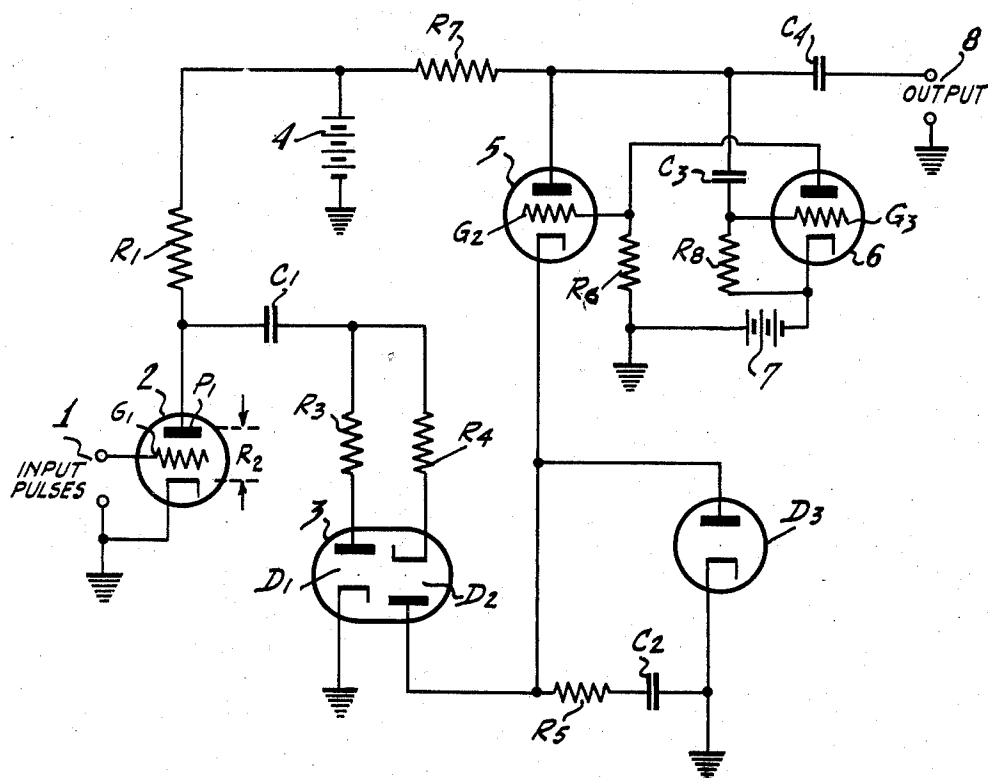


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INTEGRATING COUNTER CIRCUIT

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INTEGRATING COUNTER CIRCUIT

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This invention relates to integrating counter circuits and has for its principal object to provide a circuit arrangement which will count a series of pulses up to a certain predetermined number and while doing so will guard against the counting of spurious pulses or momentary line surges such as might otherwise result in an erroneous count.

Briefly described, our circuit arrangement for counting pulses is one in which the components are so chosen as to cause a certain amount of charge to be stored in a condenser, the total charge being an accumulation of successive charges which result from the application of a pulse train. The circuit arrangement is also provided with time constant components such as to require a definite time interval for each pulse to be counted. When the total charge reaches a predetermined amount, representing a definite number of pulses, a tube is rendered conductive.

Our invention will now be described in more detail, reference being made to the accompanying drawing the sole figure of which represents diagrammatically a preferred embodiment of the invention.

Referring to the drawing, we show input terminals 1 on which the pulses to be counted are impressed. These input terminals are connected one to the grid and the other to the grounded cathode of a discharge tube 2, shown here as a triode type. This tube is fed with direct current from a source 4 traversing a resistor R_1 . A twin diode tube 3 contains two oppositely arranged rectification paths D_1 and D_2 . The cathode of path D_1 is grounded. The anode of this same path is connected through a resistor R_3 to one electrode of a charging condenser C_1 , the other electrode of the condenser C_1 being connected to the anode P_1 of tube 2.

Condenser C_1 is also connected between the anode of tube 2 and a resistor R_4 leading to the cathode of the rectification path D_2 . The anode of this path is connected to the anode of another rectifier D_3 , whose cathode is grounded. In shunt with the rectifier D_3 is a circuit including resistor R_5 and a storage condenser C_2 .

For utilization purposes two discharge tubes 5 and 6 arranged in an aperiodic trigger circuit may be employed if desired. The cathode of tube 5 is connected to the anode of the rectifier path D_3 . The anode of tube 5 is fed with direct current from source 4 across resistor R_7 . The grid G_2 in tube 5 is connected to ground through a resistor R_6 . This grid is also directly connected to the anode in tube 6. A capacitive coupling cir-

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cuit between the anode of tube 5 and the grid of tube 6 includes condenser C_3 . The grid G_3 of tube 6 is returned to its cathode through a resistor R_8 . The cathode is connected to the negative terminal of the direct current source 7.

Utilization of the tripping action between tubes 5 and 6 may be obtained by the use of output terminals 8, one of which is grounded while the other is coupled to the anode of tube 5 through a capacitor C_4 .

There are applications in which it is desirable that a predetermined minimum length of time be assigned to each pulse in order to reach a certain count. Such a device fulfills a useful purpose in signal identification equipments or error detecting systems.

In carrying out our invention we have found it possible to provide circuit components which are so coordinated as to permit termination of the count on the start, or leading edge of the last pulse to be counted. In other words, if a count of N steps is desired, then $N-1$ of them require a predetermined minimum length of time to accumulate, but the count terminates at the start rather than during or at the end of the N th step.

Operation of the Circuit

In the following description of operation it will be observed that tube 5 is rendered conductive only after a predetermined number of pulses has been injected into the counter circuit. First let it be assumed that the potential applied to the anode of tube 2 is that of the positive terminal of source 4 due to the fact that tube 2 stands in a non-conductive state. A positive pulse applied to the input terminals of tube 2 renders this tube conductive and the voltage change on the anode is essentially a function of $I_1 R_1$, where I_1 represents the space current in tube 2. Let it also be assumed that at the outset condenser C_2 has no charge on it and, therefore, both terminals are at ground potential. The cathode of tube 5 is also at ground potential due to this condition. The grid G_2 in tube 5, however, is negative with respect to ground potential due to the voltage drop through resistor R_6 under the condition that tube 6 is normally conducting.

The critical firing voltage to which C_2 must be charged in order to render tube 5 conductive will be indicated by $-E_c$.

Assume that we wish tube 5 to conduct after three counts, the first two being integrated.

The first count: Grid G_1 is made positive and held so for a minimum time T . This causes a voltage change on the anode P_1 equal to $I_1 R_1$.

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Condenser C_1 , normally charged to the terminal voltage of source 4, will assume a new voltage due to the potential drop through resistor R_1 while tube 2 is conductive. Because of this, current will flow through a circuit which includes resistor R_4 , diode path D_2 , resistor R_5 and condenser C_2 . The diode path D_3 , as connected, prevents the discharge of condenser C_2 and yet allows an electron path for the current which traverses tube 5.

There are two points to be noted in this action. First, the cathode of tube 5 is driven somewhat negative due to the potential drop across resistor R_5 . This condition is determined by the relative ohmic values of resistors R_1 and R_2 (the effective resistance of tube 2) and of resistors R_4 and R_5 , the last two being interconnected through the diode path D_2 . The effective resistance R_2 is usually small compared to R_4 and R_5 . It will be evident that placing a negative potential on the cathode of tube 5 is equivalent to placing a positive potential on the grid of tube 5.

Second, the actual step voltage placed on condenser C_2 is reached after a time interval determined by the values of resistors R_1 , R_2 , R_4 and R_5 , and the effective condenser equal to

$$\frac{C_1 \cdot C_2}{C_1 + C_2}$$

In between successive counting pulses the capacitor C_1 must be restored to its original charge. This is accomplished by driving the grid G_1 negative so as to bias tube 2 to cut-off. The anode potential then rises to that of the terminal voltage of the source 4. The charging current through capacitor C_1 now traverses resistor R_3 and the diode path D_1 . The charge previously stored in capacitor C_2 is retained, due to the blocking action of the diode path D_2 .

An appreciable time interval is involved in the charging of capacitor C_1 and this interval is determined by the values of the components R_1 , C_1 and R_3 . This means that the negative signal voltage must persist for a minimum time interval just as the positive signal must for proper counting action.

The operation for the second count is identical with that for the first count. The voltage on condenser C_2 , however, is not doubled, as might erroneously be assumed. The reason for this is that the effective change in voltage across the two condensers is no longer $I_1 R_1$, but $I_1 R_1$ minus the step of voltage already on condenser C_2 . The total C_2 voltage at the end of the predetermined interval of the second count is

$$\frac{C_1}{C_1 + C_2} I_1 R_1 + \frac{C_1}{C_1 + C_2} \left[I_1 R_1 - \frac{C_1}{C_1 + C_2} I_1 R_1 \right]$$

The amplitude of the second pulse across resistor R_5 is also smaller than the first and becomes still smaller with each succeeding count just as each succeeding applied step voltage becomes smaller.

With proper design procedure, the first two counts apply a total voltage to condenser C_2 which is less than the critical firing voltage $-E_c$. The first step voltage plus the second initial pulse is also less than the critical firing voltage.

The third count (assuming it to be final) differs from the first two in that it is not integrated. The initial pulse at the start of the count is of such amplitude that, superimposed on the total voltage already across condenser C_2 , it immediately drives the potential of the cathode of tube

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5 more negative than the firing voltage. This being the case, tube 5 fires, the trigger circuit trips and the object of the circuit is accomplished. When tube 5 fires (becomes conductive), a positive potential is placed on the anode of diode D_3 which also becomes conductive. This diode D_3 thus provides the D. C. return path for tube 5.

In summation, the charge in flowing into condenser C_2 must flow through resistors R_5 and R_4 , hence producing a time delay (that is, requiring time) for the charge to build up on condenser C_2 . Hence, a short duration spurious pulse would add only a negligible charge to condenser C_2 and would not effect the counter. The condenser C_2 integrates the current that flows into it through resistor R_4 , rectifier D_2 , and resistor R_5 , and the resistors slow up the charging of condenser C_2 . The values of resistors R_4 and R_5 depend upon the duration of the pulse it is desired to count. The longer the pulse to be counted the higher will be the values of resistors R_4 and R_5 .

In place of the trigger circuit composed of tubes 5 and 6, a conventional locking circuit may just as well be activated after the desired number of counts.

Full integration on all counts is obtained merely by omitting R_5 and compensating for its absence, as far as the time constant is concerned, by increasing the value of resistor R_4 .

We claim:

1. An impulse counting system comprising a first electron discharge tube having an input circuit for receiving the impulses to be counted and an output circuit connected between its anode and cathode, said output circuit including an anode circuit resistor and a direct current source; a first capacitor and a second capacitor; a first unilateral circuit extending from ground through the first tube, through the first capacitor, thence through two resistive elements and through the second capacitor to ground; a second unilateral circuit extending from ground through a third resistive element, through the first capacitor, through said anode circuit resistor and said source to ground; diode rectifier means for rendering said unilateral circuits mutually opposed and conductive only as permitted by the polarity of potential differences along said circuits; and electronic means for dissipating the charge on said second capacitor after it has reached a critical potential, which potential results from the storage of incremental charges on said second capacitor corresponding in number to the impulses to be counted, and said resistors in combination with said capacitors constituting time constant means for introducing a time delay for the charge to build up on said second capacitor, whereby the effects of spurious impulses of shorter duration than the impulses to be counted are minimized.

2. An impulse counting system according to claim 1 wherein said electronic means for dissipating the charge on said second capacitor is constituted as one of two discharge tubes in a locking circuit, which tubes are arranged for mutual interaction so that when one is rendered conductive the other is blocked, and vice versa.

3. An impulse counting system comprising a first electron discharge tube having input and output circuits, said input circuit being coupled to a source of impulses to be counted, a first capacitor constituting a common circuit connection between the anode of said tube and a pair

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of opposingly poled unilateral circuits which, together with said capacitor, are in shunt with said output circuit, each of said unilateral circuits having resistive impedance in series therewith such that in combination with said capacitor a certain time constant is developed for acceptance of the impulses to be counted and for rejection of shorter duration spurious and transient pulses, a second capacitor and an additional resistor in series therewith in circuit with one of said unilateral circuits and having a certain time constant value, said second capacitor being arranged to store successive increments of charge thereon, and electronic means for discharging said second capacitor when said stored charge has reached a predetermined value corresponding to the number of impulses to be counted.

4. An impulse counting system according to claim 3 and including a diode rectifier in shunt with the circuit of said second capacitor and said additional resistor.

5. In an integrating counter circuit, two capacitors interconnected through resistive and rectifying means the circuits of which are completed through the space path of an electron discharge tube having an input circuit and an output circuit, said output circuit being external to the circuit components aforementioned, a second discharge tube coupled to a point between said two capacitors and constituting means for discharging the second of said capacitors after a predetermined number of incremental charges have been stored therein in response to the application of discrete pulses to said input circuit and thence to the first of said capacitors, said resistive means in association with said capacitors introducing a predetermined time delay for the building up of a charge on said second capacitor in response to an input pulse, said time delay being operative to nullify the counting effects of stray and spurious pulses applied to said input circuit which are of shorter duration than the pulses to be counted.

6. The method of counting pulses of electrical energy up to a predetermined number by the use of an electronic circuit arrangement which possesses resistive and capacitive circuit components arranged to accumulate in a second capacitor a series of transient charges corresponding to individual charges momentarily stored in a first capacitor, said method comprising rectifying the energy which is transferred from the first to the second capacitor, dissipating by rectification the energy stored in the first capacitor, discharging the second capacitor through a certain portion of said electronic circuit arrangement only so often as said predetermined number of energy pulses is counted, and selecting the time constant characteristics of said resistive and capacitive circuit components so as to introduce a delay in the transfer path between the first and second capacitors, to thereby discriminate against the counting of stray and spurious energy pulses which are to be distinguished from the true pulses to be counted.

7. A pulse counting circuit of the type which comprises electronic means and associated input and output circuits for storing and discharging energy pulses in one condenser while accumulating corresponding charges in a second condenser up to one less than the number N of such pulses which are to be counted, said condensers having in series therewith a plurality of resistors separated by a unidirectional current passing device, said resistors having such values as to introduce

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a delay in the time required to build up a charge on the second condenser, and means for terminating the counting operation at the start of the Nth pulse, said means including a discharge tube the output circuit of which is connected through said second condenser for discharging the energy stored therein, and an input circuit so biased as to permit conductivity in said tube only after the charge in said condenser has been built up to a critical value by the initial increment of said Nth pulse.

8. In combination, a storage condenser, a charging condenser, the series circuit of a resistor, a unilaterally conducting device and another resistor in the order named connected between one plate of each of said condensers for admitting current from said charging condenser to said storage condenser, the series circuit of a second resistor and a second unilaterally conducting device connected between the junction of the charging condenser and the first-mentioned resistor and the other plate of said storage condenser for discharging said charging condenser, means to impress a pulsating current between the other plate of the storage condenser and the other plate of the charging condenser, and means coupled across the storage condenser for discharging the storage condenser following a predetermined charge on said storage condenser, said last means comprising an electron discharge device having an anode, a cathode and a grid, a direct connection from said cathode to the junction point of the unilaterally conducting device and said other resistor of the first series circuit, a direct current connection from the positive terminal of a source of unidirectional potential to said anode, a trigger circuit coupled to said grid, and a diode having an anode directly connected to said cathode and having a cathode directly connected to said other plate of said storage condenser.

9. A pulse counting circuit comprising a vacuum tube having an anode and a cathode, a resistive circuit between said anode and the positive terminal of a source of unidirectional potential, a charging condenser and a storage condenser, the series circuit of a resistor and a unilaterally conducting device connected between one plate of each of said condensers for admitting current from said charging condenser to said storage condenser, the series circuit of a second resistor and a second unilaterally conducting device connected between the junction of the charging condenser and the first-mentioned resistor and the other plate of said storage condenser for discharging said charging condenser, a direct connection between the other plate of said charging condenser and said anode, a connection between the other plate of said storage condenser and said cathode, means coupled to and causing said vacuum tube to conduct each time a pulse is to be counted, another vacuum tube having an anode connected to said positive terminal and a cathode connected to said one plate of said storage condenser, and means for causing said last vacuum tube to conduct and discharge said storage condenser following a predetermined charge on said storage condenser, said last means including a rectifier coupled across said storage condenser through a resistor, one electrode of said rectifier being directly connected to the cathode of said last vacuum tube.

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