

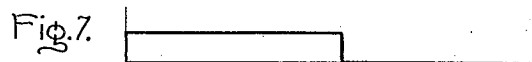
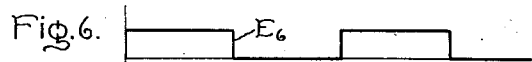
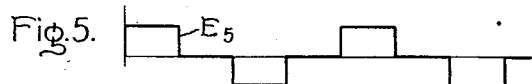
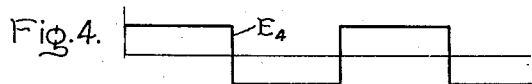
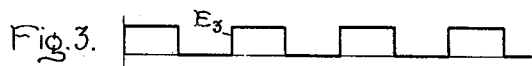
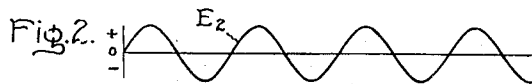
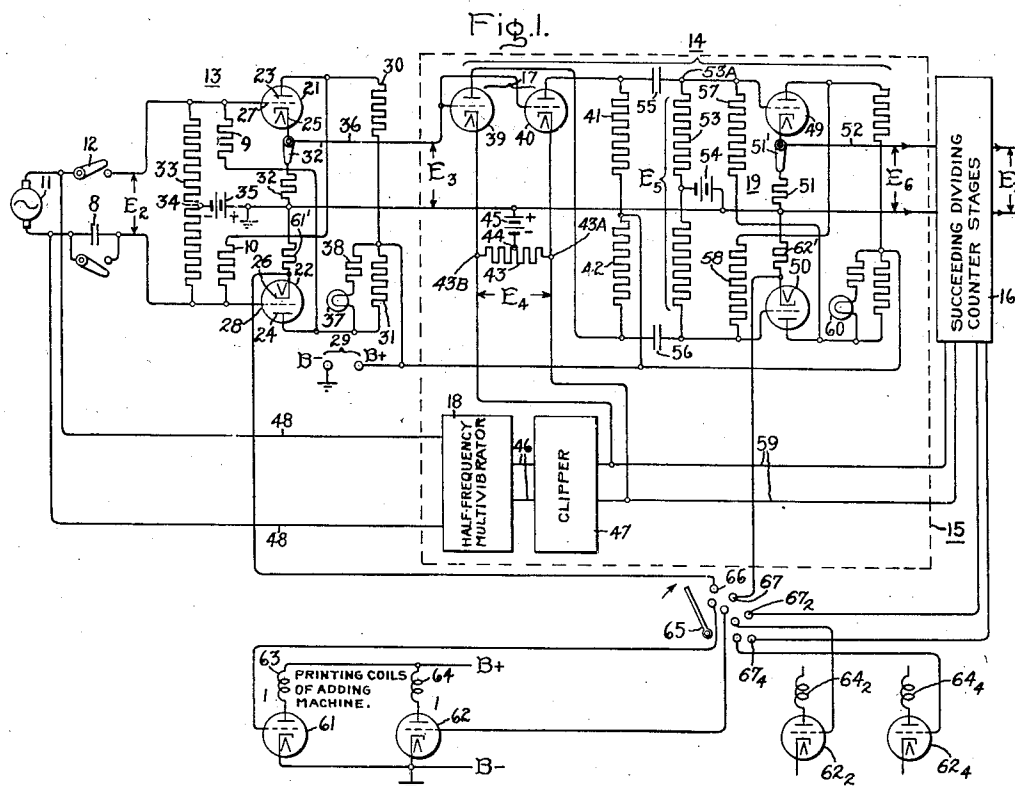
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E. D. COOK

2,349,810

COUNTER CIRCUIT

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UNITED STATES PATENT OFFICE

2,349,810

COUNTER CIRCUIT

Ellsworth D. Cook, Scotia, N. Y., assignor to General Electric Company, a corporation of New York

Application December 1, 1941, Serial No. 421,129

3 Claims. (Cl. 250—36)

My invention relates to impulse counting and interval timing and concerns particularly circuits employing electric discharge devices.

It is an object of my invention to provide an arrangement for counting impulses accurately and with high precision of indication, which operates reliably in the case of high speed impulses.

It is also an object of my invention to provide a frequency divider.

Other and further objects will become apparent as the description proceeds.

Small time intervals may be measured by counting the number of cycles of an accurately known frequency which occur between two input signals marking the beginning and the end of the required time interval. An example of such an application is a velocity determining device in which a moving body passes in inductive relation to two current conducting coils in succession and thus creates two electrical signals which actuate auxiliary apparatus to apply the accurately known frequency to the counter circuit during the time interval between the two signals. My invention is not limited to time interval measurement and relates generally to impulse or cycle counting. Nevertheless, I shall explain my invention for use with time interval measurement.

In carrying out my invention in its preferred form, I provide a vacuum tube circuit with an initial stage consisting of a pair of tubes between which current shifts back and forth with successive half cycles of the input signal, and I provide one or more frequency dividing stages. The initial stage is arranged to convert input signals (which may be a sine wave or an oscillatory wave of some other form including a unidirectional pulsating wave) into a square wave having positive loops only, of the same frequency as the input wave. Each divider stage includes a pair of tubes for inverting alternate square wave impulses of the input to the divider stage and thus forming a peculiarly shaped half-frequency alternating-current wave with square components. These two tubes are provided with a half frequency alternating voltage bias control to produce their special action. The divider stage includes also a pair of tubes acting like the initial stage of the counting apparatus for converting the peculiarly shaped alternating wave into a square wave with positive loops only. The output of each divider stage is thus a square wave having half the frequency of the input thereto. Indicators are provided in each stage for showing whether an odd or an even number of im-

pulses has been supplied thereto. The total number of impulses counted can then be determined provided there are enough counter stages so that the input impulses terminate before the last divider stage is brought back to its initial condition.

A better understanding of the invention will be afforded by the following detailed description considered in connection with the accompanying drawing, and those features of the invention which are believed to be novel and patentable will be pointed out in the claims appended hereto.

In the drawing Fig. 1 is an electrical circuit diagram schematically representing an embodiment of my invention, and Figs. 2 to 7, inclusive, are graphs representing the shape and character of voltage waves appearing at various portions of the circuits illustrated in Fig. 1. Fig. 2 represents the input voltage wave E_1 supplied to the initial stage; Fig. 3 represents the square wave E_2 produced by the initial stage and supplied to the first divider stage; Fig. 4 represents the bias voltage wave E_3 supplied to the first two tubes of the first divider stage; Fig. 5 represents the voltage E_4 produced by these two tubes; Fig. 6 represents the square wave E_5 produced by the first divider stage and which has half the frequency of the wave E_2 supplied to this divider stage, and Fig. 7 represents a square wave corresponding to the wave E_5 but having half the frequency thereof to represent the action of the second divider stage.

Fig. 1 illustrates apparatus for counting the impulses produced during a given time interval by a constant frequency generator 11, the frequency of which is known accurately. An arrangement is provided for connecting the source 11 to the circuit during the required time interval. Such a connecting arrangement is represented schematically by the switch 12. The counter circuit includes an initial stage 13 for squaring the input wave and cutting off negative loops, a first divider stage 14 consisting of the apparatus within the dotted rectangle 15, and the complete counter may include one or more additional divider stages 16. The divider stage 14 includes a section 17 comprising a pair of electric discharge devices for inverting alternate impulses of the initial stage 13, a suitable generator 18 of half frequency impulses for supplying bias voltage to the section 17, and a section 19 comprising a pair of electric discharge devices similar in action to the initial stage 13, for converting the output of the discharge devices 17 into a wave having only positive loops.

Any suitable device for generating alternating-current or pulsating continuous-current impulses may be utilized as the generator 11. Since my invention is particularly useful in the case of counting impulses which occur with high frequency, it is desirable to utilize a switching mechanism which may be controlled accurately under such conditions. For simplicity I have shown a switching arrangement in the form of a simple mechanical switch 12, as the switching arrangement is not claimed in the present application. For high frequency work an electronic switch or other suitable apparatus should be employed. For example, I may employ a control circuit of the type disclosed in my copending application, Serial No. 418,213, filed November 7, 1941, Patent No. 2,332,300 granted Oct. 19, 1943, assigned to the same assignee as the present application. If the source 11 supplies an oscillatory wave consisting of continuous-current impulses a condenser 8 may be interposed in the input lead to the stage 13.

The initial stage 13 comprises a pair of electric discharge devices 21 and 22, together with a suitable source of energizing voltage and circuit connections. The devices 21 and 22 may take the form of high vacuum tubes, each having a plurality of electrodes, including anodes 23 and 24, cathodes 25 and 26, and control electrodes or grids 27 and 28. For energizing the anode-cathode circuit, a voltage source 29 may be provided having positive and negative terminals represented by the terminals marked "B+" and "B-". The B+ terminal is connected to the anodes 23 and 24 through anode resistors 30 and 31, respectively. The B- terminal and the cathodes 25 and 26 may be connected together and grounded but for reasons which will appear hereinafter I prefer to include a cathode resistor 32 in the cathode lead of the tube 21. Cross-coupling resistors 9 and 10 are connected one between the control electrode 27 and the anode 24, the other between the control electrode 28 and the anode 23.

The output voltage E_2 of the generator 11 is applied to the control electrodes 27 and 28 through connections arranged to supply voltages of opposite polarity to the two control electrodes. For example, the voltage E_2 may be connected across a resistor 33 which has a center tap 34 and is connected at one end to the control electrode 27 and at the other end to the control electrode 28. In order to apply a negative bias to the control electrodes of the devices 21 and 22, a source of biasing potential 35 may be connected between the mid terminal 34 of the resistor 33 and a ground connection for the cathodes 25 and 26. For carrying the output voltage E_3 from the initial stage 13 to the next stage a conductor 36 may be provided which is connected to the positive end of the cathode resistor 32.

Suitable means are provided for indicating which of the two discharge devices 21 and 22 is conductive. For example, a lamp 37 may be provided which is connected in series with the resistor 38 across the anode resistor 31 of the discharge tube 22. If desired, false indication due to failure of the lamp 37 may be guarded against by providing an additional indicating lamp connected in responsive relation to the anode-cathode circuit of the tube 21, in which case the indicating lamps would be so arranged that

they could be distinguished readily, e. g., by having different colors.

In the frequency divider stage 14, the pair of electron discharge devices 17 may take the form of vacuum tubes 39 and 40, each comprising a plurality of electrodes including anodes, cathodes and control electrodes or grids. The anodes are connected to the B+ terminal of the source 29 through anode resistors 41 and 42 respectively. The control electrodes are connected to the output lead 36 from the initial stage 13 and the cathodes are connected to opposite ends of a resistor 43 having a mid tap 44. For giving the control electrodes of the tubes 39 and 40, a fixed negative bias, a voltage source 45 is provided connected between the ground lead and the mid terminal 44 of the resistor 43.

For introducing an additional bias of alternating polarity, a square wave source is provided which is connected across the resistor 43. Such a square wave source may take the form of the multi-vibrator 18 having a pair of output leads 46 connected across the resistor 43. Preferably, however, a clipper stage 47 is interposed between the output leads 46 of the multi-vibrator 18 and the ends of the resistor 43 to insure proper wave shape in this dynamic bias voltage. The multi-vibrator 18 is constructed to operate at half the frequency of the generator 11 and is synchronized with the generator 11, e. g., by connecting input leads 48 of the multi-vibrator across the output terminals of the generator 11. The circuit of the multi-vibrator 18 is not shown since it does not constitute a part of my present invention. A suitable form of multi-vibrator is shown at 38 in Fig. 3 of my copending application Serial No. 338,360, filed June 1, 1940, and assigned to the same assignee as the present application. In the vibrator shown in that application a tap 52 is provided for adjusting the circuit to operate at a predetermined natural frequency. The clipper circuit 47 may likewise take the form of circuits already known to those skilled in the art, such as illustrated at 39, for example, in my aforesaid copending application, Serial No. 338,360.

The final section 19 of the frequency divider stage 14 may also take the form of vacuum tubes 49 and 50 each having a plurality of electrodes including anodes, cathodes and control electrodes or grids. The tubes 49 and 50 are connected in a manner similar to the tubes 21 and 22. The anodes of each are connected through anode resistors to the B+ terminal of the source 29. The cathode of the tube 49 is connected to the ground lead through a cathode resistor 51, to the positive end of which the stage output lead 52 is connected. The control electrodes are connected across the ends of a resistor 53, the mid point of which is connected to the negative side of a voltage source 54 grounded on the positive side for negatively biasing the control electrodes of the tubes 49 and 50. The control electrodes of the tubes 49 and 50 are coupled to the anodes of the tubes 39 and 40, respectively, through coupling condensers 55 and 56. The tubes 49 and 50 are also resistance cross-coupled having a resistor 57, connected between the control electrode of the tube 49 and the anode of the tube 50 and a resistor 58 connected between the control electrode of the tube 50 and the anode of the tube 49.

If desired, one or more frequency divider stages represented by the rectangle 16 may be provided

each of which is similar to the apparatus shown within the dotted rectangle 15. The half frequency bias voltage source for each succeeding divider stage may be synchronized with the outputs of the half frequency biasing source of the preceding stage by means of a pair of conductors such as the conductors 59. It will be understood that the natural frequency of the bias voltage source in each succeeding stage will be half that of the bias voltage source in the preceding stage.

In conformity with the arrangement shown for the initial stage 13, the next stage 14 is provided also with an indicating lamp 60 connected across the anode resistor of the tube 50. It will be understood that similar indicating lamps would be provided in the succeeding dividing counter stages represented by the rectangle 16.

In addition to the visual indication provided by such indicating lamps, mechanism may also be provided for totalization and for printing the total counts by means of an adding machine with key operating coils controlled by voltages in suitable portions of the successive counter stages. For example, an arrangement such as that described in the copending application of Donald L. Herr, Serial No. 415,268, filed October 16, 1941, and assigned to the same assignee as the present application, may be employed.

As explained more in detail in the aforesaid Herr application the appropriate keys of an adding machine may be actuated in response to energization of the successive counter stages through relays which may be of the electronic type taking the form of Thyratrons 61 and 62 for the stages 13 and 14 with additional Thyratrons 62a, 62b and so on for successive stages (not shown in detail). The Thyatron 61 has its control electrode adapted to be connected across the cathode resistor 61' of the tube 22 of the stage 13 and similarly the Thyatron 62 has its control electrode adapted to be connected across the cathode resistor 62' of the tube 49 in the counter stage 14. The additional Thyratrons are similarly connected in succeeding stages. For an arrangement in which half cycles or impulses of each polarity are counted instead of complete cycles a Thyatron (not shown) may be provided with a control electrode adapted to be connected across the cathode resistor 32. However, I shall explain the arrangement as used for counting complete cycles. An adding machine actuating coil 63 for the unit key is connected in the anode-cathode circuit of the Thyatron 61 associated with the initial counter circuit 13. Similarly a second adding machine actuating coil 64 for the unit key is connected in the anode-cathode circuit of the Thyatron 62 associated with the second counter stage 14, the first divider stage. An adding machine actuating coil for the key number 2 would be associated with the next counter stage (second divider stage) and additional successive stages would be arranged to actuate keys for successively higher powers of 2, viz: the numbers 4, 8, 16, 32, and so on.

For the purpose of causing the adding machine keys to be actuated in succession a rotary switch 65 may be provided having pairs of contacts 66, 67, 67a, 67b, and so on for the successive Thyatron circuits to enable them to be connected to the counter stages 13, 14 and so on in succession when a count has been made and the registration thereof is desired.

From the foregoing description it will be apparent that the counter circuits indicate or reg-

ister the number of impulses of alternating polarity produced by the generator 11 during the time interval from closing of the switch 12 to reopening thereof. After the switch 12 has been closed the first positive impulse raises the potential of the control electrode 27 of the tube 21 and causes current to be carried by that tube shifting the current away from the tube 22. By proper choice of circuit elements such as 33, 9, 10, 30, 31 and bias 35 as well as plate supply potential 29, the operation is stable and whichever tube 21 or 22 is made conducting, that tube remains in that condition until an impulse of opposite polarity is applied to the opposite grid electrode. When current is shifted away from the tube 22, the lamp 37 goes out indicating that an odd number of impulses has been counted; in this case only one. The next impulse which would be a negative impulse raises the potential of the control electrode 28 of the tube 22 with respect to ground and causes the tube 22 to become conducting, shifting current away from the tube 21. The lamp 37 again becomes luminous indicating that an even number of impulses has been counted; in this case 2. Each time either of the tubes 21 or 22 becomes conducting the other is rendered non-conducting because of the resistance cross coupling provided by the resistors 9 and 10. For example, when the tube 21 becomes conducting its anode potential falls as a result of the potential drop produced by current flowing through the anode resistor 30, which depresses the potential of the control electrode 28 of the tube 22 below the point of plate current cutoff. The voltage wave E₂ of the generator 11 may be of sine form, as shown in Fig. 2. However, owing to the fact that the tubes 21 and 22 are alternately driven beyond plate current cutoff in one direction and to some fixed value in the conducting direction respectively, the output voltage E₃ across the cathode resistor 32 is of square form, as shown in Fig. 3, rising to a constant value each positive half cycle of the wave E₂, and falling to zero during each negative half cycle of the wave E₂.

Since the bias voltage E₄ for the tubes 39 and 40 in the counter stage 14 is supplied by a half frequency multi-vibrator 18 synchronized with the original wave source 11, the voltage wave E₄ will have half the frequency of the waves E₂ and E₃. As shown in Fig. 4 the wave E₄ rises to a constant value during the first complete cycle of the waves E₂ and E₃ and falls to a constant negative value during the next complete cycle. Thus it alternates between positive and negative values during alternate complete cycles of E₂ and E₃. The magnitude of the bias voltage E₄ is sufficient so that when the voltage E₃ is impressed on the control electrodes of the tubes 39 and 40 one or the other of these tubes will become conducting according to which one has its control electrode potential raised. It will be apparent that since the cathodes of the tubes 39 and 40 are connected to opposite ends 43A and 43B of the resistor 43, the bias potential of one tube will be increased and the potential of the other tube diminished during each portion of the wave E₄ and the tubes 39 and 40 will alternately be in condition to become conducting when the voltage of the oscillatory wave E₃ is impressed upon the control electrodes. Accordingly, the voltage across the resistance formed by the anode resistors 41 and 42 considered in series will take the peculiar form of E₅ shown in Fig. 5. In drawing the voltage

waves E_4 and E_5 the points 43A and 53A, are considered as the positive ends of the resistors 43 and 53, respectively.

The voltage wave E_5 alternates between positive and negative values but has half the frequency of the input wave E_2 and the wave E_3 . Its action upon the control electrodes of the tubes 49 and 50 of the divider stage 14 will be the same however as the action of the input voltage on the control electrodes of the tubes 21 and 22 of the initial stage 13. Accordingly the output voltage E_6 as shown in Fig. 6 will have a form similar to the voltage E_3 but half the frequency. The output voltage of the next counter stage following the stage 14 would in turn have a frequency half that of the voltage E_6 as represented by Fig. 7. Each succeeding stage would have an output voltage of similar wave form but with its frequency each time divided by two.

Each time the tube 21 becomes conducting the lamp 37 is extinguished to indicate that an odd number of half cycles has been counted. Each time the tube 22 becomes conducting the lamp 37 becomes luminous to indicate that an integral number of complete cycles has been counted, which is an even number of half-cycles.

Initially the lamps 37 and 60 and corresponding lamps in succeeding stages are luminous. When the tube 21 becomes conducting in response to the first half-cycle, the tube 49 of the stage 14 also becomes conducting; and the corresponding tubes of succeeding stages become conducting. Therefore, the indicating lamps 37 and 60 and corresponding indicating lamps in succeeding stages all are extinguished. The second half-cycle shifts current to the tube 22, illuminating only the lamp 37 and producing an indication of one complete cycle counted.

When the tube 21 again becomes conducting after passing through one complete cycle of operation, (i. e., upon the third half-cycle) the tube 50 in the stage 14 also becomes conducting, and the lamp 60 again becomes luminous. The lamp 60 remains luminous when the tube 22 next becomes conducting during the fourth half-cycle, and the lamp 37 becomes luminous. The illumination of both unit lamps 37 and 60 thus gives the indication that the total count of complete cycles includes the value two in the sum. The following time the tube 21 becomes conducting, current is shifted from the tube 50 to the tube 49. The lamp 60 is extinguished and an impulse is transmitted to the next stage. Simultaneously the indicating lamp (not shown) representing the numeral 2 of the next stage becomes illuminated. The next half cycle completing the third whole cycle, lights the lamp 37 but does not affect the next stage, leaving the indication that the total count is three, since the unit lamp 37, and the numeral 2 lamp (not shown) are illuminated.

Thus, illumination of the indicating lamp 37 in the initial stage 13, indicates that the total count (in whole cycles) is a sum including the value one or 2^0 ; illumination of the indicating lamp 60 in the first divider stage 14 also indicates that the total count is a sum including the value one or 2^0 ; illumination of the indicating lamp (not shown) in the second divider stage (included in the rectangle 16 and not shown in detail) indicates that the total count is a sum including the value 2 or 2^1 ; illumination of the indicating lamps (not shown) in the succeeding divider stages 16 indicates that the total count is

a sum including successively higher powers of two, viz: $4=2^2$, $8=2^3$, $16=2^4$, etc.

In the arrangement illustrated it will be apparent that the control electrode of the thyatron 61 would be energized upon every negative half cycle, i. e., with the completion of each cycle, and the control electrode of the thyatron 62 would be energized upon every second negative half cycle, i. e., every other cycle, and in the successive thyatrons (not shown) the control electrodes would be energized every fourth cycle; every eighth cycle, and so on, if the appropriate contacts of the rotary switch 65 were closed. When a registration is to be made the switch 65 is rotated and the appropriate thyatrons are energized according to the total count during the time interval.

It will be assumed that initially before the count is to be made each stage is in a condition with the lower tube, such as the tube 22, and the tube 50 conducting, and the indicating lamps 37 and 60 illuminated. In order to make sure that each counter stage will initially be in this condition switches 32', 51', and so on, may be provided in the cathode circuits of the tubes 21, 49, and so on, respectively, for momentarily opening these circuits before beginning to make a count.

If the count is made in terms of impulses of either polarity or half cycles, it will be seen that the initial stage 13 indicates unity or 2^0 half cycles; the next stage 14 indicates 2^1 , the following (not shown) 2^2 half cycles, and so on; whereas if the count is to be in complete cycles or impulses of positive polarity only, the indications of the initial stage could be disregarded, and the first divider stage 14 indicates unity or 2^0 cycles, the next stage (not shown) indicates 2^1 cycles, and so on.

I have herein shown and partially described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its practice and showing its application, but it will be obvious to those skilled in the art that many modifications and variations are possible, and I aim therefore to cover all such modifications and variations as fall within the scope of my invention which are defined in the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A counter comprising in combination a pair of electric discharge devices each including an anode, a cathode and a control electrode, input terminals adapted to have electrical impulses to be counted applied thereto, connections between said terminals and said control electrodes for applying said impulses to said control electrodes with opposite polarities, one of said discharge devices having a resistor connected in series with its cathode, connections for coupling the control electrode of each discharge device to the anode of the other, a source of anode voltage and anode resistors interposed between the voltage source and the anodes of said discharge devices, a second pair of electric discharge devices for producing inversion of alternate output waves from said cathode resistor, said inversion devices each comprising an anode, a cathode, and a control electrode, said control electrodes being connected in circuits including said cathode resistor, a half frequency square wave alternating bias voltage source having synchronizing conductors connected to the input connections of said first-mentioned pair of discharge devices, connections for applying the output of said bias voltage source

in the control electrode circuits of said second-mentioned pair of discharge devices with opposite polarities, a third pair of electric discharge devices each having an anode, a cathode and a control electrode with cross coupling between the control electrodes and anodes, and a coupling between the anode of one of the second-mentioned electric discharge devices and the control electrodes of said third pair of electric discharge devices.

2. A counter comprising in combination an initial stage and one or more divider stages, the initial stage including a pair of electric discharge devices, and input terminals with connections for shifting current from one discharge device to another alternately in response to successive impulses supplied to said input terminals, each divider stage including input terminals with connections to the anode-cathode circuit of one of the discharge devices of the preceding stage, a pair of inversion electric discharge devices each having an anode, a cathode and a control electrode, the control electrodes being connected to the divider input terminals, a device with synchronizing conductors adapted to be connected to a source synchronized with the input terminals of the initial stage for rendering said inversion discharge devices alternately responsive to impulses applied to the input terminals of the divider stage, and a second pair of electric discharge devices each having an anode, a cathode and a control electrode with coupling between

the control electrodes and the anode-cathode circuit of one of the inversion discharge devices for shifting current back and forth between electric discharge devices of the latter pair alternately in response to successive impulses transferred from said one of the inversion discharge devices through said coupling.

3. In combination, a pair of electric discharge devices with control electrodes and cross-couplings between the discharge devices for maintaining each discharge device in a condition of conductivity determined by the current flow condition of the other to produce two relatively stable conductivity conditions, in one of which the first tube has greater conductivity and the second tube has less conductivity and in the other of which the relative conductivities are reversed, connections for applying input impulses to said control electrodes for shifting the greater conductivity condition from one discharge device to the other, and means included in such connections for inverting the polarity of alternate impulses of predetermined polarity comprising a second pair of electrode controlled electric discharge devices having their output circuits connected to the control electrodes of said first pair of electric discharge devices, their control electrodes connected in parallel to the impulse source, and their input circuits connected across an alternating current source of one-half the frequency of the impulse source.

ELLSWORTH D. COOK.