

May 28, 1957

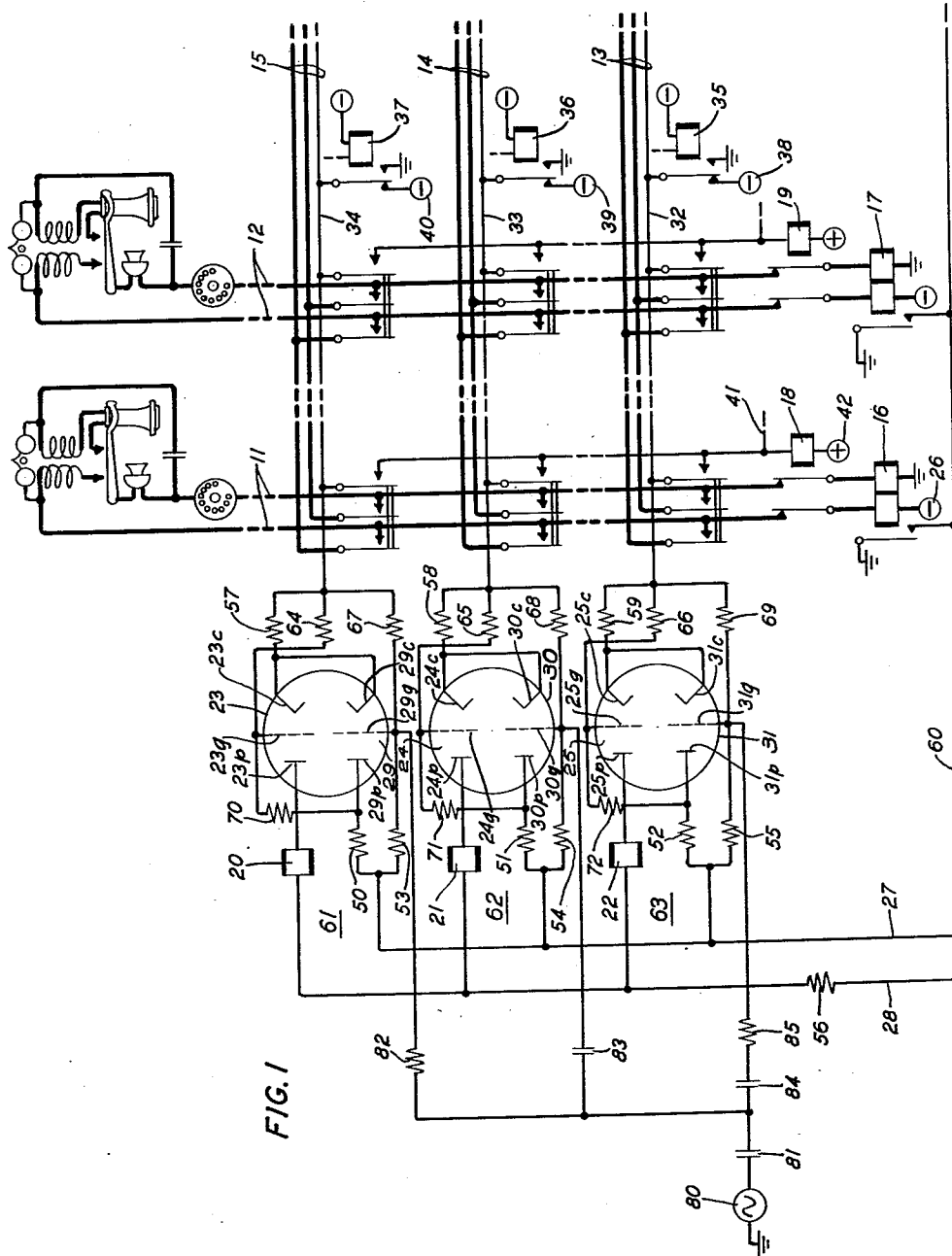
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2,794,121

LOCKOUT CIRCUIT

Filed May 22, 1952

2 Sheets-Sheet 1



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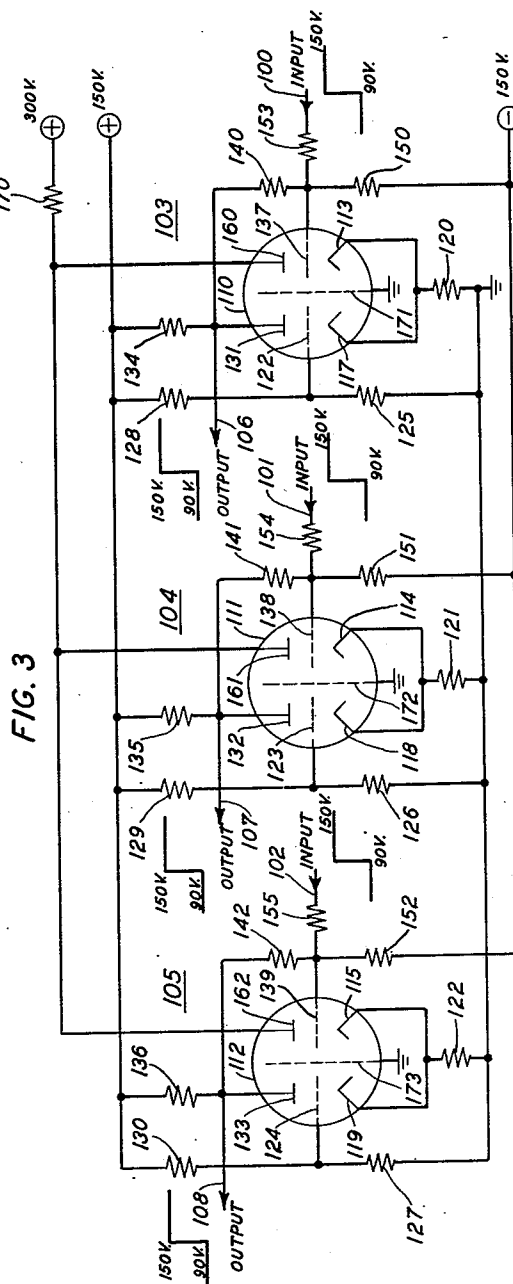
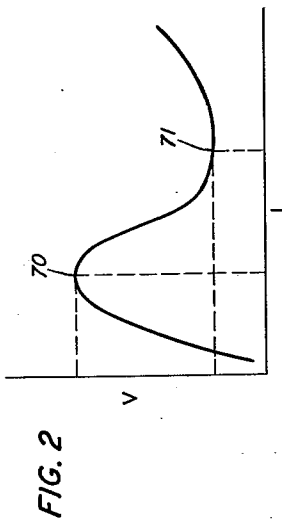
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LOCKOUT CIRCUIT

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2 Sheets-Sheet 2



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LOCKOUT CIRCUIT

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6 Claims. (Cl. 250—27)

My present invention relates to electronic lockout systems and more particularly to vacuum tube lockout systems utilizing positive feedback circuits.

More specifically my present invention provides for a novel vacuum tube lockout system which utilizes positive feedback circuits in each lockout branch to achieve current controlled negative resistance effects. A current controlled negative resistance device is herein defined as a device which, over a limited amplitude range, has a voltage current characteristic with a negative slope. This slope is sometimes referred to as a dynamic resistance or a differential resistance or a variational resistance. A current controlled negative resistance device may be characterized in the negative resistance range, as a negative resistance in series with an inductance, under a given direct-current bias, for small superimposed alternating currents of given frequency.

Heretofore in the prior art negative resistance devices have been utilized in lockout circuits. For example, it is well known in the art that when a breakdown potential is applied through a series resistor to a plurality of gas tubes connected in parallel only one of them will usually conduct. The tube having the lowest breakdown potential will usually ionize first with an accompanying reduction of potential through its negative resistance range to its ionizing sustaining potential. The reduction of potential across the parallel circuitry of gas tubes prevents the subsequent breakdown or ionization of any of the other gas tubes. Unwanted concurrent ionization, however, of two or more gas tubes and the operation of their associated output loads occasionally occur in this type of lockout circuit. Although various means have been suggested for overcoming this difficulty and decreasing the probability of the occurrence of lockout failure, no absolutely failure-proof means have been claimed. For example, an inductor or varistor, in addition to or in lieu of the common series resistor, has been connected in series with the parallel circuitry of the gas tubes to increase the time of transition through the low current range of the volt-ampere characteristics of the tubes. Multielectrode selecting tubes have also been suggested where the initial starting voltage causes the tubes to ionize in two or more successive stages. Only one of the tubes usually succeeds in transferring the ionization to its main electrodes while the other tubes are rendered inoperative by the ensuing lowering of the voltage. All of the means, however, as suggested in the prior art, are not failure-proof but only reduce, not eliminate, the probability of lockout failure and, moreover, tend to lengthen the time required to perform the lockout function. The time required for lockout to occur is dependent upon the net resistive and inductive effects in the various lockout branches. All of the negative resistance devices used in the prior art have large inherent inductive effects and thus require substantial and often prohibitive time to perform the lockout.

The present invention overcomes the difficulties existing in the prior art by providing for a novel vacuum tube

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lockout system which utilizes positive feedback circuits. Each lockout branch is substantially a negative resistance device comprised of two vacuum tubes; a control tube and an operating tube. When voltage is applied across a parallel grouping of lockout branches the control tubes begin to conduct immediately and supply a positive feedback to their associated operating tubes. The positive feedback provides a current controlled negative resistance characteristic where the inductive effects are very small. The small inductive effect results in exceedingly rapid operation so that if two or more operating tubes commence conducting, an unstable loop, or loops is established which stabilize before the output load apparatus individual to each operating tube can function. The stabilization of the loops results in only one operating tube conducting, and thus only one output load apparatus functioning.

It is then an object of the present invention to provide for an extremely rapid, failure-proof lockout system.

Another object of the present invention is to provide a novel vacuum tube lockout system utilizing the negative resistance effects achieved by positive feedback circuits.

Still another object of the present invention is to provide a novel lockout system operable at relatively high frequencies.

A feature of the present invention pertains to the provision of a novel vacuum tube lockout system having a control circuit for achieving easily alterable negative resistance effects in the individual lockout branches.

Still another feature of the present invention relates to the provision of a novel lockout system utilizing negative resistance devices having small inductive effects.

Further objects, features and advantages will become apparent upon consideration of the following description taken in conjunction with the figures, wherein:

Fig. 1 is a circuit diagram illustrating the switching system which incorporates the features of the present invention;

Fig. 2 is a typical voltage ampere characteristic of an individual lockout branch of the present invention; and

Fig. 3 is a modification of the novel lockout system of the present invention.

This invention is applicable to a wide variety of uses and to numerous kinds of systems. More specifically, it is particularly useful wherever it is desirable to make a single exclusive and random selection from a plurality of simultaneous demands. Although the invention is not limited in its application to any specific type of switching system, it is illustrated herein in connection with the system for extending the subscriber's line of a telephone system to groups of links, trunks or other circuits. It is assumed that the subscriber's lines appear on primary line switches of the well-known cross bar type and that these primary switches have access through links and secondary line switches to groups of trunk relays.

Referring now to Fig. 1, the subscribers' lines 11, 12, etc. appear in vertical rows and the outgoing lines 13, 14, 15, etc. appear in horizontal rows. The individual line relays 16, 17, etc. and switch hold magnets 18, 19, etc. represent the subscribers' lines and select magnets 20, 21, 22, etc. represent the outgoing circuits. Each outgoing circuit is also represented by operating vacuum tubes 23, 24, 25, etc. and control vacuum tubes 29, 30, 31, etc. which may be, as shown, enclosed together as a double triode. When a subscriber picks up his receiver he initiates a sequence of events, as is hereinafter described, which results in a connection of the subscriber to one of the outgoing lines 13, 14, 15, etc. The lifting of the receiver corresponding to the subscriber's line 11, for example, closes a circuit through the line 11 and line relay 16 to the negative battery 26. The energization

of relay 16 closes a circuit from ground through the armature of relay 16 and the line 60 to the lines 27 and 28. The line 27 is connected through the resistors 50, 51, 52, etc. to the plates 29p, 30p, 31p, etc. and through resistors 53, 54, 55, etc. to the grids 29g, 30g, 31g, etc. of the control tubes 29, 30, 31, etc. The line 28 is connected through the series lockout resistor 56 to the select magnets 20, 21, 22, etc. which represent, as described above, the outgoing circuits. When a subscriber picks up his receiver, he essentially places a ground potential upon the plates 23p, 24p, 25p, etc. and 29p, 30p, 31p, etc. The cathodes 23c, 24c, 25c of the tubes 23, 24, 25, etc. are connected, respectively, through the resistors 57, 58, 59, etc. and the armatures of relays 37, 36, 35, etc. to the negative batteries 40, 39, 38, etc. When the subscriber picks up his receiver a voltage is therefore placed across the tubes 23, 24, 25, etc. and 29, 30, 31, etc. which is essentially equal to the voltage from the batteries 40, 39, 38, etc. One or more of the tubes 23, 24, 25, etc. may conduct initially, but only one of the tubes remains conducting, as is hereinafter described in reference to Fig. 2, for a length of time sufficient to operate its associated select magnets 20, 21, 22, etc. The operation of the select magnet 22, for example, in response to the continued conduction of tube 25, prepares or readies the horizontal row of cross bars which appear in outgoing circuit 13. Thereafter in any suitable manner, a circuit is closed over conductor 41 for the operation of hold magnet 18 connected to positive battery 42. The operation of hold magnet 18 closes the set of cross bar contacts and establishes a circuit from the subscriber's telephone through line 11 to the outgoing circuit 13. Simultaneous with the establishment of a circuit to the outgoing line 13, the relay 35, which is under the control of a supervisory relay (not shown), operates to place ground potential upon the cathode 25c of tube 25 and also provides a holding circuit for hold magnet 18. When the hold magnet 18 is energized it opens the line 11 and deenergizes the relay 16 which, in turn, opens the circuit to lines 27 and 28. The tube 25 remains conducting until the deenergization of the relay 16 or until the grounding of cathode 25c by the relay 35. If the subscriber of line 12 should attempt to place a call during the time that a call from the subscriber of line 11 continues, the lines 27 and 28 would be grounded through the armature of line relay 17 in the manner described above with respect to line relay 16. Tube 25 would not be effective as the relay 35, being energized, as described above, throughout the duration of the call from the subscriber in line 11, keeps the cathode 25c at ground potential maintaining zero potential across the tube 25. The tube 25 cannot therefore conduct and so the line 13 cannot be selected. The remaining tubes 23, 24, etc., however, have their cathodes negatively biased by the batteries 40, 39, etc. and may initially conduct as is hereinafter described, resulting in subsequent selection and lockout.

When the subscriber of line 11 hangs up his receiver, the supervisory relay (not shown) operates to deenergize relay 35. The deenergization of relay 35 opens the holding circuit for relay 18 which, in turn, is deenergized due to the balancing of batteries 42 and 38. The reconnection of battery 38 also readies the tube 25 for possible selection by another subscriber. The use of the supervisory relay referred to above and its mode of operation are well known in the art as, for example, the patent to Clark, 1,844,147, dated February 9, 1932.

As briefly described above, only one of the tubes 23, 24, 25, etc. will operate its respective select relays 20, 21, 22, etc. in response to the lifting of the subscriber's receiver. The voltage current characteristic of a typical lockout branch which is generally designated 61, 62, 63, etc., is shown in Fig. 2 where the voltage applied is across the series combination of a tube 23, 24, 25, etc.

and its associated cathode resistors 57, 58, 59, etc. and the current is the current through the tube 23, 24, 25, etc. The lockout branches 61, 62, 63, etc. which include the tubes 23, 24, 25, etc. are connected in a parallel circuit arrangement between the lines 34, 33, 32, etc. to the lines 17 and 18, to line 60, and are comprised of a plurality of circuit components so constituted as to result in the voltage-ampere characteristic as shown in Fig. 2. The various circuit connections in the lockout branches 61, 62 and 63 are as follows: The cathodes 23c, 24c, 25c, etc. of the tubes 23, 24, 25, etc. are connected to the cathodes 29c, 30c, 31c, etc. of the tubes 29, 30, 31, etc. and to the cathode resistors 57, 58, 59, etc. The cathode resistors 57, 58, 59, etc. are connected to the lines 32, 33, 34, etc. to the grid resistors 64, 65, 66, etc. and to the grid resistors 67, 68, 69, etc. The grid resistors 64, 65, 66, etc. are connected to the grids 23g, 24g, 25g, etc. and the grid resistors 67, 68, 69, etc. are connected to the grids 29g, 30g, 31g, etc. The grids 23g, 24g, 25g, etc. are also connected to the plates 29p, 30p, 31p, etc. through the resistors 70, 71, 72, etc. and the grids 29g, 30g, 31g, etc. are also connected to the line 27 through the resistors 53, 54, 55, etc. The line 27 is also connected to the plates 29p, 30p, 31p, etc. through the plate resistors 50, 51, 52, etc. and the line 28 is connected through the series lockout resistor 56 and select magnets 20, 21, 22, etc. to the plates 20, 21, 22, etc.

When voltage is applied across the lockout branches 61, 62, 63, etc. due to the energization of lines 11, 12, etc. a sequence of voltages and currents occur within the individual lockout branches 61, 62, 63, etc. which subsequently results in lockout of all the tubes 23, 24, 25, etc. except one. In lockout branch 61, for example, when the relay 16 is energized completing a circuit to battery 40, potential is applied to the two triodes 23 and 29 and to the two parallel resistive paths which are in the branch 61; one path being from line 27 through resistors 50, 70 and 64 and the other path being from line 27 through resistors 53 and 67. Due to the effect of the lockout resistor 56 which is in series with the tubes 23, 24, 25, etc. and due to the arrangement of the various resistors as described above, the control tube 29 begins to conduct before the operating tube 23. The larger the lockout resistor 56 the greater the inductive effect or the lag between cause and effect. Since the lockout resistor 56 is only in series with the operating tubes 23, 24, 25, etc. and not with the control tubes 29, 30, 31, etc. it, together with the various circuit parameters as described above, causes a slight delay in the operation of the operating tubes. When the operating tube 23 of lockout branch 61 begins to conduct, it allows more current through the cathode resistor 57 causing the cathodes 23c and 29c to be slightly more positive. The grid 29g has a substantially fixed potential with respect to the negative battery 40 due to the resistive path of resistors 53 and 67. As the cathode 29c becomes more positive, its potential approaches and then passes the fixed potential of the grid 29g, gradually reducing the current through the tube 29 and finally cutting it off completely. As current is reduced through the tube 29 less current flows through the resistor 50 which, due to the connection through the resistor 70 to the grid 23g, causes the grid 23g to be more positive. Thus the increase of current through the tube 23 causes the reduction of current through the tube 29 which, in turn, causes a further increase in current through the tube 23. Although less current flows through the tube 29 tending to reduce the current through resistor 57, more current flows through the line 28 and lockout resistor 56. The resulting effect is that current increases rapidly through the tube 23, whereas the voltage across the tube 23 and resistance 57 reduces. The range of rapid increase of current and reduction of voltage is shown in Fig. 2 between points 70 and 71. Each of the lockout branches 61, 62, 63, etc. has a similar

associated voltage-ampere characteristic, thus artificially produced by a control element, as tubes 29, 30, 31, etc. of well-known properties, which introduces a voltage to the operating tubes 23, 24, 25, etc. in series with the external voltage. The voltage inserted by the control elements is proportional to the input current and as current rises through the operating tubes 23, 24, 25, etc. the control tubes 29, 30, 31, etc. feed back more and more positive potentials to the grids 23, 24, 25, etc. until the tubes 29, 30, 31, etc. are completely cut off. A further increase of current to the lockout branches 61, 62, 63, etc. produces no further feedback and thus the effective resistance of the branches 61, 62, 63, etc. becomes positive again. At very low and very high values of current the feedback factor therefore diminishes and the curve as shown in Fig. 2 has a positive slope. The voltage-ampere characteristics of the lockout branches 61, 62, 63, etc. can be greatly varied by changing the feedback or grid bias.

At low values of current the change-over from positive to negative slope is a gradual one as at point 70, Fig. 2. The voltage corresponding to point 70 is analogous to the breakdown potential of gas tubes and is hereinafter referred to as the breakdown voltage. If the breakdown voltage of the branches 61, 62, 63, etc. are different, the branch having the lowest breakdown voltage will have a rapid increase in current with an accompanying reduction of voltage. As the current rapidly increases the voltage across the resistor 56 becomes larger which, together with the reduction of voltage across the respective branch, allows insufficient voltage for the remaining branches to reach their respective breakdown voltages. Only one operating tube 23, 24, 25, etc. passes a current in excess of that corresponding to point 71, in Fig. 2, to operate its respective select relay 20, 21, 22, etc.

If, however, the branches 61, 62, 63, etc. have essentially identical characteristics, or at least similar breakdown potentials, two or more of the branches 61, 62, 63, etc. will pass point 70 into the negative resistance range of their characteristics. Two or more operating tubes 23, 24, 25, etc. conducting simultaneously in the negative resistance range between points 70 and 71 of their voltage-current characteristics, form an unstable loop or loops. For example, if tubes 23 and 24 conduct, a conductive loop from battery 40, line 34, resistor 57, tube 23, select magnet 20, select magnet 21, tube 24, resistor 58, line 33 and battery 39 is established. The resistances of the relays 20 and 21 are such that the sum of the positive resistance in the loop is less than the absolute value of the sum of the negative resistances due to the two tubes 23 and 24. When the positive resistance of a loop is less than the negative resistance, the loop becomes unstable and will seek a stable equilibrium condition. The loop will remain unstable until one of tubes 23 or 24 goes to a stable low current state. Even if one of the tubes 23 or 24 conducts current greater than that corresponding to point 71, in Fig. 2, making its resistance positive, the positive resistance is of such a small value as not to succeed in counteracting the increased negative resistance of the other tube as it swings downward towards a value of current corresponding to point 70. The sum of the currents through all the tubes 23, 24, 25, etc., and in this case through tubes 23 and 24 is limited, by the resistance 56 so that both tubes 23 and 24 cannot both simultaneously pass a current greater than that corresponding to point 71. As one of the tubes passes more current, the other tube passes less current with instability continuing to exist until one of the tubes swings below the current corresponding to point 70 thus achieving a high positive resistance and simultaneously becoming essentially non-conductive. When more than two of the tubes 23, 24, 25, etc. break down, a plurality of unstable loops are initiated. The instability persists as tube after tube becomes non-conductive until only one tube remains conducting. This system is an absolute failure-

proof system, for as long as the negative resistances in the loops exceed the positive resistance, under no condition can more than one tube remain conducting. The resistance of the select relays 20, 21, 22, etc., together with the other circuit resistances in the loop, are so chosen as to have this condition of instability whenever two or more tubes conduct current greater than that corresponding to point 70.

The time from the closing of the contacts due to energization of relays 16, 17, etc. to the effective non-conductance of all of the tubes 23, 24, 25, etc., except one, is called the severance time. The severance time for a given circuit containing a plurality of given tubes and circuit elements is of definite maximum duration. Thus a definite maximum time after the application of potential only one of the tubes 23, 24, 25, etc. will remain conducting. The severance time of the loops is less than the time required for the operation of the select relays 20, 21, 22, etc. This rapid operation is due to the very small inductive effect of the lockout branch 61, 62, 63, etc. As shown in the present modification of Fig. 1 the inductance due to the relays 20, 21, 22, etc. increases the severance time of the lockout branch. This inductance may be removed by having the relays 20, 21, 22, etc. operating through detectors (not shown). Fig. 3, hereinafter described, discloses a modification wherein the lockout branches do not include the inductance of a relay. The small inductive effect of such a circuit permits operation at relatively high frequencies as the impedance and delay do not become prohibitive until relatively high frequencies are utilized. No auxiliary means are required to hold the resistive value in the negative resistance range due to the high speed operation of the loops towards stability. With the high speed operation of vacuum tubes only a minute or momentary difference between the application of potential and the operation of the select relays 20, 21, 22, etc. is necessary to guarantee lockout. Simultaneous conducting branches 61, 62, 63, etc. are required to remain in the negative resistance range an exceedingly short time, which is not longer than that inherent in the natural build-up period.

Fast operation also allows very short pulses, slightly displaced in time, to control the operation of the select magnets 20, 21, 22, etc. If the lockout branches 61, 62, 63, etc. have slightly different characteristics the same select relay 20, 21, 22, etc. will be operated. The 100-kilocycle oscillator 80 introduces a voltage to the grids 29g, 30g, 31g, etc. of the tubes 29, 30, 31, etc. The difference in phase to the different grids 29g, 30g, 31g, etc. is achieved through the various impedances 81, 82, 83, 84, 85, etc. Dependent upon which instant the subscriber energizes the line 11, 12, etc. one of the grids 29g, 30g, 31g, etc. will receive a negative pulse so that its respective operating tube 23, 24, 25, etc. will have its grid more positively biased. The superimposing of the relatively high frequency voltage is a form of impulse multiplex circuit and provides for the random selection of one of the select relays 20, 21, 22, etc. The vacuum tube lockout circuits facilitate application of controls, such as the impulse multiplex circuit, requiring low power and inexpensive equipment.

In the modification as shown in Fig. 3 the inputs 100, 101, 102, etc. are connected through the lockout branches 103, 104, 105, etc. to the output leads 106, 107, 108, etc. The lockout branches 103, 104, 105, etc. are negative resistance devices having voltage current characteristics similar to that depicted in Fig. 2 and, as hereinafter described, are sensitive to voltage steps providing also voltage step outputs. In the normal state with the inputs 100, 101, 102, etc. remaining at a relatively low voltage level each lockout branch 103, 104, 105, etc. is stable and acts substantially as a large positive resistance passing only a small current. This value of current would be smaller than the current corresponding to point 70 of Fig. 2. The operation of the circuit shown in Fig. 3

is similar to the operation of the circuit described in the reference Fig. 1, with a substantial difference being in a plurality of inputs 100, 101, 102, etc. instead of a single line 60 which functions as an input for the lockout branches 61, 62, 63, etc. in Fig. 1. A pulse at any of the input leads 100, 101, 102, etc. will trigger its respective lockout branch 103, 104, 105, etc. into the negative resistance range of its voltage current characteristic. The respective lockout branch 103, 104, 105, etc. thereafter draws a large current which rapidly increases to a value in excess of the current corresponding to point 71, in Fig. 2. The resulting voltage drop across the lockout branch 103, 104, 105, etc. prevents the other lockout branches 103, 104, 105, etc. from being triggered and thus lockout is accomplished. The output lead 106, 107, 108, etc. associated with the selected lockout branch 103, 104, 105, etc. provides an output indication as is herein-after described, whereas the other output leads 106, 107, 108, etc. do not. This output is provided when the selected lockout branch 103, 104, 105, etc. is in a high current condition, that is, a current in excess of the current corresponding to point 71 of Fig. 2. Removal of the energization to the input 100, 101, 102, etc. will restore the circuitry to normal in preparation for a subsequent input pulse.

Simultaneous inputs to more than one input lead 100, 101, 102, etc. will result in only one output from the output lead 106, 107, 108, etc. due to the nature of the negative resistance devices which operate in a similar manner, as described above, in reference Figs. 1 and 2.

The connections in the lockout branches 103, 104, 105, etc. resulting in the voltage current characteristic as shown in Fig. 2 are as follows: The double triodes 110, 111, 112, etc. have their cathodes 113, 114, 115, etc. and 117, 118, 119, etc. connected together and thence to ground through 3000-ohm cathode resistors 120, 121, 122, etc. The grids 122, 123, 124, etc. are connected to ground through the 24,000-ohm resistors 125, 126, 127, etc. and to the 150-volt positive battery through the 160,000-ohm resistors 128, 129, 130, etc. The 150-volt positive battery is also connected to the plates 131, 132, 133, etc. through the 9100-ohm plate resistors 134, 135, 136, etc. The plates 131, 132, 133, etc. are also connected to the output leads 106, 107, 108, etc. described above and to the grids 137, 138, 139, etc. through the 270,000-ohm resistors 140, 141, 142, etc. The grids 137, 138, 139, etc. are also connected to a 150-volt negative battery through 240,000-ohm resistors 150, 151, 152, etc. and to the input leads 100, 101, 102, etc., described above, through the 360,000-ohm resistors 153, 154, 155, etc. The other plates 160, 161, 162, etc. are connected through the 20,000-ohm lockout resistor 170 to 300-volt positive battery. The resistors 128, 129, 130, etc. and 125, 126, 127, etc. have been so chosen that the plates 131, 132, 133, etc. are saturated when the input level to the grids 137, 138, 139, etc. is 90 volts. Ninety volts is the normal input voltage and the output voltage from leads 106, 107, 108, etc. for this value of input voltage is also 90 volts. When the input voltage rises to 150 volts the plates 160, 161, 162, etc. pass current through the right side of the tubes 110, 111, 112, etc. which is separated from the left side by the grounded shields 171, 172, 173, etc.

The operation of the circuitry thereafter proceeds exactly in the manner to that as described above in reference Fig. 1 with the left side or the operating side of the double triodes 110, 111, 112, etc. becoming conductive and supplying an output to the output leads 106, 107, 108, etc. and the right side or the control side of the double triodes 110, 111, 112, etc. being essentially cut off. If two of the input leads 100, 101, 102, etc. are energized simultaneously by increasing the voltage from 90 volts to 150 volts, an unstable condition will result which after the time will result in the selection of one of the lockout branches 103, 104, 105, etc. providing ener-

gization or an increase in voltage from 90 volts to 150 volts in only one of the output leads 106, 107, 108, etc. When the output lead 106, for example, has its voltage level increased from 90 volts to 150 volts, the potential on the plate 160 reduces to approximately 110 volts. Thus an input to one lockout branch 103 drops the potential at all of the plates 160, 161, 162, etc. preventing an output from any lockout branches 103, 104, 105, etc. Lockout of such a vacuum tube circuit is aided by very rapid operation as a slight momentary unbalance between lockout branches 103, 104, 105, etc. which receive simultaneous inputs is sufficient to insure lockout, since the branches 103, 104, 105, etc. will so rapidly separate. In the lockout circuitry as described above in reference to Fig. 3, only .3 microsecond is required for the branches 103, 104, 105, etc. to separate and achieve lockout in a failure-proof manner.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of this invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A lockout system comprising a plurality of branches, a lockout resistor connected in series with said plurality of branches, each of said branches having a negative resistance characteristic and comprising at least one vacuum tube connected to said resistor, means for applying concurrently a potential to all of said branches for causing the conduction of at least one of said branches, the conduction of a plurality of said branches forming at least one conductive loop, and means for maintaining the total resistance of said loop negative during the transient build-up of current through said vacuum tubes.

2. A lockout system comprising a plurality of branches, each of said branches comprising an operating vacuum tube and a control vacuum tube and a feedback circuit connecting said operating and said control tubes, means for causing the conduction of said control tube in at least one of said branches, each said feedback circuit providing a positive potential to said operating tube which is inversely proportional to the conduction of said control tube, means including said control tubes and said feedback circuits for maintaining the conduction of only one of said operating tubes in said plurality of said branches and output means responsive to the maintained conduction of said operating tube to provide an output indication.

3. A lockout system comprising a plurality of branches, each of said branches comprising at least one vacuum tube and having a negative resistance characteristic; a lockout resistor connected in series with said plurality of lockout branches; and means for applying a potential to all of said branches for causing the conduction of at least one of said branches; means including said vacuum tubes responsive to the conduction of a plurality of said branches to form at least one conductive loop; and means for maintaining the severance time of said loop to be less than the transient build-up time of current through said branches to a value greater than the current values in the negative resistance range of said branches.

4. A lockout system comprising a plurality of lockout branches; and a series lockout resistor connected to said branches; each of said lockout branches having an operating circuit, a control circuit, delay means causing said control circuits to conduct before said operating circuits, a feedback circuit responsive to the conduction of said control circuit for supplying a positive feedback to said operating circuits, and means including said feedback circuit causing said operating circuits to have negative resistance characteristics and only one of said operating circuits to remain conducting after the severance time of said lockout branches.

5. A lockout system comprising a plurality of lockout branches; and a series lockout resistor connected to said

branches; each of said lockout branches having an operating circuit, a control circuit, means causing said control circuits to conduct before said operating circuits, means supplying a positive feedback to said operating circuits causing said operating circuits to have negative resistance characteristics, and means including said first- and second-mentioned means whereby only one of said operating circuits remains conducting after the severance time of said lockout branches, said lockout branches having a severance time less than the transient build-up time of the current through said operating circuit. 10

6. A lockout system comprising a plurality of lockout branches; and a series lockout resistor connected to said branches; each of said lockout branches having an operating circuit and a control circuit, delay means causing said control circuits to conduct before said operating circuits, feedback means responsive to the conduction of said control circuits to supply a positive feedback to said operating circuits causing said operating circuits to 15

have negative resistance characteristics, and means including said feedback means maintaining only one of said operating circuits conductive after the severance time of said lockout branches, each of said operating circuits comprising a vacuum operating tube and an output apparatus device connected to said tube, said lockout branches having a severance time less than the natural build-up time of the current through said operating tube so that only one of said output apparatus devices is activated.

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