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ELECTRONIC COUNTER CIRCUIT

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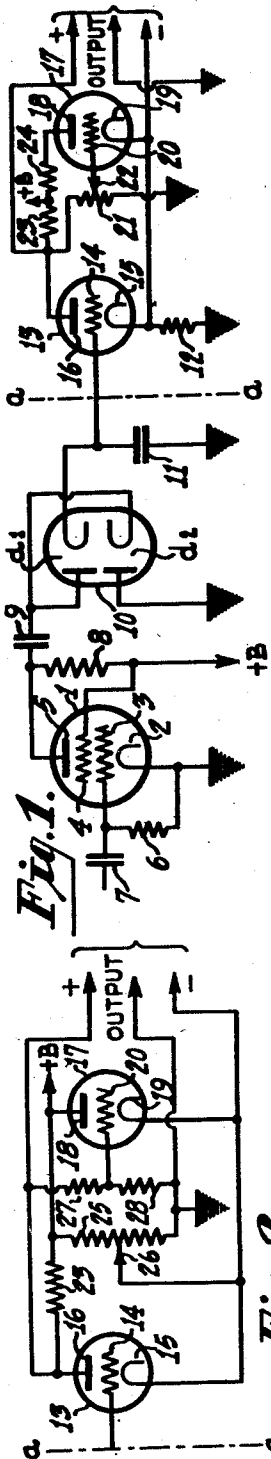


Fig. 2.

CRITICAL VOLTAGE ON CAPACITOR 11
TO WHICH TUBE 29 RESPONDS.

INITIAL VOLTAGE ON CAPACITOR 11

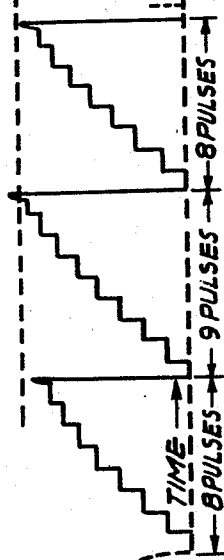


Fig. 4.

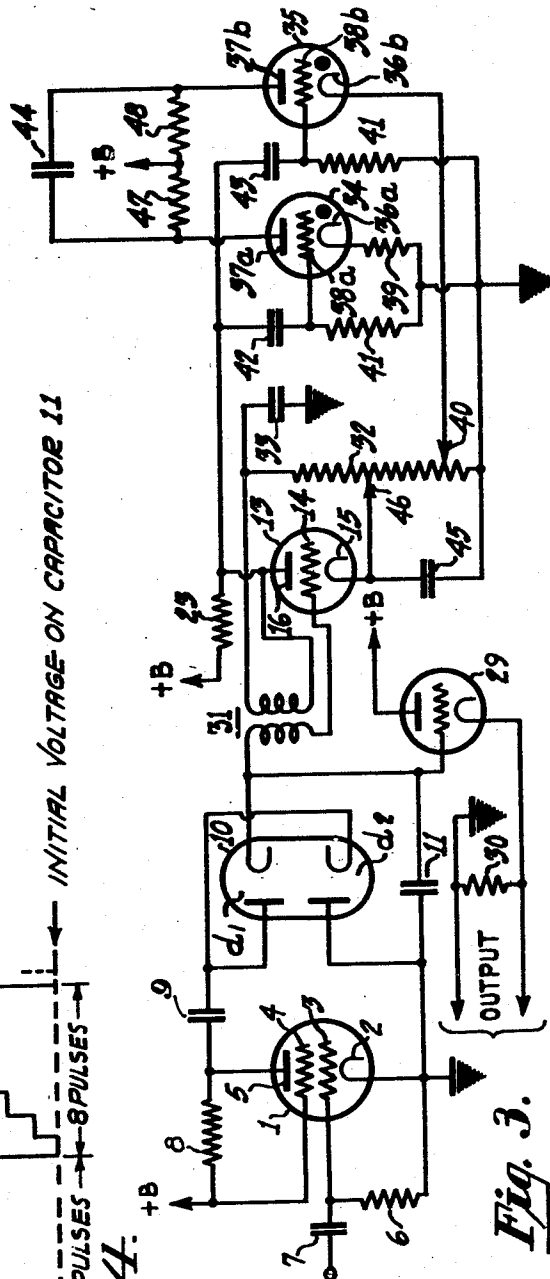


Fig. 3.

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ELECTRONIC COUNTER CIRCUIT

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This invention relates to electronic counter circuits and has particularly to do with the provision of a device of such character that it operates substantially as a frequency divider for delivering in an output circuit one pulse following a succession of input circuit pulses of any predetermined number.

Frequency dividers are well known in the art. These frequency dividers are often used for counting purposes. Difficulties have arisen in the past if it is attempted to count accurately a large number of pulses from a given source. When a counter is set up to divide by two, the tolerances of critical voltages in the circuit parameters are very great. For division by three, the tolerances are reduced. As the number of input pulses is increased, the tolerances are reduced more and more. Counts up to thirty or thirty-five have been obtained, but the tolerances have been so close that no dependence can be placed on the results. It has, therefore, been a practice to split the count into two or more stages. Thus a count of 50 might be obtained by first counting five pulses, and then in the second stage counting ten pulses. As another example, a count of 49 might be obtained in successive stages in which seven and seven are counted.

It is obvious that where two stages of counting are employed, the divisor used in each stage must be one of two factors of the number to be counted. Hence it would be impossible to count a prime number in this manner, i. e. in two steps or stages, since the number itself is unfactorable.

It is an object of my invention to provide an electronic circuit arrangement for frequency division or counting of pulses wherein the operation is substantially independent of frequency and may be controlled by pulses which are aperiodic.

It is another object of my invention to provide a system of the class described in which the counting of pulses is not adversely influenced by voltage variation within wide limits occurring in any of the circuit parameters.

It is another object of my invention to provide a system of the class described in which frequency division may be obtained by the use of a single stage possessing two alternate ratios of sub-division, whereby the units of a prime number of relatively high order may be counted, as well as any factorable number.

It is another object of my invention to provide an electronic counter which is substantially aperiodic in action.

It is still another object of my invention to provide an electronic counter for counting a rela-

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tively large but unfactorable number of pulses.

Again, it is an object of my invention to provide an electronic counter such that after counting a predetermined number of pulses in a given series, a different predetermined number of following impulses of that series may be counted, thus producing a summation of the two counts.

My invention will now be described in more detail, reference being made to the accompanying drawing, in which:

Fig. 1 shows a relatively simple circuit arrangement for electronic counting purposes;

Fig. 2 shows an alternative circuit arrangement for substitution in the complete circuit of Fig. 1, the modification being disposed to the right of a dividing line *a-a*;

Fig. 3 shows a more elaborate circuit arrangement for pulse counting purposes in which means are provided for counting any number of pulses, even though it be a prime number; and

Fig. 4 shows a diagram of voltages produced over a period of time in a counting circuit, such as that of Fig. 3.

Referring first to Fig. 1, I show an electron discharge tube 1 which is preferably of the tetrode type having a cathode 2, a control grid 3, a screen grid 4, and an anode 5. This tube is provided with an input circuit including a resistor 6 which is connected between the grid 3 and the cathode 2. Input pulses from any given source may be impressed across the capacitor 7 for controlling the tube 1.

The screen grid 4 is preferably maintained at the full positive potential of the operating source, while the voltage applied to the anode 5 is varied with the tube impedance, since the anode current is conducted through a resistor 8 in the output circuit.

Pulses of input potential are amplified by tube 1 and impressed across a capacitor 9 for conduction to ground through a twin diode rectifier tube 10. Full-wave rectification takes place in this tube in the usual manner. Half waves of one polarity of output from the tube 1 traverse the space path *d*₁ and are used to charge a capacitor 11 cumulatively. Half waves of the opposite polarity are dissipated to ground through the space path *d*₂ of the twin diode tube 10.

It will be noted that there are no resonant circuits in the arrangement thus far described. Hence, the action may be aperiodic if desired. The effects of the successive impulses which are amplified in the tube 1 are, however, such as to build up a charge on capacitor 11 until it reaches a critical value. The build-up time is determined

by several factors including the values assigned to capacitors 11 and 9 respectively, the value of a cathode resistor 12 which is provided for an electronic tube 13 of a following stage, and the adjustment of a tap 22 on a potentiometer 21 for controlling the bias on a grid 20 in a tube 17.

Tube 13 may, if desired, be a simple triode. Its circuit arrangement is, however, peculiar in that it possesses no grid leak connection between its control grid 14 and its cathode 15. The space path between the grid 14 and the cathode 15 is, however, influenced by the charge on capacitor 11 and is, in effect, used as a discharge path for the capacitor 11 after the grid voltage has been raised to a critical value.

Discharge tubes 13 and 17, both triodes, are disposed in the relationship of multivibrator tubes in order to produce a see-saw action, the time constant of which is made dependent upon the summation of incremental charges on capacitor 11 where each successive increment is made up of an individual transfer of charge from the capacitor 9. Such individual charges are conducted through the space path d_1 in the rectifier tube 10.

Tube 17 possesses an anode 18, a cathode 19, and a grid 20. Anode potential derived from a source indicated as +B is applied through resistor 23 to the anode 16 in tube 13, also through resistor 24 to the anode 18 in tube 17. The cathodes 15 and 19 in the respective tubes 13 and 17 are interconnected and have a common cathode resistor 12 leading to ground.

A potentiometer 21 is connected between the anode 16 of tube 13 and ground. It has a tap 22 which is connected to the grid 20 in tube 17.

In the operation of the circuit arrangement of Fig. 1, let it be assumed first that a negative pulse is applied across capacitor 7 and resistor 6, such that grid 3 in tube 1 is biased to cut-off. Since no current would then flow in the tube 1, there would be no appreciable potential drop in resistor 8. The full +B voltage would, therefore, be applied to capacitor 9 for charging the same. The surge impulse which develops this charge traverses the space path d_1 in tube 10 and applies a limited charge to capacitor 11 which is of a higher microfarad rating than capacitor 9.

Assume now that a voltage change takes place on the input side of capacitor 7 and that this capacitor upon discharging reduces the voltage drop in the resistor 6 so that the bias is removed from grid 3 in tube 1. This tube then becomes conductive and produces a voltage drop across resistor 8 such that capacitor 9 discharges through the space path d_2 in the rectifier tube 10. This condition has no effect upon capacitor 11 since the space path d_1 now becomes non-conductive.

With current reversals applied to capacitor 7, it will be seen that successive, but diminishing, amounts of charge will be applied to capacitor 11, thus building up a voltage thereon in step-wise fashion somewhat as shown in Fig. 4.

As the charge increases on capacitor 11, the normally negative bias on grid 14 with respect to the cathode 15 in tube 13 is reduced until tube 13 becomes conductive. A triggering action takes place due to the interruption of current flow in tube 17. A conductive state in tube 13 produces a voltage drop in resistor 23 which results in applying a relatively negative bias potential to the grid 20 in tube 17. This bias eventually becomes sufficiently negative to cut off

conduction in tube 17. The voltage drop in cathode resistor 12 is then entirely attributable to the discharge in tube 13. The conductive state in tube 13, however, is such that there is sufficient grid current to discharge capacitor 11 to ground potential. This discharge is quite sudden and permits subsequent application of incremental charges on capacitor 11 from ground potential as heretofore described. The number of such incremental charges which is required to produce conduction in tube 13 after it has been biased to cut off is largely dependent upon the ratio between the capacitances of capacitors 9 and 11 and is also dependent upon the setting of the tap 22 on potentiometer 21. The reason for the influence of the latter is explained as follows:

The see-saw interaction between tubes 13 and 17 can readily be understood, since conduction in tube 13 produces a negative surge impulse through resistors 23 and 21 for application to the grid 20 in tube 17, thereby cutting off current flow in this tube. The reverse action occurs upon an increase in the voltage drop in potentiometer 21 when a cut-off bias on grid 14 causes the voltage on anode 16 to rise. It is then that the bias on grid 20 permits current to flow in tube 17. Its cathode 19 has a tendency to develop a greater voltage drop in cathode resistor 12 so as to drive both cathodes 15 and 19 more positive. The resulting effect is to increase the negative bias of the grid 14 with respect to cathode 15, which accelerates the interruption of current flow in tube 13.

If the ratio between the capacitances of elements 9 and 11 is small, the increments or steps of charge on capacitor 11 are few in number. If the ratio is large, it requires a larger number of increments to charge capacitor 11 to full voltage. It is the number of these increments of charge which determines the count or integration of applied input pulses before the charge on capacitor 11 becomes effective in rendering the tube 13 conductive. The count can be varied, however, by varying the time constant of the interaction between tubes 13 and 17 as by adjustment of the tap 22 on potentiometer 21.

A significant feature of the circuit arrangement of Fig. 1 may be appreciated when it is seen that there are no resonant circuits to be dealt with, so that it is of no importance, relatively speaking, what the periodicity or aperiodic nature of the input impulses may be. A definite number of such impulses is counted with each cycle of operation of the tube 13. Hence the output pulses which may be taken off between the anode 16 and the cathode 15 is a definite sub-multiple of the number of impulses applied across the capacitor 7.

Referring now to Fig. 2, a modification is shown with respect to that part of the circuit of Fig. 1 to the right of the dividing line a-a. Like parts in the two figures are given like reference numbers.

The interaction between tubes 13 and 17 is somewhat different from that which is explained above in reference to Fig. 1. In Fig. 2, the grid 20 in tube 17 is connected to a junction point between two resistors 27 and 28 of a voltage divider which corresponds with potentiometer 21 in Fig. 1. That is to say, resistors 27 and 28 interconnect the anode 16 of tube 13 and ground. It is, however, unnecessary to provide a movable tap for control of the bias on the grid 20 since provision is made by means of an adjustable potentiometer

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25 for adjusting the cathode potential in tubes 13 and 17 with respect to ground. Variation of this cathode potential is due to variations in the potential drop across resistor 23 which in turn arises with changes in the conductive state of tube 13. A triggering action is explained in more detail as follows:

Assuming first that the charge on capacitor 11 is so far reduced that a negative bias is applied to the grid 14 in tube 13. This tube is then non-conductive. The lack of anode current reduces the voltage drop in resistor 23 to a negligible value. The portion of potentiometer 25 which lies above the tap 26 is in shunt with the space path in tube 17. The position of tap 26 is adjusted to carry the cathodes 15 and 19 at a positive potential with respect to ground. The full voltage of the anode supply source extends through resistors 24a, 23, 27 and 28 to ground, thus impressing a relatively positive bias on grid 20.

Under the conditions set forth in the preceding paragraph, tube 17 is rendered conductive because the grid 20 has a bias potential which is close to or above the potential applied to cathode 19.

Assume now that a charge has been built up on capacitor 11 sufficient to render tube 13 conductive. The potential drop in resistor 23 renders the grid 20 negative with respect to the cathode 19, and tube 17 becomes non-conductive. The effect of this is to reduce the potential drop in that portion of potentiometer 25 which extends from the tap 26 to ground. The potential of the cathode 15 then approaches that of ground potential, which thereby swings tube 13 abruptly into a saturated conductive state. This accelerates the discharge of capacitor 11 and the cycle of recharging by small increments is repeated.

Referring now to Fig. 3, I show therein a modification in which the principles explained in reference to Figs. 1 and 2 are applied along with a technique which permits the counting of incremental charges on the capacitor 11 to be differentiated in successive cycles. That is to say, if the input pulses applied across capacitor 7 and amplified in the tube 1 are to be counted up to a number such as 17, this can be done by two stages in one of which eight incremental charges on the capacitor 11 are counted, and, subsequent to the discharge of capacitor 11, nine incremental charges are counted. The latter action will be such as to build up a final voltage sufficient to be responded to by a cathode follower tube 29 which possesses a cathode resistor 30 across which a potential drop is produced when the tube 29 becomes conductive and this potential drop may be utilized in an output circuit for controlling any desired utilization device. By way of explaining the circuit arrangement of Fig. 3 in more detail, the following description is given:

The amplifier tube 1 is associated with a rectifier tube 10 in substantially the same manner as is shown in Fig. 1. The capacitor 11 also is connected in the same manner between one of the cathodes in tube 10 and ground. Connection is made between the same cathode in tube 10 and the grid 14 in tube 13 through one winding of a transformer 31. The other winding of this transformer constitutes a feedback circuit between the anode 16 and a potentiometer 32 which leads to a ground connection. The potentiometer 32 is in shunt with a by-pass capacitor 33.

The tube 13 is subject to different biases at

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different times in dependence upon the see-saw interaction between two gaseous discharge tubes 34 and 35. Each of these gaseous tubes is constituted as a triode having a cathode 36a, 36b, an anode 37a, 37b, and a control grid 38a, 38b. The cathode 36a is connected to ground through a cathode resistor 39. The cathode 36b, however, is connected to a tap 40 on the potentiometer 32. The grids 38a and 38b both possess grid leak resistors 41 connected to ground. Control impulses for igniting the tubes 34 and 35 alternately are applied across capacitors 42 and 43 respectively. The anodes 37a and 37b are intercoupled by capacitor 44. A capacitor 45 is in shunt with a portion of the potentiometer 32 which lies between the tap 46 and ground. Anode potential is applied to the anodes 37a and 37b through resistors 47 and 48 respectively.

In the operation of the circuit arrangement of Fig. 3, the taps 40 and 46 are adjusted on the potentiometer 32 so that the desired count of incremental charges on the capacitor 11 will be obtained covering the periods between successive discharges of this capacitor.

If, for example, the input pulses applied to the tube 1 and rectified in the tube 10 are to be effective in a series of first eight and then nine charges upon capacitor 11, then the tube 13 will in the first case be held non-conductive while eight incremental charges are applied to capacitor 11, and in a subsequent case, the tube 13 will be held non-conductive while nine incremental charges are impressed upon the capacitor 11. In order to accomplish this result, the potential drop between tap 40 on the potentiometer 32 and ground is varied so as to swing the cathode potential 15 between two values depending upon whether tube 35 is ionized or extinguished. The amount by which the potential of cathode 15 differs from ground potential determines the ultimate charge on capacitor 11 before this charge is drawn off through the space path between the grid 14 and the cathode 15 in tube 13. Each time that tube 13 becomes biased to cut-off, a surge impulse of positive value is applied across capacitors 42 and 43 for igniting one of the tubes 34 or 35 which was at that instant non-conductive. The control pulse, however, has no effect upon the gaseous tube which is already ignited. The ignition of one of these tubes lowers its anode potential suddenly and produces a surge impulse across capacitor 44 so as to reduce the anode of the previously ignited tube to the extinction voltage.

Thus when tube 35 becomes ignited, the cathode 36b rises in potential and renders the cathode 15 in tube 13 more positive. When tube 35 is extinguished, then the cathode 15 is reduced to the lower of its two limiting potentials.

Fig. 4 illustrates the voltages which are applied incrementally across the capacitor 11 in successive trains. One train has seven incremental charges, and the other eight, by way of illustration. The tube 29 has circuit parameters such that it is rendered conductive only after a build-up of voltage on the capacitor 11 equal to eight elemental increments. As previously explained, the control of a conductive state in tube 29 may be used to derive the desired output pulses which count any desired number, including a large prime number. This will be understood when it is seen that it requires the two flights of steps 8+9 to render the tube 29 conductive. In other words, this tube becomes con-

ductive only once in seventeen applications of the input pulses across capacitor 7.

It will be apparent that by suitable choice of the circuit parameters in the arrangement of Fig. 3, any desired number of input pulses can be counted. This circuit arrangement has a wide range of applications in electronic fields, particularly in television systems and in synchronization of different forms of apparatus.

My invention is not limited in its scope to the few illustrative embodiments hereinabove described and shown in the drawings. Modifications may readily be made by those skilled in the art.

I claim:

1. An electronic counting system comprising a coupling condenser and a storage condenser, a twin diode discharge device having one set of complementary electrodes in circuit between the two said condensers, the second set of complementary electrodes being disposed in a discharge path for said coupling condenser, means including an electron discharge tube having a cathode, an anode and at least one grid for intermittently discharging said storage condenser, said tube having means in circuit therewith for producing staggered conductive states therein whereby it is caused at intermittent times to respond to the build-up of a storage condenser charge having the integrated value of one predetermined number of uni-directional pulses transferred from said coupling condenser to said storage condenser, and whereby said tube is caused at alternately intermittent times to respond to the build-up of a storage condenser charge having the integrated value of a different predetermined number of such uni-directional pulses.

2. A system in accordance with claim 1 and including a multivibrator circuit arrangement in said means for producing staggered conductive states therein, said arrangement being of the gaseous discharge tube type.

3. An electronic counting system having a single frequency-dividing stage, an input circuit for said stage characterized by the inclusion of a storage capacitor receptive of incremental charges which are derived from an energy pulse source, said capacitor being intermittently dischargeable through a path of electronic emission in said stage, a source of control bias potential for blocking the emission in said stage, and means for shifting the unblocking bias between two alternate values effective with each successive discharge of said capacitor, whereby first one submultiple and then another submultiple of the energy pulses are derived.

4. A system according to claim 3 in which a multivibrator circuit arrangement is included in said bias shifting means.

5. In an electronic counting system having a single frequency-dividing stage and a storage capacitor in the input circuit of said stage, the method of counting two successive trains of energy pulses which are applied to said capacitor

for building up thereon different values of total charge, said method comprising discharging said capacitor by producing an electronic discharge in said frequency dividing stage and shifting the unblocking bias between two alternate values effective with each successive discharge of said capacitor, whereby the number of said capacitor discharges is maintained in fixed ratio to the total number of said pulses in the two said trains.

6. An electronic impulse counter comprising an input circuit receptive of energy pulses, a first capacitor chargeable by each of said pulses to a predetermined voltage, a second capacitor, a unilaterally conductive device interconnecting the two said capacitors and operative to transfer half-waves of pulse energy to the second capacitor, means including a second unilaterally conductive device in circuit with the first said capacitor for reversing its charges, a trigger-acting electronic circuit of the multivibrator type having two space discharge systems which are rendered conductive at mutually exclusive times, one of said discharge systems being controlled by the build-up of a predetermined triggering potential in the second said capacitor, a discharge path for said second capacitor being produced by a conductive state in the same one of said discharge systems, means for so adjusting the parameters of said trigger-acting circuit that a predetermined number of said energy pulses, irrespective of their frequency, occurs between successive discharges of the second said capacitor, and input electrode biasing means applicable to one of two discharge systems in said trigger acting circuit whereby a predetermined count of pulses in certain intermittent trains is complemented by a different predetermined count of pulses in intervening trains.

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