit, i. e., to cause current to flow in tube V_4, it is necessary for both tubes V_1 and V_2 to cease conducting. For this to take place E_1 must drop to zero and E_2 must become negative. These are two separate and independent changes.

Under these conditions of tube V_1 and tube V_2 non-conductive, a relatively large positive voltage is coupled into the grid of tube V_4 from the source E_{bb} and a small negative voltage is supplied to the same grid from $-E_{cc}$. Now the net grid voltage of tube V_4 will be zero or even slightly positive. When, under these conditions, tube V_4 passes current, the positive voltage coupled into tube V_3 grid is reduced sufficiently, as a result of the potential drop in R_4, to render tube V_3 non-conductive. When tube V_3 ceases to conduct, the positive voltage applied to the grid circuit of tube V_4 is increased still farther. Consequently, tube V_4 will continue to pass current, even though either tubes V_1 or V_2 should conduct individually for any reason.

To return tube V_4 to the non-conducting condition, both tubes V_1 and V_2 must be made to conduct. This can take place only if voltage E_1 becomes positive and E_2 goes to zero.

The output may be taken at various points in the tripping circuit. For example, the voltage or potential across R_4 may be taken and used as desired.

In the foregoing description the voltages E_1 and E_2 are referred to as representing mark and space frequencies in a two-tone telegraphy system. Obviously, our improved high speed electronic polar relay may be put to wide use in the radio and allied arts. All that is essential for controlling our polar relay is one voltage which varies from zero to a positive potential, and a second voltage which varies from a zero to a negative value.

When the voltages E_1 and E_2 represent two-tone frequencies such as used in a spaced wave telegraphy system they may be derived as illustrated in Fig. 3. Fig. 3 shows the embodiment of the invention in a two-tone telegraph system. The incoming signal is amplified and limited in the first four tube structures. After limiting, the composite two-tone signal is supplied to two individual, simple channel filters. One channel accepts only spacing tone, the other only marking tone.

The input at **40** includes energy of two frequencies which may be tone frequencies of say the order of 2,000 cycles per second. The tones are separated by the desired band of frequencies.

The separation should at least be sufficient to permit separation of the same in the circuits following the amplifier and limiter stages. A separation of 400 cycles per second has been found satisfactory in one application.

Circuit 42 is tuned so as to pass both tone frequencies. The amplifying and limiting circuits of tubes 48, 58, 68 and 78 are substantially similar and are well known in the art. Considering tube 78, for example, the limiting action of the tube on positive input signals is improved by resistor 79. Resistor 79 causes the grid of tube 78 to see a relatively high resistance generator as compared with the low grid-cathode resistance for positive grid-cathode voltage. As a result, voltages that cause the grid to become positive with reference to its cathode are divided down by a very high ratio. Further, this grid-cathode resistance is a non-linear function of current which decreases with increasing current so that when the input voltage increases farther positive, the division ratio between the resistor 79 and grid-cathode resistance of the tube increases. The net result is that the positive peaks of input voltage are not present in the plate circuit of tube 78 because the grid cannot become appreciably positive with respect to its cathode.

The negative peaks of input voltage are not present in the plate circuit of the tube 78 either, due to plate current cutoff. Thus we have essentially symmetrical limiting as well as amplification in tubes 48, 58, 68, and 78. Tubes 58 and 68 with resistances 59 and 69 operate like tube 78 as described hereinbefore.

The tone voltages representing mark are selected by tuned circuit M and fed to an amplifier and coupling stage tube 80 while the voltages representing space are selected by a tuned circuit S and fed to an amplifier and coupling stage tube 90. The circuit M is resonated at the mark frequency and the circuit S at the space frequency.

The oscillations of mark frequency are amplified by tube 80 and applied to tube V_1 across resistor 95. Tube V_1 is a plate rectifier which gives a direct current output proportional to the peak value of the sinusoidal input signal. Resistors 96 and 98 are so proportioned that V_1 is at or beyond plate current cutoff. Resistor 96 and capacitor 99 serve as an R. C. filter to isolate the power supply from signal circuit (with respect to A. C. variations) at the point shown. Resistor 94 prevents the grid 49 from going more than slightly positive with respect to the cathode and tends to flatten the plate current peaks of V_1.

Assume that V_3 is off and no signal voltage appears across resistor 95. Capacitor 102 will have a voltage difference across its terminals equal to E_{bb} (approximately). If signal is now applied to resistor 95, tube V_1 will conduct on the positive voltage peaks. Capacitor 102 will discharge through tube V_1 to some lower value of voltage, the discharge taking place rapidly due to the small internal resistance of tube V_1. This voltage discharge occurs, of course, when V_1 conducts due to a positive signal peak. When the input signal goes negative tube V_1 ceases conducting and capacitor 102 commences to charge back to E_{bb}. However, it must now charge through R_{21}, R_5 and R_3 whose combined resistance is much larger than the internal resistance of V_1. Thus capacitor 102 will charge slowly (compared with a cycle of signal voltage) and will not reach E_{bb} before V_1 begins to conduct again. Consequently, the voltage across capacitor 102 remains at the lower potential (except for a slight ripple) as long as signals of mark frequency are being received. When the signal ceases, the capacitor voltage again rises to E_{bb} in a time that may be equal to two or three tone cycles but which is small compared with the length of the shortest signal element received.

Since the tube V_1 is biased to cutoff by $-E_{cc}$ the potential at its anode 51 is positive when the signal drops out and less positive when signal comes in. Thus voltage is coupled into the tripping circuits by resistance R_{21}.

The space frequency voltages selected at S are amplified in tube 90 and excite the cathode 106 of a diode rectifier 108 the anode of which is coupled to the grid 59 of tube V_2. The tube V_2 is normally conductive. The source E_{bb} produces across resistance 110 a positive potential at the cathode 106 end of said resistance so that the diode 108 is biased to cutoff normally. When space tone voltages come in the positive peaks thereof are ineffective. The negative peaks reduce the positive potential on the cathode of the diode so that it passes current which develops across resistance 112 a negative potential to swing the grid 59 negative to cut off this tube and thereby reduce the negative potential fed by $-E_{cc}$ to the grid 20 of tube V_4. The condenser 114 smooths out the rectified pulses in about the same manner in which the pulses are smoothed out by condenser 102.

The operation of the two-tone system will now be described. In this description which repeats the description of Fig. 2 given above, reference will be made to the chart of Fig. 2*a*.

With no signal coming into either channel, tube V_1 is cut off and tube V_2 conducts. If a marking signal comes in, E_1 becomes positive, turning tube V_1 on, making the grid of V_4 less positive. E_2 is zero, and V_2 continues to conduct making the grid of V_4 very negative. The combination of the two voltages will keep V_4 shut off and allow V_3 to conduct. If the marking signal drops out (indicated by dash in the second line of the first column of the chart) E_1 becomes zero, cutting off V_1, making the grid of V_4 more positive. E_2 remains zero and V_2 remains on, keeping a high negative bias at V_4. In this case the combination of the voltages keeps the grid of V_4 below cutoff, and V_4 does not conduct.

If the spacing signal comes in E_1 remains zero, V_1 remains cutoff, and the voltage at the grid of V_4 remains the same due to this act. However, E_2 becomes negative, shutting off V_2 which raises the potential of the grid of V_4 to a point above cutoff. In this case the combination of the two voltages allows V_4 to conduct, thereby shutting off V_3. If the spacing signal drops out E_1 remains zero and the voltage at the grid of V_4 due to V_1 remains the same. However, E_2 goes to zero and V_2 again conducts, tending to make the voltage at V_4 more negative. However, it is not sufficient to drive the grid of V_4 below zero, and V_4 will remain on.

If a marking signal again comes in, E_1 will again go positive, turning V_1 on, lowering the potential of the grid of V_4 to a point where the combination of this voltage and the highly negative voltage due to V_2 remaining on turns V_4 off, thereby switching V_3 on again.

Noise coming into the spacing channel while a marking signal is being received may turn V_2 off, raising the grid potential of V_4. However, this increase in grid voltage is not sufficient to make V_4 conduct and V_3 will remain on.

The first six rows of Fig. 2a represent conditions at successive instants of time, while the last row represents conditions which may occur at an instant during the "space" conditions of the third row, while a spacing signal is coming into tube V_2. If noise appears in the marking channel. Under "space" conditions tube V_4 is on and tubes V_1, V_2, and V_3 off. If noise appears in the marking channel under these conditions, tube V_1 will be turned on, decreasing the positive voltage coupled into the grid of tube V_4. In this case, the decrease of positive grid voltage at V_4 caused by the conduction of tube V_1 is not sufficient to drive said grid below zero potential, and V_4 remains on. The output is taken from the anode of tube V_4.

It should be realized that any good type of simple single coil (non-polar) relay may be used in conjunction with the electronic polar relay of Figs. 2 and 3, for example, connected in series with R_4 as shown in Fig. 3, in order to obtain polar operation of a set of contact points.

To those versed in the art, many modifications of the basic invention will suggest themselves. As an example, separate circuits could be provided for adding voltages E_1 and E_2 in a suitable manner and then applying their resultant voltage, or one obtained therefrom, to a single point in a locking circuit.

What is claimed is:

1. Apparatus for keying including two electron discharge systems having input and output electrodes cross-coupled and biased to be alternatively conductive and non-conductive, a first control tube biased to draw current, a second control tube biased to cutoff, means for applying alternatively present potentials to said first and second tubes to alternately bias said first tube to cutoff and said second tube to be conductive, and a connection between said first tube and an input electrode of one of said systems, a connection between said second tube and said input electrode of said one of said systems, the connections and arrangement being such that one of said systems is made conductive only when both of said tubes are biased to be conductive and the other of said systems is made conductive only when both of said tubes are biased to cutoff.

2. An electronic polar relay including two tubes each having an anode, a control grid and a cathode, with the anodes and control grids cross-connected, a direct current impedance interconnecting the grid and cathode of one tube, a third and a fourth tube each having a control grid and a cathode, means for applying independent signals normally alternately present to the control grid and cathode respectively of said third and fourth tubes, a connection between the anode of the third tube and the control grid of said one tube, and a connection between the anode of the fourth tube and the control grid of said one of said two tubes, the arrangement being such that when one signal only is applied the said one tube has an output of a first value, which is maintained if said one signal drops out or said other signal comes in, and when the other signal only is applied the said one tube has an output of a second value, and said output is maintained if said other signal drops out or said one signal comes in.

3. In a telegraphy system, in combination, a first pair of tubes each having a control grid, a cathode and an anode, with the control grids and anodes cross-coupled so that a change of potential on the anode of one tube changes the potential on the grid of the other tube and vice versa, a second pair of tubes one of which is normally conductive and the other of which is normally non-conductive, a coupling between the output of that one of said second pair of tubes normally non-conductive and the anode of one tube of the first pair of tubes, a coupling between the output of the other tube of said second pair and the control grid of the other tube of said first pair of tubes, and means for applying potentials which appear alternately to the inputs of said tubes of said second pair of tubes.

4. In combination, two tubes having their control grids and anodes cross-coupled by impedances so that when one tube is biased to cut off the voltage on the grid of the other tube becomes less negative and vice versa, a first control tube having its output electrodes coupled with the anode of one of said tubes to vary the potential thereof and as a consequence the potential of the grid of the other of said two tubes, a second control tube having its output electrodes connected by a voltage divider to the control grid of the other of said two tubes to also control the bias on said grid, means for applying a bias potential to the grid of said first control tube which varies between a positive value and zero potential, and means for simultaneously applying to the grid of said second control tube a potential which varies between zero potential and a negative value.

5. In combination, two tubes having their control grids and anodes cross-coupled by impedances so that when one tube is biased to cut off the voltage on the grid of the other tube becomes less negative and vice versa, a first control tube having a control electrode and output electrodes and having its output electrodes coupled with the anode of one of said tubes to vary the potential thereof and as a consequence the potential of the grid of the other of said two tubes, means for biasing said first control tube to cutoff, a second control tube having a control electrode and output electrodes and having its output electrodes connected by a voltage divider to the control grid of the other of said two tubes to also control the bias on said grid, means for biasing the control electrode of said second control tube by a potential such that it is conductive, means for applying a control potential to the control electrode of said first control tube which varies between a positive value and zero potential, and means for simultaneously applying to the grid of said second control tube a control potential which varies between zero potential and a negative value.

6. In a telegraphy system of the type wherein the signals are represented by two potentials of varying magnitude, alternatively present, two tubes each having electrodes including a control electrode and an anode and having their control electrodes and anodes interconnected by impedances so that when one tube is biased to cut off, the voltage on the control electrode of the other tube becomes less negative, and vice versa, a first control tube having a control electrode and having output electrodes coupled directly to the control electrode of one of said first two tubes to vary the potential thereon in accordance with the signals, a second control tube having a control electrode and having its output electrodes coupled directly to the control electrode of said one of said first two tubes to vary the potential thereon in accordance with said signal potentials, means for applying one of said signal potentials to the control electrode of said first control tube, and

means for applying the other of said signal potentials to the control electrode of said second control tube.

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