

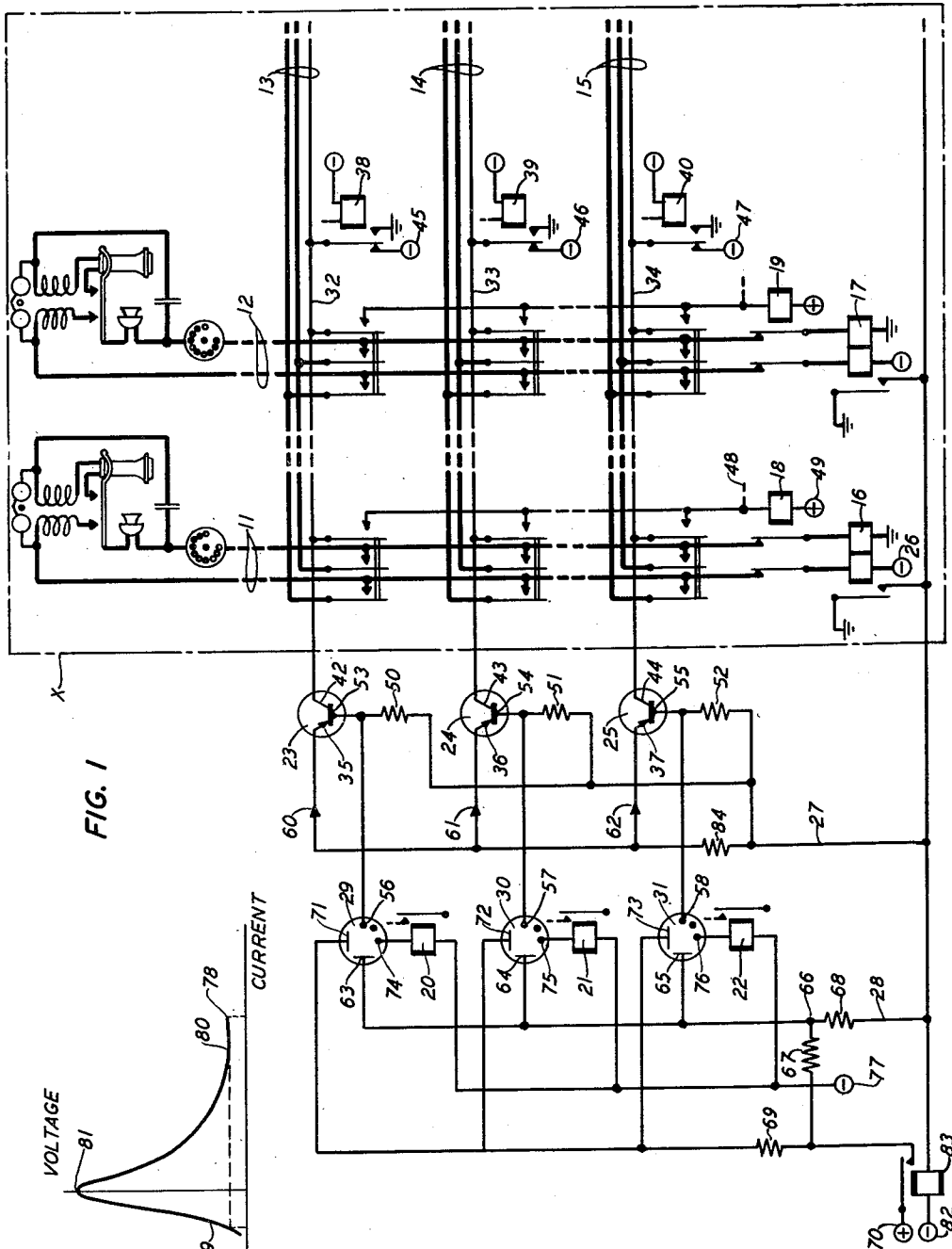
April 12, 1955

B. G. BJORNSON
TRANSISTOR LOCKOUT CIRCUIT

2,706,222

Filed May 22, 1952

2 Sheets-Sheet 1



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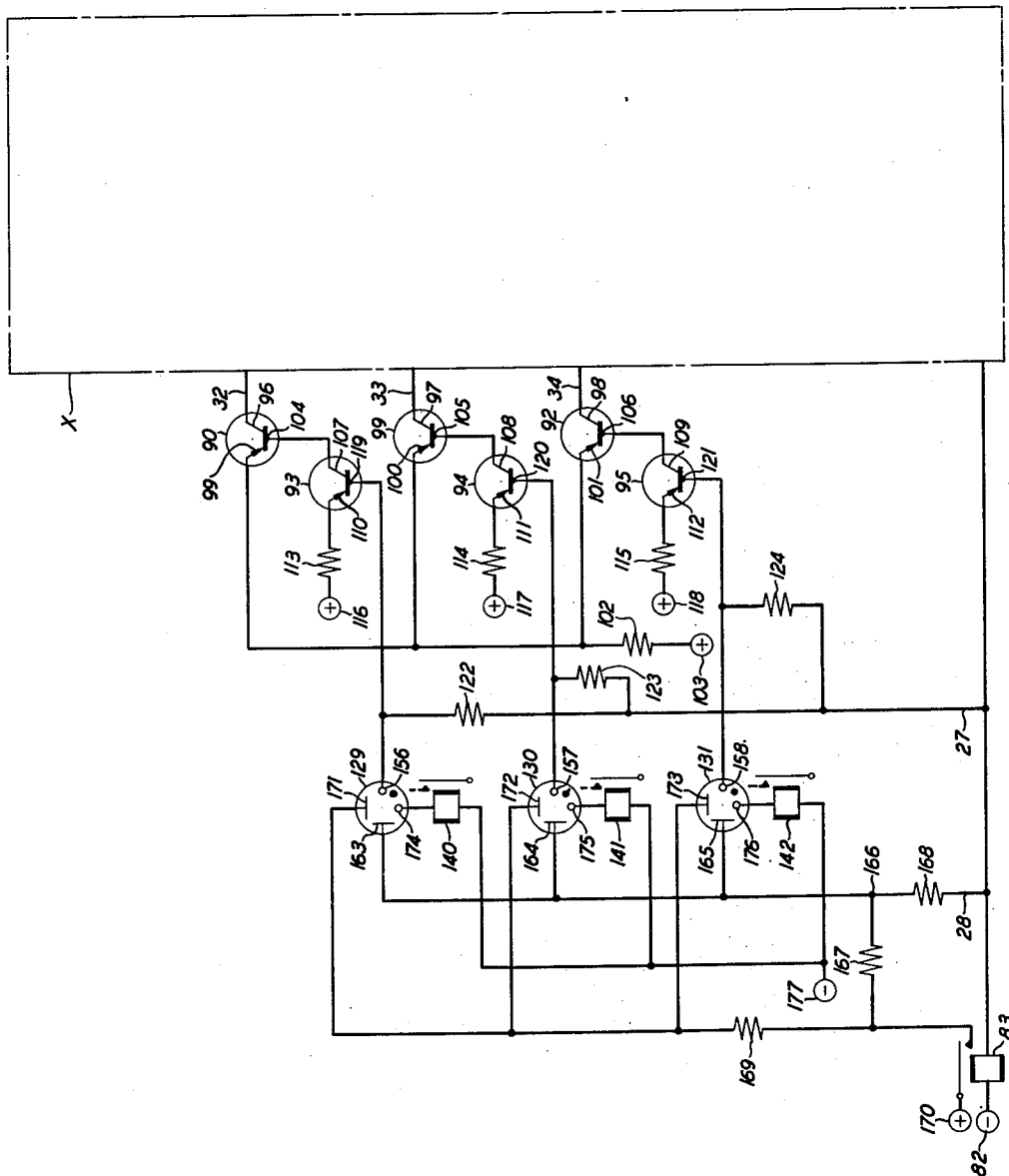


FIG. 3

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2,706,222

TRANSISTOR LOCKOUT CIRCUIT

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10 Claims. (Cl. 179—18)

My present invention relates to lockout systems and more particularly to lockout systems utilizing the negative resistance characteristics of transistors to effect the lockout function.

A lockout circuit is here defined as a circuit which under the influence of a number of incoming circuits provides an output indication corresponding to one and only one of the incoming circuits at any time, and a negative resistance device is here defined as a device which over a limited amplitude range has voltage current characteristic with a negative slope. A current controlled negative resistance device such as a transistor, may be characterized in a certain range as a negative resistance in series with an inductance under a given direct-current bias for small superimposed alternating current of given frequency. Heretofore in the prior art negative resistance devices have been utilized in lockout circuits as, for example, a plurality of gas tubes connected in parallel. The tube having the lowest breakdown voltage will usually ionize first with an accompanying reduction of voltage through its negative resistance range to its ionizing sustaining voltage. The reduction of voltage across the parallel circuitry of gas tubes prevents the subsequent breakdown of any of the other gas tubes. Unwanted breakdown, however, of two or more gas tubes and the operation of their associated output load devices 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 failure-proof means have been found. For example, an inductance or varistor in addition to 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 characteristic of the tube. 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 these means, however, 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 various 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 function.

The present invention overcomes the difficulties existing in the prior art by providing for a novel transistor lockout system where each lockout branch has at least one transistor. A potential is supplied through a resistance to a plurality of transistors where each transistor has associated therewith a gaseous tube with an output load device. If the application of voltage causes more than one of the transistors to conduct an unstable loop or loops will be formed. The loops remain unstable until only one of the transistors remains conducting and causes the discharge of its associated gas tube and the operation of its associated output load device. The selection of one transistor is accomplished before the possible ionization of any of the gas tubes.

It is then an object of the present invention to provide

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for a novel lockout system that is absolutely failure-proof.

Another object of the present invention is the provision of a novel transistor lockout system which utilizes the negative resistance characteristics of the transistors at relatively high currents to achieve the lockout function.

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

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

Still another object of the present invention is the provision of a novel random transistive lockout system that operates successfully even when the characteristics of the transistors are identical.

Still another object of the present invention is the provision of a novel combination of a lockout and lockin system which utilizes in each lockout branch a transistor performing the lockout function and a gas tube performing the lockin function.

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

Fig. 1 is a circuit diagram illustrating a switching system incorporating the novel features of the present invention in which transistor circuits are utilized;

Fig. 2 is a voltage current characteristic of a typical transistor utilized in the present invention; and

Fig. 3 is a circuit diagram illustrating a second embodiment of the present invention in which two transistors are associated with each lockout branch.

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 to 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 trunks appear in horizontal rows 13, 14, 15, etc. The individual line relays 16, 17, etc. and switch hold magnets 18, 19, etc.; represent the subscribers' lines 11, 12, etc., and select magnets 20, 21, 22, etc., represent the outgoing circuits 13, 14, 15, etc. Each outgoing circuit 13, 14, 15, etc., is also represented by a transistor 23, 24, 25, etc., and gas tubes 29, 30, 31, etc., which may be as shown four electrode gaseous tubes. When a subscriber picks up his receiver he initiates the 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 line 11, for example, closes the 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 to the lines 27, 28 and also to the negative battery 82 through the relay 83. The line 27 is connected through the series lockout resistor 34 and varistors 60, 61, 62, etc. to the emitters 35, 36, 37, etc. of the transistors 23, 24, 25, etc. When the subscriber picks up his receiver he essentially places a ground potential upon the emitters 35, 36, 37, etc. The collectors 42, 43, 44, etc. of the transistors 23, 24, 25, etc. are connected through the lines 32, 33, 34, etc. and the armatures of relays 38, 39, 40, etc. to the negative batteries 45, 46, 47, etc. When the subscriber picks up his receiver a voltage is therefore placed across the transistors 23, 24, 25, etc. which is essentially equal to the voltage from the batteries 45, 46, 47, etc. One or more of the transistors 23, 24, 25, etc. may conduct initially but only one of the transistors remains conducting, as is hereinafter described, in reference to Fig. 2, for a length of time sufficient to ionize gas tubes 29, 30, 31, etc. Each of the tubes 29, 30, 31, etc. has associated therewith a select

relay 20, 21, 22, etc. which is operated only when its respective gas tube 29, 30, 31, etc. becomes ionized. The operation of the select magnet 22 for example, in response to the conduction of tube 31, prepares the horizontal row of cross-bars which appear in outgoing circuits 15 for further operation. Thereafter, in any suitable manner, a circuit is closed over line 48 for the operation of hold magnet 18 connected to positive battery 49. The operation of hold magnet 18 closes a set of cross-bar contacts and establishes a circuit from the subscriber's phone through line 11 to the outgoing circuit 15. Simultaneous with the establishment of the circuit to the outgoing line 15 the relay 40 which is under the control of a supervisory relay, not shown, operates to place ground potential upon the emitter 44 of transistor 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, 28 and to battery 82. The transistor 25 remains conducting until the deenergization of the relay 16 or until the grounding of the collector 44 by the relay 40. 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 line 27 would be grounded through the armature of line relay 17 in the manner described above with respect to line relay 16. Transistor 25 would not be effective as the relay 40 being energized, as described above, throughout the duration of the call from the subscriber of line 11 would keep the collector 44 at ground potential maintaining zero potential across the transistor 25. The transistor 25 cannot be energized and therefore the line 13 cannot be selected. The remaining transistors 23, 24, etc., however, have their collectors 42, 43, etc. negatively biased by the batteries 45, 46, etc. and may initially pass current 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 40. The deenergization of relay 40 opens the holding circuit for relay 18 which in turn is deenergized due to the balancing of batteries 47 and 49. The reconnection of battery 47 also readies the transistor 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, one of the transistors 23, 24, 25, etc. will operate its respective gas tube 29, 30, 31, etc. and thus its respective select magnet 20, 21, 22, etc. in response to the lifting of the subscriber's receiver. The voltage current characteristics of a typical transistor 23, 24, 25, etc. is shown in Fig. 2 where the voltage is taken across the transistor 23, 24, 25, etc. and base resistance 50, 51, 52, etc. from the emitter 35, 36, 37, etc. and the current is the emitter current. The characteristic has a negative slope between the maximum voltage 81 and voltage 80 there the slope passes through zero to become positive. It is evident therefore that for any value of emitter current between the current values corresponding to the voltages 81 and 80 the transistors 23, 24, 25, etc. will present a characteristic of decreasing voltage with increasing current, sometimes called a negative resistance effect. When a subscriber lifts his receiver a circuit is closed through each of the parallel transistors 23, 24, 25, etc. with a negative potential from the batteries 45, 46, 47, etc. being applied to the collectors 42, 43, 44, etc. The negative potential is applied to the collectors 42, 43, 44, etc. unless, as described above any one of the respective output lines 13, 14, 15, etc. is being used. If an output line 13, 14, 15, etc. is busy, its respective transistor 23, 24, 25, etc. and in particular its respective collector 42, 43, 44, etc. receives no potential and remains non-conducting. If the transistors 23, 24, 25, etc., having a potential applied, have different maximum or breakdown potentials 81, only one of them will commence conduction with accompanying rapid reduction in voltage to voltage 80. The remaining transistors 23, 24, 25, etc. will remain non-conducting as their breakdown potential was never reached. When, however, the transistors 23, 24, 25, etc. have substantially identical characteristics a plurality of them will conduct upon the application of potential as described above. When, for example, transistors 23 and

transistor 24, line 33 to battery 46. The resistances of the lines 32, 33, etc. in the loop are such as to have the total positive resistances less than the sum of the negative resistances due to the two transistors 23 and 24. When the positive resistance of a loop is less than the negative resistance, the loop becomes unstable and the current in one device will increase, in the other decrease, until a stable equilibrium condition is established with one device at high current, and the other at low current. The sum resistance will remain negative and the loop will remain unstable until one of the transistors 23 or 24 ceases conduction. Even if one of the transistors 23 or 24 commences to pass current greater than that corresponding to voltage 80 in Fig. 2, thus making its resistance positive, the positive resistance is of such small value as not to succeed in counteracting the increased negative resistance of the other transistor as it swings downward towards zero. As one transistor 23 or 24 passes more current, the other transistor 24 or 23 passes less current with instability continuing to exist until one of the transistors swings below zero, thus achieving a high positive resistance and stabilizing the loop. When more than two transistors 23, 24, 25, etc. commence conducting, a plurality of unstable loops are initiated and the instability persists as transistor after transistor becomes non-conducting until only one transistor remains conducting. The system is an essentially failure-proof system, for as long as the negative resistances in the loop exceed the positive resistances, no more than one transistor can continue to conduct. This condition must of necessity exist, as is hereinafter described until after the stabilization of the loops. The currents are so restricted by the circuit parameters as to have a current through the lockout resistor 84 less than twice the current corresponding to voltage 80. A maximum current is necessary during lockout to insure instability when only two of the transistors 23, 24, 25, etc. remain conducting. Generally when using negative resistance devices in order to have random operation, a definite minimum current which is equal to the current corresponding to breakdown potential times the number of tubes utilized is necessary. This minimum current through a series lockout resistor allows the discharging of all the devices. Since the current corresponding to breakdown potential 81 is zero, there is essentially no limit on the number of transistors 23, 24, 25, etc. which may be placed in parallel.

The lockout features, as described above, operate when all the transistors 23, 24, 25, etc. have identical voltage-ampere and all operate in identical manner during a short transient interval, since any initial disturbance will start this unstable circuit toward binding a stable equilibrium which culminates in the selection of one, and only one, of the transistors 23, 24, 25, etc.

The time from the closing of the contacts due to energization of relays 16, 17, etc. to the effective non-conductance of all the transistors 23, 24, 25, etc. except one, is called the severance time. The severance time for a given circuit containing a plurality of given transistors and circuit elements is of definite maximum duration. Thus a definite maximum time after the application of potential only one of the transistors 23, 24, 25, etc. will remain conducting. The severance time of the loops is less than one-half a microsecond so that stabilization is rapidly accomplished. This extremely rapid operation is due to the very small inductive effects of the transistor. A current controlled negative resistance device, such as a transistor, may be characterized in its 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. The small inductive effects permit operation at relatively high frequencies if necessary. No auxiliary means are required to hold or delay the rise of current to the negative resistance range due to the high speed stabilization of the loops. Simultaneous conducting transistors 23, 24, 25, etc. are required to remain in the negative resistance range for an interval of time which is shorter than the natural build-up period of the transistor circuits and so are necessarily stabilized. The conductance of the transistors 23, 24, 25, etc. upon the application of potential from the batteries 45, 46, 47, etc. causes a voltage to appear across the base resistances 50, 51, 52, etc. described above. The base resistances 50, 51, 52, etc. are connected to the line 27 and thence to ground when the line relays 16, 17, etc. are energized. The voltage across

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the base resistances 50, 51, 52, etc. is used to fire the starter gap of the four-electrode cold cathode gas tubes 29, 30, 31, etc. as is hereinafter described. The bases 53, 54, 55, etc. are connected to the starting cathodes 56, 57, 58, etc. of the tubes 29, 30, 31, etc. The starting anodes 63, 64, 65, etc. are connected to the tap 66 of a voltage divider consisting of the resistances 67 and 68. The resistance 68 is connected to the line 28, described above, and the resistance 67 is connected to the resistor 69 and to the positive battery 70 through the armature of relay 33 described above. The selection of one of tubes 29, 30, 31, etc. due to the selection and lockout of the transistors 23, 24, 25, etc. is accomplished with the ionization of the starting gap from the anodes 63, 64, 65, etc. to the cathodes 29, 30, 31, etc. The energization of the relay 83 in response to the energization of relay 16, 17, etc., described above, causes the application of positive potential to the start anodes 63, 64, 65, etc. and also to the main anodes 71, 72, 73, etc. through the resistor 69. The discharge is thereafter transferred across the main gap between the plates 71, 72, 73, etc. and cathodes 74, 75, 76, etc. The cathodes 74, 75, 76, etc. are connected through the select relays 20, 21, 22, etc. described above to the negative battery 77.

If the two transistors 23 and 24 initially conduct, one transistor, for example 23, will pass a high positive emitter current 78, shown in Fig. 2 and the transistor 24 will pass a low emitter current 79. With a -68 volt collector voltage from battery 45, the voltage across the base resistor 50 would be approximately -66 volts upon the selection of the transistor 23. The voltage across the base resistor 50 together with the bias voltage across the resistor 69 is sufficient to fire the gas tube 29. The base voltage from across resistor 51 and from the quiescent resistors 52, etc. is insufficient to fire their associated tubes 30, 31, etc. The voltage supplied across the base resistors 50, 51, 52, etc. is fairly uniform with transistor and temperature variations.

For a failure-proof lockout the longest severance time of the transistors 23, 24, 25, etc. must be shorter than the minimum breakdown time of the gas tubes 29, 30, 31, etc. The minimum breakdown time of the gas tubes 29, 30, 31, etc. is approximately 10 microseconds, whereas the maximum severance time is less than one-half a microsecond. With this large difference between the severance time and breakdown time of the starting gaps, the circuit combination is failure-proof in lockout.

The input impedance of the gas tubes 29, 30, 31, etc. should be high to prevent interference with the transistors 23, 24, 25, etc. when the tubes 29, 30, 31, etc. fire and the capacity between the emitters 35, 36, 37, etc. and ground should be as low as possible as this capacity momentarily shorts the lockout resistance 84 and thus increases the severance time. The capacity between the bases 53, 54, 55, etc. and ground slows down the operation time and increases the severance time by effectively supplying a positive reactive component in series with the lockout resistance 34.

In the modification as shown in Fig. 3 the box X signifies the same circuitry as shown in the dotted box marked X in Fig. 1. The variations in the various circuit components may sometimes require a greater voltage differential between breakdown and no breakdown than can be supplied by a single transistor in a selectable circuit. As shown in Fig. 3 a transistor 90, 91, 92, etc. and a transistor 93, 94, 95, etc. are connected to the lines 32, 33, 34, etc. The lines 32, 33, 34, etc. are connected to the collectors 96, 97, 98, etc. supplying a negative potential as described above in reference to Fig. 1 with respect to transistors 23, 24, 25, etc. The emitters 99, 100, 101, etc. of the transistors 90, 91, 92, etc. are connected through the series lock-out resistor 102 to the positive battery 103, and the bases 104, 105, 106, etc. are connected to the collectors 107, 108, 109, etc. of the transistors 93, 94, 95, etc. The emitters 110, 111, 112, etc. of the transistors 93, 94, 95, etc. are connected through the resistances 113, 114, 115, etc. to the positive batteries 116, 117, 118, etc. and the bases 119, 120, 121, etc. are connected through the base resistances 122, 123, 124 to the line 27 which is similar to the line 27 described in reference to Fig. 1. When the subscriber lifts his receiver to initiate a call a voltage is placed between the collectors 96, 97, 98, etc. and the emitters 99, 100, 101, etc. causing the selection of one of the transistors 90, 91, 92, etc. and the lockout of the re-

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mainder thereof in a similar manner as described above in reference to transistors 23, 24, 25, etc. in Fig. 1. The selection of one of the transistors causes the application of negative potential to one of the collectors 107, 108, 109, etc. of transistors 93, 94, 95, etc. Since the emitters 110, 111, 112, etc. are positively biased by the batteries 116, 117, 118, 119, etc. the transistor 93, 94, 95, etc. having its collector 107, 108, 109, etc. negatively biased will commence conducting. The conduction of one of the transistors 93, 94, 95, etc. supplies a negative potential to the starting cathodes 156, 157, 158, etc. of the tubes 129, 130, 131, etc. The bases 119, 120, 121, etc. are connected to the cathodes 156, 157, 158, etc. of the tubes 129, 130, 131, etc. The starting anodes 163, 164, 165, etc. are connected to the tap 166 between the resistances 167 and 168. The resistance 168 is connected to the line 28, similar to line 28 in Fig. 1 and the resistance 67 is connected to the plate resistor 169 and to the positive battery 170 through the armature of the relay 83, which is similar to the relay 83 described in Fig. 1. The discharge across the gap from the anodes 163, 164, 165, etc. to the cathodes 156, 157, 158, etc. is transferred across the main gap from the anodes 171, 172, 173, etc. to the cathodes 174, 175, 176, etc. The anodes 171, 172, 173, etc. are connected to the plate resistor 169 and the cathodes 174, 175, 176, etc. are connected to the negative battery 177 through the select relays 140, 141, 142, etc. The select relays 140, 141, 142, etc. are exactly similar in operation to the select relays 20, 21, 22, etc. described above in reference to Fig. 1.

With the double transistor circuit of Fig. 3 the voltage across the selected base resistors 122, 123, 124 can be maintained at approximately -66 volts while the voltage across the remaining selectors can be varied and even made positive thus providing a much larger safe range for operating. This larger operating range allows for variations in the transistors, gas tubes, and supply voltages so that non-critical components may be utilized. More than two transistors may be utilized in each circuit of a greater differential in potentials is required. The utilization of more than one transistor provides for a larger negative resistance range in the voltage-ampere characteristic and so provides greater insurance for lockout as the build-up time is slightly greater through the transistors.

The output indication is not necessarily taken from the base circuitry as shown in Fig. 3 but may be taken from the emitters or collectors of the transistors in the selectable circuit.

Various other modifications are possible without departing from the spirit of the invention as, for example, connecting the select relays directly in the emitter, collector or base circuitry. An ordered selection and lockout is sometimes desired in cross-bar circuits which can readily be accomplished by placing capacitors of increasing magnitudes across the base resistances 50, 51, 52, etc. in Fig. 1. Random operation can be further insured if so required by applying short pulses separated in time to the bases 53, 54, 55, etc. of transistors 23, 24, 25, etc. in Fig. 1. This could be done by utilizing phase shifting networks using high frequency priming impulses.

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 randomly selectable parallel circuits, each of said parallel circuits having at least one transistor having a negative resistance range and positive resistance components, a potential source connectable to said parallel circuits, and means including said transistors responsive to the connection of said source to said parallel circuits for causing the time for the transient rise of current through the negative range of said transistors to be greater than the severance time of said parallel selectable circuit.
2. A lockout system comprising a plurality of randomly selectable parallel circuits, each of said circuits including a transistor having a similar volt-ampere characteristic and an output load device, means for applying a potential to all of said transistors causing the conduction of at least one of said transistors, means responsive to the conduction of a plurality of said transistors to form at least one unstably conductive loop, and means responsive

to the conduction of said transistors for maintaining the instability of said loops until only one of said transistors remains conducting to operate the respective one of said output load devices.

3. A completely random lockout system comprising a large plurality of selectable parallel circuits, each of said circuits comprising at least one similar transistor having a volt-ampere characteristic with a negative resistance range, means for restricting the total current through all of said large plurality of circuits during the transient rise of current through said negative resistance range to be greater than zero and means for restricting the total current through all of said large plurality of circuits during the transient rise of current through said negative resistance range to be less than twice the largest current of said negative resistance ranges.

4. A lockout system comprising a plurality of randomly selectable parallel circuits, each of said circuits including a transistor having a similar volt-ampere characteristic, a gas tube connected to said transistor and an output load device, means for applying a potential to all of said transistors causing the conduction of at least one of said transistors, means responsive to the conduction of a plurality of said transistors to form at least one unstably conductive loop, the severance time of said loops being less than the time required to ionize said gas tubes, the ionization of one of said tubes initiating the operation of the associated of said output load devices.

5. A lockout system comprising a plurality of randomly selectable parallel circuits, each of said circuits including a transistor having a similar volt-ampere characteristic, a multielectrode gaseous tube connected to said transistor and an output load device, means for applying a potential to all of said transistors causing the conduction of at least one of said transistors, means responsive to the conduction of a plurality of said transistors for forming at least one unstably conductive loop, the severance time of said loops being less than the sum of the statistical time delay and transfer time of said tubes, the transfer of discharge of said tubes causing the operation of the associated of said output load devices.

6. A lockout system comprising a plurality of selectable circuits, each of said selectable circuits having a negative resistance characteristic and comprising at least one transistor, a resistor connected in series with said selectable circuits, and means for applying a potential to all of said selectable circuits, the conduction of a plurality of said selectable circuits forming at least one conductive loop, means for maintaining the total resistance of said loops negative during the natural build-up of current through said transistors.

7. In combination, a plurality of selectable circuits,

transistors having the collector paths individual respectively to said selectable circuits, output apparatus connected respectively to the emitters of said transistors, and means for applying a potential to said transistors causing only one of said emitters to pass current for a sufficient time to operate the respective of said output apparatus.

8. A lockout system comprising a plurality of selectable circuits, a transistor individual respectively to each of said selectable circuits, a resistor connected to the emitters of all of said transistors, a multielectrode gaseous tube individual respectively to each of said transistors, a resistor connected to the base of each transistor, means for causing an unstable condition to exist when at least two of said emitters have a positive current, the starting gap of said tubes being respectively connected across said second-mentioned resistors.

9. A lockout system comprising a plurality of selectable circuits, a transistor individual respectively to each of said selectable circuits, a resistor connected to the emitters of all of said transistors, a multielectrode gaseous tube individual respectively to each of said transistors, a resistor connected to the base of each transistor, means for causing an unstable condition to exist when at least two of said emitters have a positive current, the starting gap of said tubes being respectively connected across said second-mentioned resistors, and means for maintaining the starting gaps of said tubes un-ionized until after stability occurs.

10. A lockout system comprising a plurality of selectable circuits, a transistor individual respectively to each of said selectable circuits having a volt-ampere characteristic which includes a negative resistance region, a resistor connected to the emitters of all of said transistors, a multielectrode gaseous tube individual respectively to each of said transistors having a starting gap, a resistor connected to the base of each transistor, said starting gap of said tube being respectively connected across said second-mentioned resistors, means for applying a potential to the idle of said selectable circuits for causing a plurality of said transistors to have a positive emitter current, means for causing an unstable current condition to exist in said selectable circuits by restricting the currents thereon to the negative resistance region of the volt-ampere characteristic of said transistors when at least two of said emitters have a positive current, the severance time of said selectable circuits being smaller than the natural build-up time of emitter current, and means for maintaining said starting gaps of said tubes un-ionized until after stability occurs.

No references cited.