June 28, 1949. H. LYONS 2,474,266

STEP WAVE GENERATOR

Filed May 22, 1945 3 Sheets-Sheet 1

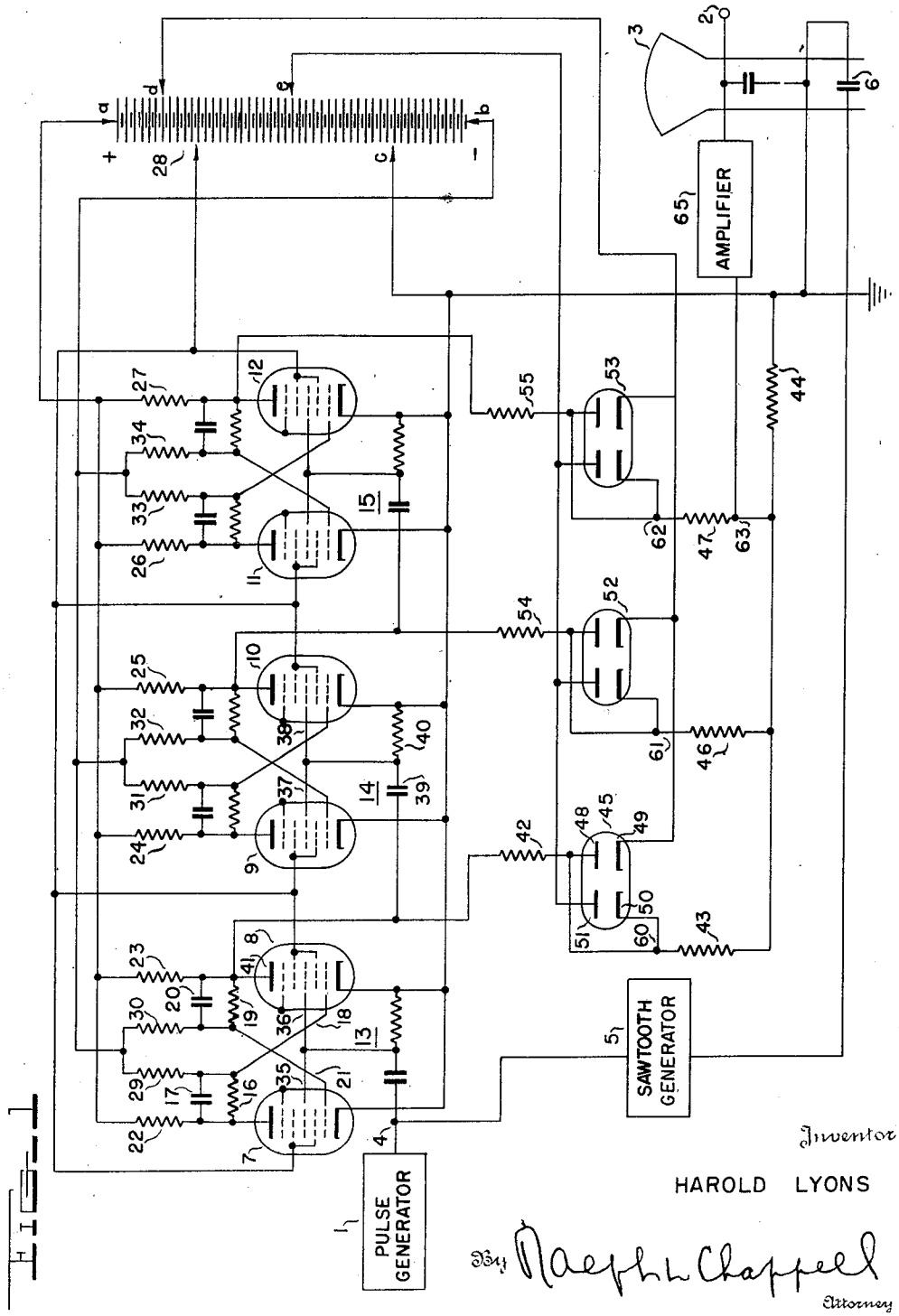


FIG. 1

Inventor

HAROLD LYONS

By Ralph W. Chappell

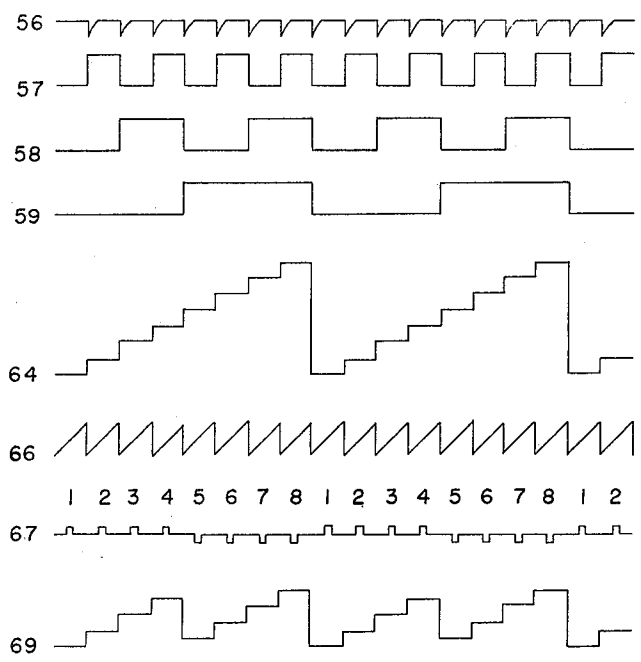
Attorney

June 28, 1949. H. LYONS 2,474,266

STEP WAVE GENERATOR

Filed May 22, 1945 3 Sheets-Sheet 2

FIG. 2



Inventor

HAROLD LYONS

By Ralph L. Chappell

Attorney

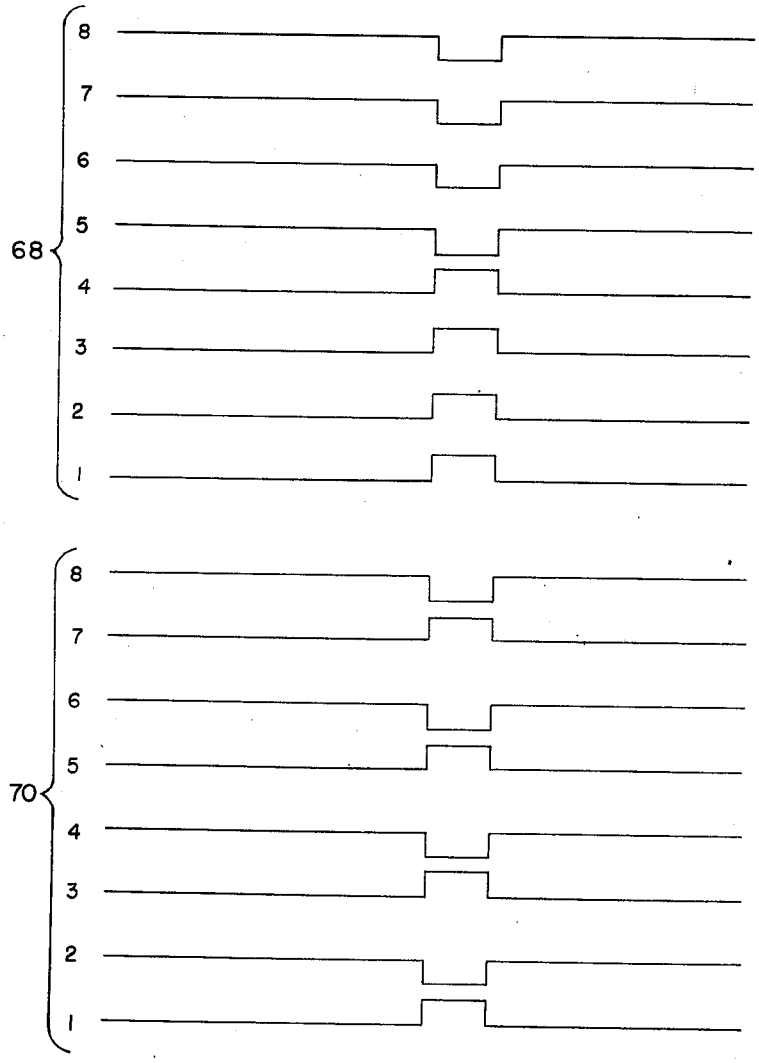
June 28, 1949. H. LYONS 2,474,266

STEP WAVE GENERATOR

Filed May 22, 1945

3 Sheets-Sheet 3

FIG. 3



Inventor

HAROLD LYONS

By Ralph L. Chappell

Attorney

Patented June 28, 1949 2,474,266

UNITED STATES PATENT OFFICE

2,474,266

STEP WAVE GENERATOR

Harold Lyons, Washington, D. C.

Application May 22, 1945, Serial No. 595,221

7 Claims. (Cl. 315—24)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

1

This invention relates in general to electronic control circuits and in particular to an electronic step wave generator.

It is frequently necessary in electronic devices, and particularly in radar, television and other devices employing cathode ray tubes, to utilize auxiliary circuit components which function, in synchronism with related circuits, to provide potentials which vary in a difinite predetermined manner with respect to time. The conventional sawtooth generator, providing a potential which varies in a substantially linear manner with respect to time and which finds wide use as a time base for oscilloscope work, is an example of this. Another example is the driven multivibrator which, in response to synchronizing pulses, operates to produce as its output a pontential which varies between the two levels which correspond to the two states of the circuit. The output of such a multivibrator, when viewed on an oscilloscope takes the form of a rectangular waveform with the voltage variations in the form of steps corresponding to the rapid transition from one state to the other and back again. The output of a multivibrator may be applied to the vertical deflecting plates of a cathode ray tube in synchronism with the output of a sawtooth generator applied to the horizontal plates in such a manner that alternate horizontal excursions of the beam appear at different levels on the face of the tube. Such a sweep arrangement permits the simultaneous visual examination of two different wave forms. If it becomes necessary to view wave forms on more than two levels of electron beam deflection, the multivibrator will not serve since it provides only two voltage levels. As in television work, a sawtooth voltage generator operating at a submultiple of the sawtooth generator whose output is applied to the horizontal deflecting plates may be applied to the vertical deflecting plates. While this provides a plurality of wave form examination levels, it has the disadvantage that the levels are themselves changing during the horizontal sweeps. In television, where intensity modulation may be employed, this linear change in level is not objectionable. If, however, signals are applied to the vertical plates in the usual manner to cause beam deflection proportional to the amplitude of the signal, the angle between the horizontal sweep trace and a line drawn through the position of the beam at any instant and through the position which would be assumed by the beam in the absence of the signal is not 90°. In order to secure such a 90° angle, it is necessary that, during each horizontal

2

sweep, the potential applied to the vertical plates remain constant. The need, therefore, is for a voltage generator the output of which varies in definite steps but which between such steps, remains constant during a horizontal sweep trace.

It is an object of this invention to provide an electronic step wave generator.

It is another object of this invention to provide an electronic generator the output of which varies between a plurality of constant pontential or current levels in a predetermined manner.

It is another object of this invention to provide an electronic circuit which has a plurality of stable states which may be called into being in a predetermined order by the application of signals from an external source and which presents, at its point of output, a different constant electrical condition corresponding to each stable state.

Other objects and features of this invention will become apparent upon a careful consideration of the following detailed description, when taken together with the accompanying drawings in which:

Fig. 1 is the diagram of one embodiment of this invention partly in block form and partly in circuit form;

Fig. 2 is a series of wave forms found useful in the explanation of the embodiment shown in Fig. 1; and

Fig. 3 is an oscillographic representation useful in explaining the operation of the embodiment of Fig. 1.

Reference is now had in particular to Fig. 1 wherein there is shown one form of a step wave generator constructed according to the teachings of this invention. Pulse generator 1, which may be constructed in any one of the various ways well known to the art and which may be either free running or driven synchronously by the same signals as are applied at input 2 of cathode ray tube 3, produces sharp negative pulses at its output 4. These sharp negative pulses serve as triggering signals to sawtooth generator 5, which in response to each such triggering signal, applies to horizontal deflecting plate 6 of cathode ray tube 3 a potential which varies in a substantially linear fashion with time. In this way the electron beam is swept horizontally across the face of cathode ray tube 3 each time a negative pulse appears at output 4 of pulse generator 1. Any electrical signal applied at input terminals 2 causes a vertical deflection of the beam during its horizontal sweep proportional to the magnitude of such electrical signal. The variation of

such electrical signals with respect to time may therefore be examined in the usual oscillographic manner.

Tubes 7, 8, 9, 10, 11 and 12 represent the multi-grid vacuum tube components of a scale-of-eight type of electronic counter circuit. This circuit comprises three conventional type of scale-of-two counter stages 13, 14 and 15, connected in cascade. The first stage 13 consists of multi-grid vacuum tubes 7 and 8, connected so that the output from tube 7 is coupled through resistance 16 shunted by capacitor 17 to first control grid 18 of tube 8, while the output of tube 8 is coupled through resistance 19 shunted by capacitor 20 to first control grid 21 of tube 7. In the second counter stage 14, which consists of tubes 9 and 10, and third counter stage 15, which consists of tubes 11 and 12, the corresponding tube elements are connected in the same manner as in first stage 13. In this way, each stage is directly connected in a regenerative manner so that one tube in each stage will be conducting and the other tube non-conducting and in which condition the stage will remain until it receives some small electrical disturbance. Whereupon, this disturbance will be regeneratively amplified until the conditions of the stages are reversed. The plate of each tube of the counter circuit is connected through a respective resistanc 22, 23, 24, 25, 26 and 27 to a positive point, designated as *a*, on supply battery 28, while the first control grids of the tubes are connected through respective resistances 30, 29, 32, 31, 34 and 33 to a negative point *b* on the same battery. The input to first stage 13 is derived from pulse generator 1 and applied in parallel to second control grids 35 and 36, while the input to second stage 14 is obtained from plate 41 of tube 8 and applied in parallel to second control grids 37 and 38 of tubes 9 and 10 through a low time constant coupling circuit consisting of condenser 39 and resistance 40. The function of this coupling circuit is to apply to second control grids 37 and 38 of second stage 14 a negative pulse each time tube 8 passes from non-conduction to conduction and a positive pulse each time it passes from conduction to non-conduction. Likewise third stage 15 receives its input from the plate of tube 10 through a low time constant coupling circuit which has a similar function to that connecting stage 14 to stage 13.

By constructing a counter circuit with multi-grid tubes arranged as shown, each stage is made to respond only when a negative impulse is applied to its second control grids and an input of two negative pulses to each stage is required to cause that stage to complete its cycle. This cycle results in impressing but a single negative pulse on the succeeding stage so that the circuit, in effect, "counts down." The count down factor of a single stage counter is two, inasmuch as two negative input pulses are required to produce a single output pulse. Similarly, a two stage counter produces one output pulse for every four input pulses and thereby yields a count down factor of four. A three stage counter yields a count down factor of eight and, in general, a counter having m stages yields a count down factor of $2m$. In a multi-stage counter, the first stage has a count down factor of two, the second stage a factor of four, the third stage a factor of eight, the fourth a factor of sixteen, etc.

In the embodiment shown, a total of eight negative impulses is required at input 4 to cause the three stage counter circuit to pass through a complete cycle of operation. Each of such eight

negative pulses calls into being a different state within the counter circuit, in which each such state is distinguished by the particular tubes which are conducting and the particular tubes which are non-conducting.

Subject only to the limitation that one tube in each stage 13, 14 and 15 must be conducting and the other non-conducting, any combination of conducting and non-conducting tubes may exist until a triggering pulse is applied at input 4 which changes the combination and hence the state. The plate potential of the non-conducting tubes will be at some voltage substantially equal to the potential at tap *a* on supply battery 28, while the plate potential of the conducting tubes will be at some voltage substantially equal to ground as at *c* on battery 28. Thus, as a tube passes from conduction to non-conduction its plate voltage will vary from *c* to *a*.

Serially connected from plate 41 of tube 8 to ground potential *c* are current limiting resistor 42, resistor 43 and resistor 44. Were it not for the parallel connections to limiting double diode 45 and resistors 46 and 47, the difference of potential existing between plate 41 and ground would be distributed according to the relative sizes of resistors 42, 43 and 44. The function of parallel connected double diode 45, however, is to establish both the highest and lowest potentials which can exist at juncture 60 of resistance 42 and resistance 43. When tube 8 is non-conducting and plate 41 is at potential *a*, plate 48 of diode 45 tends to rise to some point above potential *d* of battery 28 by virtue of the voltage divider action of resistance 42, 43 and 44. Cathode 49 is so connected to potential *d* and the resistance of diode 45 is so low when conducting that the highest potential to which plate 48 can rise is substantially *d*. Likewise, when tube 8 is conducting and plate 41 is at ground potential *c*, cathode 50 of diode 45 tends to drop to ground also. Plate 51 is so connected to positive potential *e*, however, that the lowest potential to which cathode 50 can drop is substantially *e*. This double limiting action of diode 45 thereby causes the potential at juncture 60 of resistance 42 and resistance 43 to change from potential level *d* to *e* as tube 8 goes from non-conduction to conduction and back from *e* to *d* when tube 8 goes from conduction to non-conduction. Diodes 52 and 53 are similarly disposed with respect to serially connected resistors 54, 46 and 44 and serially connected resistors 55, 47 and 44 so that juncture 61 of resistors 54 and 46 and juncture 62 of resistors 55 and 47 also change in potential from *d* to *e* and back again as tubes 10 and 12 to which they are connected change condition.

In Fig. 2, wave form 56 is representative of the negative pulse output of pulse generator 1 applied in parallel to the counter circuit and the sawtooth generator 5. The variations in potential of plate 41 as it alternates between conduction and non-conduction in response to the negative pulse input at 4 are represented by wave form 57. Wave form 58 is representative of the voltages existing at the plate of tube 10 and wave form 59 is representative of the voltages existing at the plate of tube 12 during the same interval of time. When taken as representative of the counter tube plate voltages, the upper potential level of these wave forms corresponds to potential *a* and the lower level corresponds to potential *c*. Wave forms 57, 58 and 59 are also representative of the diode limited potentials appearing respectively at the junctures 60, 61

and 62. When taken in this latter sense, the upper potential level corresponds to potential *d* and the lower level corresponds to potential *e*.

For purposes of illustration, assume that resistance 43 is so chosen that it is two times the magnitude of resistance 46 and four times the magnitude of resistance 47. In this way, an eight step wave is generated at point 63, all steps of which are equal, in a manner which is explained in the following paragraphs.

So as to provide a starting point in time, let it be assumed that the counter is in the one of its eight states in which tubes 8, 10 and 12 are all conducting. This corresponds to the condition existing just prior to the arrival of the first pulse of wave form 56. Points 60, 61 and 62 are all at potential *e* and the potential existing at point 63 is the lowest which can exist during any of the eight counter states. With potential *d* chosen as five times potential *e* and resistor 44 chosen as equal to resistor 47, the potential existing at point 63 is $\frac{7}{11}$ of *e*. Upon the arrival of the first pulse of wave form 56 at input 4, tube 7 is rendered conducting and tube 8 is rendered non-conducting while stages 14 and 15 are unaffected. Point 60 therefore rises to potential *d* while points 61 and 62 remain at *e*. With the voltages and resistance values described above and under the conditions of voltages at 60, 61 and 62 just described, the potential at point 63 rises to *e*, an increase of $\frac{4}{11}$ *e*. Upon the arrival of the second pulse of wave form 56 at input 4, tube 7 is rendered non-conducting and tube 8 is rendered conducting. At the same time, tube 9 is rendered conducting, tube 10 non-conducting, and stage 15 remains unaffected, all in the hereinbefore described manner of counter operation. Point 60 therefore returns to potential *e*, 61 rises to *d* and 62 remains at *e*. Under these conditions of voltage at 60, 61 and 62, the potential at point 63 again rises, this time to $\frac{15}{11}$ *e*, another increase of $\frac{4}{11}$ *e*. These uniform increases of $\frac{4}{11}$ *e* continue with each successive change of state of the counter circuit until the eighth negative pulse is applied at input 4. Upon application of this pulse, the counter returns to the original assumed starting condition and the process repeats itself as long as pulse generator 1 continues to operate. Wave form 64 is representative of the step-like wave form appearing at point 63 of the step wave generator. Each of the seven increases in potential is identical and the eight different potential levels correspond to the eight states of the counter circuit. This step wave form appearing at point 63, applied to amplifier 65 is amplified so as to cause suitable vertical deflection of the cathode ray beam corresponding to each potential level existing at point 63. Wave form 66 is representative of the sawtooth voltage applied to the horizontal deflecting plates of cathode ray tube 3 by sawtooth generator 5. Each linear increase in this wave form starts with a negative pulse from pulse generator 1 and ends with the succeeding negative pulse so that the frequency of sawtooth generator 5 is the same as that of pulse generator 1. The frequency of the sawtooth generator is also the same as the frequency of the change in vertical deflection level so that each horizontal beam sweep occurs at a different level until eight such horizontal sweeps have been made, at which time the process repeats itself in the same manner as the counter proceeds through a complete cycle of eight states and repeats itself.

Wave form 67 is representative of a signal applied at input 2 which is to be viewed on the face of cathode ray tube 3. It represents a pulse group wave train which has a group repetition frequency one-eighth that of pulse generator 1 so that individual signal pulses appear each time on the same horizontal trace level of cathode ray tube 3. The pattern as seen on the face of tube 3 would be that of oscillogram 68 of Fig. 3. It will be noted from 68 that, since each horizontal sweep is made at a potential which is constant during that sweep, the signals are oriented with respect to the sweep trace in the same manner as they are oriented with respect to the time base of the original pulse group signal, i. e., the angular displacement of the beam is 90° with respect to the horizontal sweep trace.

For certain applications, interlacing of multiple horizontal sweep traces is desirable. One manner in which interlineation is accomplished in the present invention is by proper choice of the resistance elements represented by resistances 43, 46 and 47 of Fig. 1. If, for example, resistor 47 be made two times the resistance of resistor 43 and four times the resistance of resistor 46, a simple type of interlineation results, which comprises superposing the last half cycle of signal 67 over the first half cycle. Wave form 69 of Fig. 2 is representative of the step wave thus generated and oscillogram 70 of Fig. 3 is the configuration given wave form 67 on the cathode ray tube face.

Various other changes may be made in the circuit of Fig. 1 for certain specialized operations without exceeding the teachings of this invention. For example, resistors 42, 54 and 55 may be connected to the plates of counter circuit tubes 7, 9 and 11 respectively, rather than to tubes 8, 10 and 12, and thereby produce at point 63 a step wave voltage which comprises a series of downward steps in lieu of the upward steps of wave form 64. Another example would be a choice of resistors 43, 46 and 47 such that the ratios of their values are not integral. In this case, non-uniform steps of the step wave form are produced. Still another example would be the removal of limiting diodes 45, 52 and 53 and resistors 42, 54 and 55. In such an event, points 60, 61 and 62 would alternate between levels *a* and *c* rather than *e* and *d*. This type of operation does not, however, provide the resolution quality provided by clipping the counter circuit plate variations by means of the diodes. Still another example would be the insertion of an inductance in series with resistance 44 between point 63 and ground for the purpose of "squaring up" the step wave. It will be apparent that the particular type of electronic counter employed in the circuit is not a limiting feature. The only basic requirement in this respect is that the counter employed provide one or more points which vary in a regular manner between two voltage levels. It will also be apparent that a counter of any scaling ratio above two may be used. For example, if a scale-of-32 rather than a scale-of-eight counter had been employed in the circuit of Fig. 1, 32 distinct horizontal sweeps could have been secured on the cathode ray tube face. The application of a step wave generator constructed according to the teachings of this invention is not limited to oscillographic presentation but may be extended to any field in which the characteristics of its output can be made to serve a useful purpose.

Since certain further changes may be made in the foregoing construction and different em-

bodiments of the invention may be made without department from the scope thereof, it is intended that all matter shown in the accompanying drawings or set forth in the accompanying specification shall be interpreted as illustrative and not in a limiting sense.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. The combination of, a counter circuit which is comprised of a plurality of stages arranged to form a counter of the scale of N variety, each of said stages being of the scale of two type, separate impedance means connecting a predetermined point in each of said counter stages to a common junction point, the predetermined point in each of said counter stages being one which alternates between two distinct voltage levels as the counter stages are caused to change electrical states, and a single impedance means connecting said junction point to a point of fixed potential, each of said impedance means being predeterminedly related in magnitude, with the magnitude of the impedance means connecting the first stage of the counter to said junction point being arbitrarily chosen and the magnitude of the remaining impedance means connecting each of the succeedent stages of the counter to said junction point being progressively smaller than the impedance means connecting said first stage to said junction point.

2. The combination of, a counter circuit which is comprised of a plurality of stages arranged to form a counter of the scale of N variety, each of said stages being of the scale of two type, separate resistance means connecting a predetermined point in each of said counter stages to a common junction point, the predetermined point in each of said counter stages being one which alternates between two distinct voltage levels as the counter stages are caused to change electrical states, and a single resistance means connecting said junction point to a point of fixed potential, the magnitude of the resistance means connecting the predetermined point in the first stage of said counter to said junction point being arbitrarily chosen, and the magnitude of the resistance means connecting each of the remaining stages to said junction point determined as the product of the ratio of the count down factor of said first stage to the count down factor of the stage under consideration times the resistance connecting said first stage to said junction point.

3. The combination of, a counter circuit which is comprised of a plurality of stages arranged to form a counter of the scale of N variety, each of said stages being of the scale of two type, separate resistance means connecting a predetermined point in each of said counter stages to a common junction point, the predetermined point in each of said counter stages being one which alternates between two distinct voltage levels as the counter stages are caused to change electrical states, separate vacuum tube means connected to each of the stages in said counter and arranged so as to control the voltage levels between which each of the stages will alternate, and a single resistance means connecting said junction point to a point of fixed potential, each of said resistance means being predeterminedly related in such a manner as to cause the voltage appearing across said last named resistance means to vary in a predetermined manner as said counter is driven through a cycle of operation.

4. The combination of, a counter circuit which is comprised of a plurality of stages arranged to form a counter of the scale of N variety, each of said stages being of the scale of two type, separate resistance means connecting a predetermined point in each of said counter stages to a common junction point, the predetermined point in each of said counter stages being one which alternates between two distinct voltage levels as the counter stages are caused to change electrical states, separate vacuum tube means connected to each of the stages in said counter and arranged so as to control the voltage levels between which each of the stages will alternate, and a single resistance means connecting said junction point to a point of fixed potential, the magnitude of the resistance means connecting the predetermined point in the first stage of said counter to said junction point being arbitrarily chosen, and the magnitude of the resistance means connecting each of the remaining stages to said junction point determined as the product of the ratio of the count down factor of said first stage to the count down factor of the stage under consideration times the resistance connecting said first stage to said junction point.

5. The combination of, a cathode ray tube, a beam deflection voltage generator connected to said cathode ray tube and adapted to deflect the electron beam thereof in one direction, a counter circuit which is comprised of a plurality of stages arranged to form a counter of the scale of N variety, each of said stages being of the scale of two type, a pulse source arranged to synchronously drive both said counter and said beam deflection generator, separate resistance means connecting a predetermined point in each of said counter stages to a common junction point, the predetermined point in each of said counter stages being one which alternates between two distinct voltage levels as the counter stages are caused to change electrical states, and a single resistance means connecting said junction point to a point of fixed potential, and means connecting said junction point to said cathode ray tube to deflect the electron beam thereof in a direction perpendicular to said one direction, each of said resistance means being predeterminedly related in such a manner as to cause the voltage appearing across said last named resistance means to vary in a predetermined manner as said counter is driven through a cycle of operation.

6. The combination of, a counter circuit which is comprised of a plurality of stages arranged to form a counter of the scale of N variety, each of said stages having a pair of vacuum tubes arranged in the form of a scale of two counter stage, separate resistance means connecting the plate of one of the tubes in each of said stages to a common junction point, and a single reistance means connecting said junction point to a point of fixed potential, each of said resistance means being predeterminedly related in magnitude, with the magnitude of the resistance means connecting the first stage of the counter to said junction point being arbitrarily chosen and the magnitude of the remaining resistance means connecting each succeedent stage of the counter to said junction point being progressively smaller than the resistance means connecting said first stage to said junction point.

7. The combination of a circuit arranged to

have a plurality of alternating potential points therein, the potential at each of said points alternating in harmonic relationship between two distinct potential levels, separate impedance means connecting each of said alternating potential points to a common junction point, a single impedance means connecting said junction point to a point of fixed potential, each of said impedance means being predeterminedly related in magnitude with the magnitude of the impedance means connecting the highest frequency point in said circuit to said junction point being arbitrarily chosen and the magnitude of the impedance means connecting each succeedent lower frequency point to said junction point being progressively smaller than the impedance means connecting the highest frequency point to said junction point.

HAROLD LYONS.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,284,101	Robins	May 26, 1942
2,402,372	Compton et al.	June 18, 1946
2,407,320	Miller	Sept. 10, 1946

OTHER REFERENCES

Review of Scientific Instruments, vol. 9, Mar. 1938, pp. 83–89.