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RANDOM SIGNAL GENERATOR

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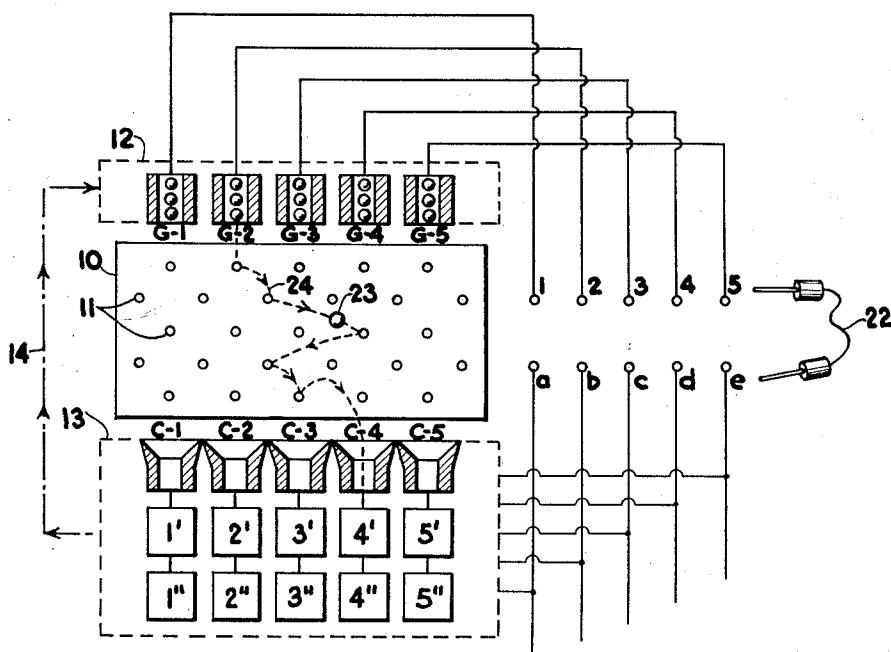


FIG. 1

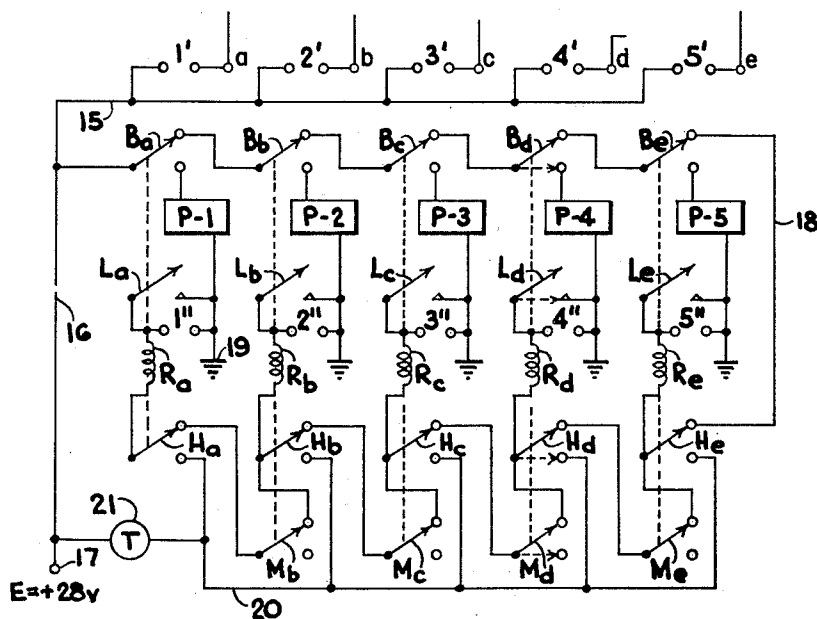


FIG. 2

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RANDOM SIGNAL GENERATOR

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This invention relates generally to random signal generators and more particularly to an electro-mechanical apparatus for continuously supplying random numbers.

Many different types of apparatus have been proposed for generating random signals. For example, some generators employ gas tubes which discharge in a random manner. Random numbers may be obtained from such an apparatus by providing a set of digits corresponding to a linear time scale and then selecting the digits in accordance with the random time intervals between gas tube discharges. Most generators of this type provide a normal random number distribution; that is, the distribution of the numbers tend to congregate about a central number and taper off on either side in accordance with the well known normal distribution curve.

It is somewhat more difficult to obtain a rectangular random distribution of numbers. In a rectangular distribution, one number is as equally likely to occur as any other number so that over long periods of time there is no tendency for certain numbers to be favored. Rectangular distributions, as well as normal and other types of distribution curves, all find valuable applications in industry.

The principal difficulty with employing machines for generating random numbers lies in the very nature of the machine itself. Being precisely designed and of relatively constant internal dimensions, various components necessarily operate in a cyclic manner so that an ordered output is expected. In order to make the output random, it is usually necessary to complicate the machine by adding a sufficient number of components that the likelihood of one component operating in response to a given signal is the same as another whereby the output will supposedly be random. Even with relatively complicated machines, however, there is a tendency for the machine itself to develop a bias so that after periods of long use its output will no longer represent true randomness. It is for this latter reason that many random signal generating devices employ a basic component such as a gas tube in which the characteristics thereof depend upon the statistical distributions of gas molecules, or on the arbitrary ionization effects of cosmic radiation, wherein the generation of a signal in the tube is primarily dependent on a statistical phenomena.

There are many applications in industry in which an apparatus for providing random numbers at a relatively slow rate, for example, ten or so per second, would be highly useful. Thus, a continuous output of such random numbers could be employed to sample products coming off an assembly line. From such sampling the excellence or inferiority of all the products could be assumed with a high degree of confidence. Other uses for random number generators include the testing of computers and other data correlating instruments. In all such tests, it is extremely important that a continuously fresh supply of random numbers be provided so that no prior sequence of random numbers will be repeated.

Bearing the above in mind, it is a primary object of

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the present invention to provide a greatly improved random signal generator which will produce random numbers ranging from one to forty, for example, at a rate of approximately ten per second.

5 More particularly, objects of the present invention are to provide a random number generator of the above type in which rectangular, normal, bi-modal, cascading and decaying random distribution functions as well as others may be readily provided.

10 These and other objects and advantages of the present invention are attained generally by providing a peg board having a plurality of rows of pegs in staggered array such that the pegs of a given row fall below the midpoint of the intervals between the pegs in the row above. A ball reservoir capable of holding a hundred or so steel balls of given diameter and of substantially identical characteristics is provided above the top edge of the peg board and includes a row of release gates uniformly spaced along the top edge of the board. Preferably, the number of release gates corresponds to the number of pegs in the topmost row, each of the release gates being positioned correspondingly above respective pegs.

A ball receiver including a row of ball collectors is provided along the bottom edge of the peg board, the number of collectors being equal to the number of release gates and correspondingly positioned from a side edge of the peg board such that in the absence of the staggered array of pegs, a ball released from any one of the release gates will drop into the correspondingly positioned ball collector directly below such gate. A ball lift means is provided to transport balls from the ball receiver to the ball reservoir. Upon release of a ball from any one of the release gates, it will traverse the pegs under the influence of gravity to be received randomly in one of the ball collectors. The path of the balls past the pegs constitute random courses as a result of random collisions with the pegs.

An individual responsive means is associated with each of the ball collectors. In one embodiment of the invention, the responsive means in each collector is arranged to actuate the corresponding release gate directly above such collector so that upon reception of a ball, the release gate immediately releases another ball at the upper edge of the board, which ball in turn will progress through the peg array. In this manner, a re-entrant field is provided and the effect is the same as though the peg board were infinitely long.

Signal generating means are respectively connected to the individual responsive means associated with each collector whereby random signals will be generated corresponding to the random reception of balls in the collectors. By varying the connections between the individual responsive means and the release gates, various types of random distributions may be obtained. The invention also includes blocking means such that upon reception of a ball in any one collector the signal generating means connected to the remaining collectors are temporarily disabled. Thus, upon sampling the individual responsive means for obtaining random signals at periodic intervals, the likelihood of simultaneously received balls generating simultaneous signals is prevented.

A better understanding of the invention and its versatility will be had by referring to the accompanying drawings in which:

Figure 1 is a schematic view partly in block form showing the essential elements of the invention; and,

Figure 2 is a detailed circuit diagram of the various components within the block 13 of Figure 1.

Referring first to Figure 1, there is shown a peg board 10 supporting a plurality of pegs 11 arranged in horizontally staggered rows such that the pegs in any given row fall below the midpoint of the intervals between the pegs

in the row above. Only five such rows of pegs are shown, each row containing five or six pegs. In an actual embodiment of the invention, there are provided forty rows of pegs, each row containing forty pegs uniformly spaced in a horizontal line, alternate rows being staggered as described. For purposes of clarity, the invention will be described with respect to only five rows of five pegs each, it being understood that many more rows and pegs as well as associated components are provided in the actual machine.

Above the top edge of the pegboard 10 there is schematically indicated by the dotted line a ball reservoir 12 including a row of release gates G-1, G-2, G-3, G-4, and G-5 corresponding in number to the number of pegs in the uppermost row and positioned directly above corresponding pegs. Each of the release gates is arranged to release one ball from the reservoir 12 upon reception of a signal in the corresponding gate conductor terminal jack indicated respectively at 1, 2, 3, 4, and 5.

Below the bottom edge of the pegboard 10 there is disposed a ball receiver indicated by the dotted line block 13 including a row of uniformly spaced ball collectors C-1, C-2, C-3, C-4, and C-5. These collectors are equal in number to the release gates and are correspondingly uniformly spaced in position from the left side of the pegboard 10 such that in the absence of the staggered array of pegs a ball released from any one of the release gates will be received in the corresponding ball collector directly therebelow. As indicated by blocks, there are associated with each of the collectors individual responsive contact means 1', 2', 3', 4', and 5' together with suitable blocking and signal generating contact means 1'', 2'', 3'', 4'', and 5''. A ball lift means indicated schematically by the arrows 14, serves to transport balls received in the receiver 13 to the reservoir 12.

The various individual responsive contact means 1', 2', 3', 4', and 5' are arranged to complete a power connection to corresponding jacks a, b, c, d, and e through conductors which are shown leading into the block 13.

Figure 2 illustrates the detail circuitry represented by the blocks within the dashed line 13 of Figure 1. As shown in Figure 2, a voltage line 15 is connected to the individual contacts 1', 2', 3', 4', and 5' in parallel. Voltage line 15 in turn branches from a power line 16 supplied from a voltage source E, of 28 volts, for example, connected to an input terminal 17. Each contact is arranged to be closed, momentarily, upon reception of a ball in the particular collector of Figure 1 associated with such contact, to supply 28 volts to a corresponding collector jack terminal a, b, c, d, or e, positioned under the corresponding gate jacks 1, 2, 3, 4, and 5 of Figure 1.

The blocking and signal generating contact means 1'', 2'', 3'', 4'', and 5'' are illustrated in Figure 2 in position to connect the upper ends of a plurality of relay coils Ra, Rb, Rc, Rd, and Re to ground whereby upon reception of a ball in any one collector, the corresponding blocking and signal generating contact means will be momentarily closed, grounding the upper end of the corresponding relay. Electrical energy is supplied to the lower ends of the relays Ra through Re from the power line 16 through a series of blocking switch arms Ba, Bb, Bc, Bd, and Be, a branch lead 18 and a double series of holding switch arms He, Me; Hd Md; Hc, Mc; Hb, Mb; and Ha.

A series of recording circuits P-1, P-2, P-3, P-4 and P-5 are provided as shown and include input terminals arranged to be engaged respectively by the switch arms Ba through Be upon actuation. Thus, when any one of these switch arms is actuated by its corresponding relay coil voltage is blocked from the power line 16 to the lower ends of the other relays Ra through Re and this voltage is supplied to a corresponding input terminal of one of the recording circuits associated with the energized relay coil. Each of the output terminals from the

recording circuits is grounded such as shown at 19, for example, for the recorder P-1.

The various holding switch arms Ha through He are arranged upon actuation to engage a corresponding terminal connected to a common voltage line 20 connected through a synchronous timer 21 to the power line 16 as shown. Simultaneously, the switch arms Mb through Me, upon actuation, prevent power from the line 20 from passing to any other relay except the one energized. Finally, there are provided locking switch arms La, Lb, Lc, Ld, and Le, also arranged to be actuated by the relay coils Ra through Re serving to lock any one of the corresponding relay coils in energized position after the corresponding contacts 1'' through 5'' are open as a result of a ball having already passed therethrough.

Referring again to Figure 1, the arrangement of the gate jacks 1 through 5 and the collector jacks a through e are such that various combinational connections of the two may be effected by means of suitable jumper conductors such as the jumper 22.

As an example of the operation of the random number generator of this invention, assume it is desired to provide a continuous output of random numbers having a rectangular distribution. For example, considering the digits 1, 2, 3, 4, and 5, the recorders P-1, P-2, P-3, P-4, and P-5 would be arranged upon energization to print the digit corresponding to the number of the particular recorder. For a rectangular distribution, jumpers 22 are employed to connect the gate jack 1 to the collector jack a, the gate jack 2 to the collector jack b, the gate jack 3 to the collector jack c, the gate jack 4 to the collector jack d, and the gate jack 5 to the collector jack e.

To start the machine, one or more of the release gates G-1 through G-5 may be manually opened to release a ball.

Upon manual actuation of one of the release gates such as the gate G-2, for example, one of the steel balls 23 will traverse the staggered array of pegs along a random course or path 24, the ball making random collisions with the various pegs such that it may fall into any one of the five collectors spaced below the bottom edge of the pegboard. Assume that the ball 23 falls in collector C-4. The ball will then momentarily close the contacts 4'. Referring to Figure 2, closing of these contacts will supply voltage from the power line 16 to the collector jack d and thence to the gate jack 4 and gate G-4 to release a ball.

Because of the direct connection of the jack d to the jack 4, and because the gates and collectors are in space correspondence, the ball released from G-4 will be in a position directly above the collector C-4. Thus, in a manner of speaking, the new ball released from the gate G-4 may be considered the same as the ball 23 received in the collector C-4 traversing down an extension of the pegboard 10. Now, assume that the ball from G-4, after following a random course as a result of random collisions with the pegs, falls in the collector C-1. In this event, the contacts 1' will be momentarily closed to supply a voltage signal to the collector jack a and thence to the gate jack 1 to release a ball from the gate G-1. This ball will start at the top of the pegboard at the corresponding position that the previous ball left the bottom of the pegboard and will in turn progress through the peg array and randomly be received in one of the collectors. This process will continue indefinitely. In the event several balls are simultaneously released, as would preferably be the case for obtaining a rectangular random distribution, there may be a hundred or so balls within the peg array at all times. These balls may make random collisions with each other as well as with the pegs.

Following the above example further, it will be noted that when the ball 23 is first received in the collector C-4, after the contacts 4' are closed, the ball will progress downwardly to close the contacts 4'' thereby ener-

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gizing the relay *Rd*. Upon energization of the relay *Rd* the switch arms *Bd*, *Ld*, *Hd*, and *Md* will be simultaneously actuated to the dotted line positions. Movement of the switch arm *Bd* to the input of the recorder P-4 will simultaneously break the voltage supplied to the relay coils through the various switch arms *Ba* through *Be*, branch lead 18, and the switch arms *Ha*, and *Hb*, *Mb* through *He*, *Me* whereby none of the other relays can be energized. This movement of the switch arm *Bd* to the input of the recorder P-4 will apply voltage from the power line 16 through the recorder to ground and cause the number 4 to be printed.

The movement of switch arm *Ld* to its closed position serves to ground the upper end of the relay *Rd* and the simultaneous movement of the holding switch arm *Hd* to the terminal on the voltage line 20 serves to provide voltage to only the relay *Rd* whereby the relay *Rd* is locked in its energized position. The simultaneous movement of switch arm *Md* to the open terminal blocks voltage from line 20 and switch arm *Md* from passing to the coils *Rc*, *Rb*, and *Ra* thus rendering these coils inactive. Therefore, even after the ball leaves the contacts 4", the relay *Rd* will remain energized and balls received subsequently in any of the other collectors will not operate the signal generating means. However, these balls will still operate the various gates to maintain balls in the peg field as described above.

The synchronous clock 21 is arranged to periodically break the connection so that voltage is removed from this line after one of the recorders has printed a digit. Thus, assuming it is desired to obtain digits at the rate of perhaps one a second, the synchronous clock 21 may be arranged to break the circuit 20 at the rate of once a second. During the "on" time of the clock 21 in which voltage is applied to the voltage line 20, the particular collector within which there is received a ball will operate whereby one of the digits 1 through 5 will appear on one of the recorders. Subsequent removal of power from the voltage line 20 will de-energize the particular relay under consideration so that its switch arms will return to their normal positions as indicated in solid lines in the drawing. Thus, in the example when the ball 23 is received in the collector C-4, a read-out of the digit 4 will be obtained. Subsequent momentary removal of the voltage from the voltage line 20 by the clock will then release the relay *Rd* such that the switch arms *Bd*, *Ld*, *Hd*, and *Md* return to their normal position illustrated in solid lines. Voltage is then returned to the line 20 by the clock 21 immediately after release of the relay. Upon subsequent reception of a ball in the collector C-1, as described above, after closing of the contacts 1', the ball will close the contacts 1" to energize the relay *Ra*. Energization of the relay *Ra* will throw switch arms *La* and *Ha* to lock the relay *Ra* in energized position and simultaneously remove the voltage applied to the other relays by throwing of the switch arm *Ba* in a manner analogous to that described in connection with the relay *Rd*. Movement of the switch arm *Ba* to the input terminal of the recorder P-1 will thence print the digit 1. Since relay *Ra* is not preceded by any other relay a second blocking switch arm corresponding to switch arms *Mb* through *Me* is not necessary.

It will thus be seen that during each time the voltage line 20 is energized one digit will be printed on a corresponding recorder. The various printed digits are quite random inasmuch as the reception of the balls in the various collectors is random.

With the particular connections described above, a rectangular random distribution will ordinarily be obtained. Thus, in the schematic illustration taken for purposes of explanation, this type distribution means that any one of the digits 1 through 5 will be as likely to be recorded as any other. As mentioned heretofore, in actual practice there will be many more pegs and re-

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corders and a corresponding numbers of gate releases and collectors such that many more than five different random numbers may be obtained.

Suppose now it is desired to obtain a normal distribution of random numbers. In this event, all of the collector jacks *a*, *b*, *c*, *d*, and *e* would be connected to gate jack 3 to actuate the center gate G-3 on top of the peg board. Thus, regardless of the particular collector in which a ball is received, the reception of such a ball will always actuate only release gate G-3 so that a ball will always be supplied from the center top portion of the board. As a result of these interconnections between the collector jacks and the gate jack, the random numbers produced will tend to bunch about the digit 3, the numbers 1 and 5 appearing less frequent.

As another example of the possible random number distributions that may be obtained, assume a bi-modal distribution is desired in which the numbers tend to congregate about two particular integers so that a double humped curve is provided. In order to achieve this end, the odd numbered collectors C-1, C-3, and C-5, for example, may have their corresponding collector jacks *a*, *c*, and *e* connected to gate jack 2 while the even numbered collectors C-2 and C-4 may have their corresponding collector jacks *b* and *d* connected to the gate jack 4. Thus, balls will be released from the left hand and right hand portions of the peg board and not from the center portion whereby the random collections of balls will occur more often in those collectors positioned to the left and right of the board whereby a double humped distribution curve will be obtained. It should be understood, of course, that in an actual embodiment, wherein perhaps 40 gate and 40 collector jacks are available, the much larger numbers of connections made will insure that the bi-modal humps will be substantially symmetrical.

Still another possibility is to provide a means of investigating cascading events. In order to provide a cascading or ever increasing output, each collector jack may be connected to two gate jacks. For example, collector jacks *a* and *b* could each be connected to both the gate jacks 1 and 2, the collector jacks *c* and *d* each connected to both the gate jacks 3 and 4 and the collector jack *e* connected to the gate jack 5. In this manner, reception of a ball in any one collector will result in the release of two balls at the upper end of the board with the exception of the last jack in the row. Upon reception of each of these two balls in two collectors, four balls will be released at the upper end of the board and there will thus be provided a cascading series of random signals generated.

In the same manner, decading series of events may be provided by initially rendering all of the gates active to release balls periodically and at a constant frequency. Upon reception of the balls in the collectors, the corresponding signals would be employed to render one of the gates inoperative. Thus, as more balls are received, more gates are rendered inactive and less balls are released from the top. The events taking place will, therefore, decade until all of the gates are closed off.

Various other configurations may be worked out by suitable cross connections between the collector jacks and the gate jacks. In the event that no ball is received during the period of time that the synchronous clock 21 is applying voltage to the voltage line 20, the event could be interpreted as a zero digit. Ordinarily, the period of time that the synchronous clock provides voltage on the line 20 is always sufficiently long to insure that at least one ball will be received.

In the preferred embodiment of the present invention, there are provided forty rows of forty pegs each together with forty sets of gates, collectors, relays *R*, and corresponding switch arms such that random numbers from 1 to 40 may be provided at approximately the rate of 10 per second. The number of balls employed in the peg

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field may be varied considerably. By employing a relatively large number of balls, and sampling the circuit with the clock 21 at a greater frequency, an increased rate of random number output may be obtained. Further, random numbers of two, three, or more digits may be obtained by simply grouping the connections to provide, in effect, a series of independent random generators each operating in accordance with the principles set forth herein.

Various other modifications within the scope and spirit of the present invention will occur to those skilled in the art. The random number generator is, therefore, not to be thought of as limited to the one embodiment disclosed for illustrative purposes.

What is claimed is:

1. A random signal generator comprising, in combination: a plurality of pegs; means supporting said pegs in a staggered array; a ball reservoir including a row of individual ball release gates uniformly distributed and sequentially numbered along the top edge of said staggered array; a ball receiver including a row of individual ball collectors, equal in number to the number of release gates, uniformly distributed and similarly sequentially numbered along the bottom row of said staggered array in positions corresponding to the positions of said release gates such that a ball released from any one particularly numbered release gate will be received only in the correspondingly numbered ball collector in the absence of said staggered array; a plurality of balls in said release gates which, upon release, transverse said pegs under the influence of gravity to be randomly received in said ball collectors, the paths of said balls past said pegs constituting random courses as a result of random collisions with said pegs; individual responsive means associated with each ball collector for actuating said release gates to release automatically balls from said release gates; and means responsive to the random reception of balls in said ball collectors to provide corresponding random signals.

2. A random signal generator comprising, in combination: a plurality of pegs; means supporting said pegs in a staggered array; a ball reservoir including a row of individual ball release gates along the top edge of said staggered array; a ball receiver including a row of individual ball collectors along the bottom row of said staggered array in positions such that a ball released from any one particular release gate will be received only in a particular ball collector in the absence of said staggered array; a plurality of balls in said ball release gates which, upon release, transverse said pegs under the influence of gravity to be randomly received in said ball collectors, the paths of said balls past said pegs constituting random courses as a result of random collisions with said pegs; individual responsive means associated with each ball collector for actuating said release gates in response to the random reception of balls in said ball collectors to release automatically balls from said release gates; and means responsive to the random reception of balls in said ball collectors to provide corresponding random signals.

3. A generator according to claim 1, in which the individual responsive means associated with any one numbered collector is connected to actuate only that correspondingly numbered release gate whereby a substantially rectangular random signal distribution is provided.

4. A generator according to claim 1, in which all of said individual responsive means are connected to actuate only that release gate positioned halfway between the ends of said row of individual ball release gates, whereby a normal random signal distribution is provided.

5. A generator according to claim 1, in which the individual responsive means in all odd numbered collectors are connected to actuate a release gate at the center of one half of said release gates and the individual responsive means in all even numbered collectors are connected to actuate a release gate at the center of the

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other half of said release gates, the half portions of said release gates being defined by a dividing line passing through the center of said row of individual release gates whereby a bi-modal signal distribution is provided.

6. A generator according to claim 1, in which each of said individual responsive means is connected to actuate at least two of said release gates simultaneously, whereby said random signals cascade.

7. A generator according to claim 1, in which each of said individual responsive means is connected to render inoperative at least one of said release gates whereby the number of said random signals per unit of time automatically decreases.

8. A generator according to claim 1, in which said second means includes individual blocking and signal generating means coupled to each collector, each blocking and signal generating means being responsive to reception of a ball in its corresponding collector to temporarily render inactive each of said other blocking and signal generating means whereby only one signal is provided at a time.

9. A generator according to claim 8, including means for periodically removing energy supplied to said blocking and signal generating means to de-energize that blocking and signal generating means rendering inactive each of said other blocking and signal generating means, whereby after said one signal is provided all of said blocking and signal generating means are placed in condition for subsequent actuation.

10. A random signal generator comprising, in combination: a peg board; a plurality of pegs supported by said board in horizontally staggered rows such that the pegs of a given row fall below the midpoints of the intervals between the pegs in the row above; a ball reservoir comprising a row of uniformly spaced ball release gates positioned along a top edge of said board, the spacing between said release gates corresponding to the spacing between the pegs in the top row so that the total number of release gates equal the number of pegs in said top row of said peg board; a ball receiver comprising a row of uniformly spaced ball collectors positioned along the bottom edge of said board, the number of said collectors being equal to the number of said release gates and occupying corresponding space positions as measured from one side edge of said peg board; a plurality of balls in said reservoir which, upon release by said release gates, transverse said pegs under the influence of gravity to be randomly received in said ball collectors, the paths of said balls past said pegs constituting random courses as a result of random collisions with said pegs; individual responsive means coupled to each of said ball collectors and connected to actuate said release gates automatically upon reception of balls in said collectors; and blocking and signal generating means individually coupled to each of said collectors and responsive to reception of a ball in its corresponding collector to temporarily render inactive each of said other blocking and signal generating means to provide a random signal corresponding to any one random reception of said balls in said collectors.

11. A generator according to claim 10, including means for periodically removing energy supplied to said blocking and signal generating means to de-energize that blocking and signal generating means rendering inactive each of said other blocking and signal generating means, whereby after said one signal is provided all of said blocking and signal generating means are placed in condition for subsequent actuation.

12. A random signal generator comprising, in combination: a reservoir for holding a plurality of substantially identical objects; individual release means connected to said reservoir and serially arranged along a line to release individually said objects from said reservoir at different spatial positions from a given reference point; a corresponding number of individual collector means

serially arranged along a line in spatial positions corresponding to the spatial positions of said release means to receive individually said objects from said release means; a receiver connected to all of said collector means for receiving objects therefrom; obstruction means disposed between said release means and said collector means interrupting the free movement of said objects while they are progressing from said release means to said collector means; means for continuously recirculating said objects from said receiver to said reservoir; means connected between each of said release means and its corresponding spatially positioned collector means responsive to reception of one of said objects in said corresponding collector means to release automatically another of said objects from the corresponding release means whereby a re-

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entrance arrangement is automatically provided; and signal means responsive to reception of any one object in any one collector for providing a signal characteristic of only that one collector.

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