April 4, 1939. H. J. NICHOLS 2,153,202

ELECTRICAL FILTER

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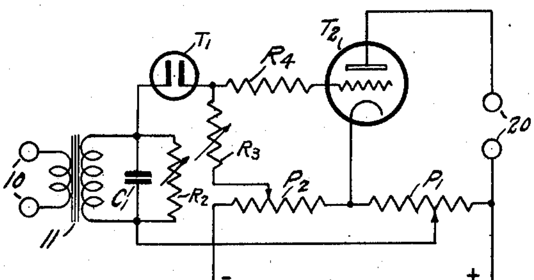


Fig. 3.

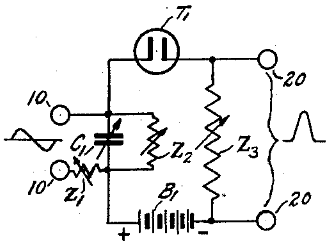


Fig. 2.

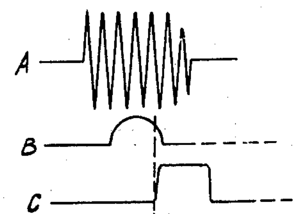


Fig. 1.

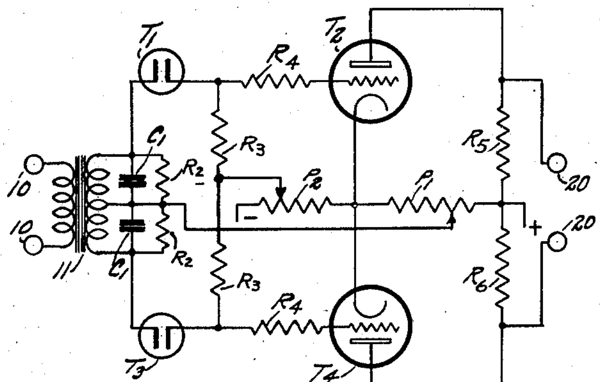


Fig. 4.

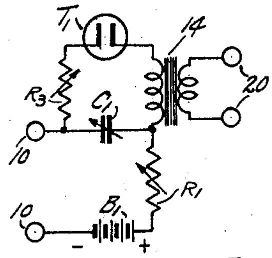


Fig. 7.

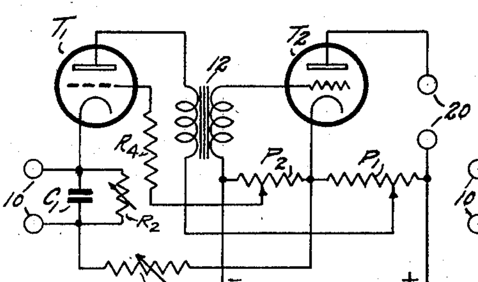


Fig. 6.

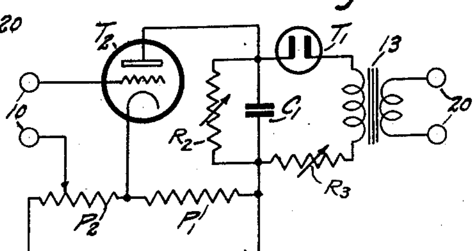


Fig. 8.

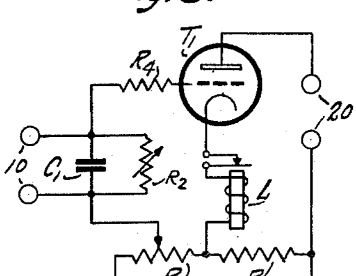


Fig. 5.

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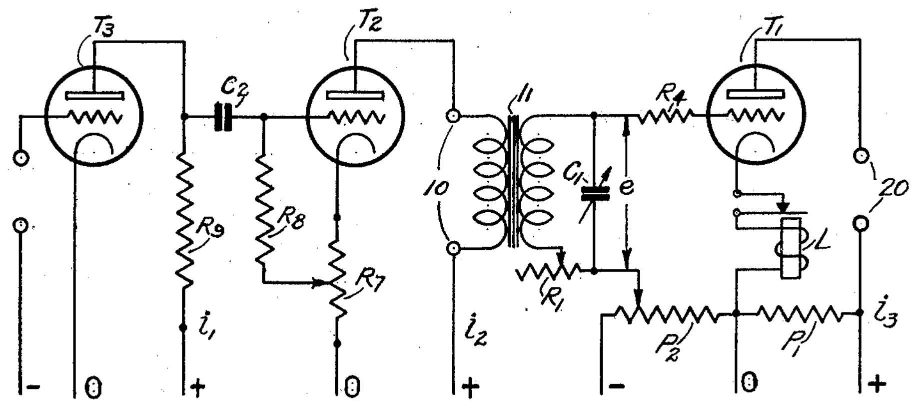


Fig. 9.

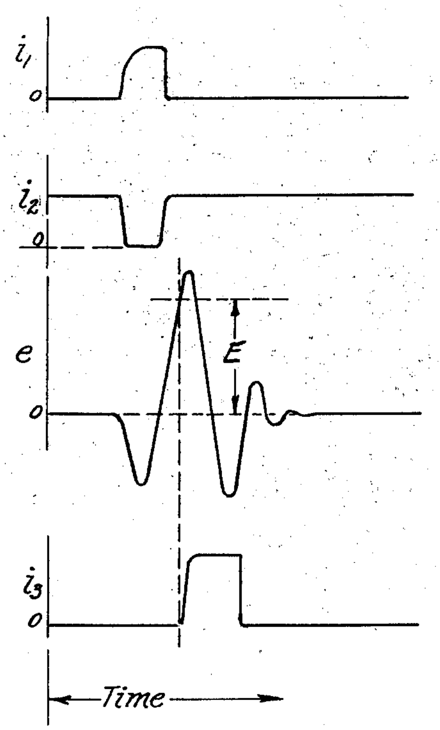


Fig. 10.

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# UNITED STATES PATENT OFFICE

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## ELECTRICAL FILTER

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Application August 17, 1934, Serial No. 740,285

4 Claims. (Cl. 178—44)

This invention relates to electrical filters and particularly to anti-interference filters for telegraph apparatus.

The invention is described mainly with reference to printing telegraph signal impulses, but it is generally applicable to the elimination of interference in impulse circuits, and in reshaping, and counting impulses.

In the operation of printing telegraph apparatus over radio systems, it is particularly desirable to eliminate the effects of static and other forms of interference before they reach the printing telegraph apparatus since not only are erroneous characters printed, but faulty operation of the printing apparatus as to shifting, carriage return, piling up of typebars, etc. is also liable to occur.

It is therefore a general object of the invention to eliminate the undesired effects above mentioned, and thus to minimize the chance of improper operation.

A further object is to provide a filter effective to eliminate unwanted interference and which will at the same time amplify the desired signals.

A further object is to provide means for reshaping and grouping impulses.

Other objects and features will be in part obvious and in part hereinafter pointed out in connection with the following description, the accompanying drawings, and the appended claims.

In the drawings,

Fig. 1 shows in graphic form the general character of interference signals, the signal impulses, and the shaped output impulses respectively.

Fig. 2 shows in diagrammatic form one embodiment of the invention illustrating the basic elements and the principle of the filtering action.

Fig. 3 shows in diagrammatic form another embodiment of the invention employing the electronic filter arrangement of Fig. 2 applied to the grid circuit of a three element amplifying tube.

Fig. 4 shows a dual arrangement of the circuit shown in Fig. 3 adapted to transmit bi-directional impulses.

Fig. 5 shows an embodiment of the invention employing a gaseous-discharge triode applied to the grid circuit of a three element amplifying tube.

Fig. 6 shows another embodiment of the invention utilizing a grid-controlled, gaseous-discharge tube of the triode type.

Fig. 7 shows another embodiment of the invention which may be used as a timed signal excluding device to group or count periodic signal impulses.

Fig. 8 shows a filter arrangement in accordance with the invention, adapted to group or count periodic signal impulses.

Fig. 9 shows a circuit arrangement according to the invention particularly adapted to eliminate interference signals and to amplify wanted signal impulses in a printing telegraph transmission system.

Fig. 10 illustrates graphically the currents and voltages in certain branches of the circuit arrangement shown in Fig. 9.

In the several figures, like characters represent like parts.

Referring now to Fig. 1, line A indicates graphically the general character of static or other forms of interference signals which are to be eliminated, and will be referred to as the unwanted or interference signals. Such signals are characteristically of varying frequency and amplitude, but their frequency is ordinarily of a higher order than the equivalent frequency of printing telegraph signals. Line B indicates generally the incoming signal impulses, referred to as the wanted signals, which are to be passed on in amplified form. Line C indicates an amplified, regenerated or "squared" impulse as passed on by the filter-amplifier to the output circuit and will be referred to as the outgoing impulse.

Referring now to Fig. 2 in detail, the basic arrangement of the invention comprises a signal receiving input circuit designated by numeral 10, an integrating or filtering capacitor C1 across the terminals of which are applied electrical variations representing the received signals, impedance Z1 representing the equivalent series impedance of the input circuit to C1, impedance Z2 representing the parallel impedance across C1, a relay device T1, current limiting means Z3 controlling the discharge of current through T1, a steady potential source of electrical energy represented by B1, and an output circuit 20.

T1 is preferably an electronic relay device such as a gaseous discharge tube or a vacuum tube biased to or below cut-off, but may be any relay device which operates to energize an output circuit upon the application of a predetermined threshold potential to its input circuit. Because of the low energy requirement for actuation, its quick response, and possible high amplification factor, a gaseous discharge tube is the preferred relay device.

The voltage of B1 is preferably less than the operating or break-down voltage of T1, this voltage difference being referred to for convenience as the voltage margin.

As previously stated, Z1 represents the equivalent series impedance of the input circuit to C1 including the fixed impedance of associated circuits and apparatus and any variable impedance added for corrective or control purposes. Likewise, Z2 represents the parallel impedance across C1 including any variable additions for control purposes. Z1 is always a material factor in the filtering action, while Z2 may in some cases be a negligible factor. The variable impedance additions may be omitted, especially in established applications, but it is usually found preferable to have a variable component of either Z1 or Z2, or both, to facilitate precise adjustment of the filtering action.

The values of C1 and Z1, and Z2 if present, should be suitable to the duration of the wanted signal impulses, since the filtering action is mainly dependent upon the time constant of the input circuit including C1. It is to be observed that increasing Z1 increases the time of charging C1, while increasing Z2 has the opposite effect, hence Z1 and Z2 are complementary in action. Until T1 is energized, the output circuit is virtually isolated from the input circuit, hence the effect of the output circuit on the filtering action is usually negligible.

Z3 represents in general the means used to limit the duration and/or amplitude of the outgoing impulses, and may comprise a limiting impedance, or may include a relay or other cut-off means adapted to terminate the outgoing impulses after a predetermined interval.

The operation of the arrangement shown in Fig. 2 is as follows: Assume first that intermittent trains of interference signals are being applied to the input circuit. Their effect is to charge C1 in varying degree depending mainly upon the capacitance of C1, the impedances Z1, Z2, and the amplitude and duration of the signal waves composing the train. Only the positive portions of the waves tend to charge C1 in a direction to aid B1, and during intervening negative portions of the waves, C1 is charged in opposition to B1. Furthermore, the effect of C1, Z1 and Z2 is to smooth out potential variations in the input circuit, and such smoothing effect is more pronounced in respect to waves of high frequency. Hence so long as a single positive wave does not charge C1 above the voltage margin, T1 remains un-ionized and no signals appear in the output circuit. Signals of brief duration, even though of high amplitude, may be effectively filtered out by the arrangement shown.

Assume next that a signal impulse as illustrated by line B1 of Fig. 1, either alone or as a mixed signal containing interference signals, is applied to input circuit 10. In this case C1 is charged mainly in a positive direction, and after an interval its potential is raised above the voltage margin and T1 is "tripped" or ionized. It is a characteristic of gaseous-discharge tubes that when ionized the cathode-anode impedance is greatly lowered, and a comparatively large current may be caused to flow in the cathode-anode circuit. Such flow of current may be effectively regulated by the discharge limiting impedance Z3 (assuming that the output circuit is of comparatively high impedance), and under suitable conditions Z3 will also cause T1 to de-ionize or cut-off after an interval. By proper selection of circuit constants, the outgoing impulse may be caused to have a square top, as indicated by line C of Fig. 1, and the outgoing impulse may be of greater amplitude and duration than the incoming signal. Such amplified, "squared" impulses are particularly desirable in the operation of various types of telegraphic instruments.

Various characteristics and adjustments of the basic arrangement shown are available to control its filtering action, to obtain amplification, and to control the shape and duration of the outgoing impulse. The manner of manipulating these factors to obtain desired results in particular applications will be evident to those skilled in the art, and therefore does not require detailed discussion.

Referring now to Fig. 3, the basic arrangement of Fig. 2 is shown as applied to the grid circuit of a three-element vacuum amplifier tube T2 of conventional type having an anode or plate, cathode, and control grid. The input circuit 10 is shown as coupled to the filter arrangement comprising integrating capacitor C1 and timing resistor R2 by means of transformer 11, although other coupling means may be employed if desired. A grid suppressor resistor R4 is connected in series with the grid of T2 to limit the grid current on positive swings and to eliminate the possibility of T1 being held ionized by current flowing through the cathode to grid circuit of T2. A potentiometer P1 provides a steady potential for the plate circuit of T2 and for T1, while potentiometer P2 provides a negative bias for the grid of T2.

The operation of the circuit is as follows: Assume that potentiometer P1 is adjusted to provide a potential somewhat below the breakdown voltage to T1, and potentiometer P2 is adjusted to bias T2 to the cutoff point. Under the assumed conditions, the plate current of T2 flowing through the output circuit 20 is negligible. Now assume that a signal impulse of the proper amplitude and duration is applied to the input circuit 10, charging C1 positively in excess of the voltage margin, thus causing T1 to become ionized. Current flows from P1 through C1, T1, R3 and return to P1 via P2. T1 being of low impedance when ionized, the potential at the junction of R3 and R4, and hence at the grid of T2, becomes more positive and remains so until C1 becomes charged sufficiently to cause T1 to cut off, restoring initial conditions. Plate current flows through T2 so long as the grid of T2 is positive relative to the cut-off point, causing a current pulse to flow in output circuit 20. Due to the operation of the C1—R2 combination, signals not meeting the requirements as to amplitude and duration are excluded from the output circuit. Hence, as in the arrangement shown in Fig. 1, unwanted signals do not appear in the output circuit, while wanted signal impulses appear in the output circuit in amplified form, and reshaped, if desired. It will be understood that a double amplification of the wanted signals may be obtained, the first amplification resulting from the ability of T1 when ionized to swing the grid of T2 to a more positive degree than that due to the input signal impulses alone, while the second amplification results from the amplifying properties of T2. The overall amplification factor is the product of the amplification factors of T1 and T2.

By adjustment of R3 various wave forms for the output signal impulses may be obtained.

Referring now to Fig. 4, the arrangement shown is a symmetrical, dual arrangement of the circuit of Fig. 3 adapted to filter and amplify both positive and negative signal impulses, T1 and T2 being responsive to positive impulses and T3 and T4 to negative impulses or vice versa. The operation of each half of the dual arrangement is similar to the circuit of Fig. 3, and will be manifest from the description thereof. Resistors R5 and R6 are shunted across output circuit 20 in order to produce single positive and negative outgoing impulses.

Referring now to Fig. 5, T1 is a grid-controlled, gaseous-discharge tube of triode type having a cathode, grid, and anode or plate. In this type of tube, the breakdown voltage is mainly a function of the potential of the grid, while the tube-drop voltage when ionized is comparatively low, being usually of the order of 15 to 25 volts. The grid is provided with a suitable bias by potentiometer P2, while a suitable plate voltage is provided by potentiometer P1. Since the grid of this type of tube loses control when the tube is ionized and is normally unable to cause the tube to cut off, separate cut-off means must be provided. The preferred means is a cut-off relay L connected in the anode-cathode circuit as shown, although other alternative means may be employed. The filter arrangement comprises integrating capacitor C1 and timing resistor R2 whose operation is identical with that described in connection with prior figures, and hence does not require further description. The function of resistor R4 is to limit the grid current when tube T1 becomes ionized. The grid has a negligible effect on the flow of plate current, hence the amplitude and form of the output impulse must be controlled by the output circuit, while the duration is controlled by the cutting off of the plate current by relay L. Since L performs the function of limiting the duration of the outgoing impulse, it is equivalent in function to R3 in the other arrangements.

The arrangement shown in Fig. 5 is characterized by the high amplification factor and heavy plate current obtainable.

Referring to Fig. 6, T1 is a grid-controlled gaseous-discharge triode, similar to T1 of Fig. 5, but preferably of lower current rating. A triode amplifier tube T2 of vacuum type, has its grid circuit coupled to the plate circuit of T1 by means of transformer 12. Potentiometer P2 supplies a steady grid bias to T1 and T2, while potentiometer P1 supplies plate potential to both tubes. T2 is preferably biased to cut-off, while T1 is biased in such manner that the potential rise of C1 due to the wanted signal impulses will exceed the voltage margin between the voltage supplied by P1 and the breakdown voltage of T1. The filter arrangement comprising integrating capacitor C1 and timing resistor R2 is preferably connected in the cathode-plate circuit of T1 as shown. Limiting resistor R3 is connected in the same circuit and assists capacitor C1 in cutting off the discharge current of T1. Limiting resistor R3 should be of relatively high value in order to cooperate with C1 and R2 in their cutoff action.

The operation is as follows: The wanted signals raise the potential of C1 above the voltage margin causing T1 to ionize; unwanted signals are filtered out by the C1—R2 combination as before. When T1 becomes ionized and conducting, the ionization current flows through the primary of transformer 12, the secondary of which swings the potential on the grid of T2 causing a current pulse in the plate circuit of T2, and hence in the output circuit 20. The flow of current in the cathode-anode circuit of T1 charges C1 until the back E. M. F. across C1 plus the IR drop across R3 causes T1 to cut off. It is to be observed that the wave form and duration of the outgoing impulse are under the control of the grid of T2, which in turn is controlled by the secondary voltage of transformer 12. There is therefore no direct relation between the impulses in the input and output circuits, and a wide variety of output impulse forms, together with high amplification, may be obtained. Since the breakdown voltage of T1 is closely controlled by the bias on the grid of T1, the voltage margin may be adjusted within close limits.

Referring now to Fig. 7, an impulse filtering circuit is shown which is characterized by a definite exclusion period readily cariable between wide limits. The circuit comprises an input circuit 10, a timing condenser C1, a timing resistor R1 connected in series therewith as shown, a gaseous discharge tube T1, and discharge limiting resistor R3. A transformer 14 or other coupling device, is connected in series with T1 in such manner as to cause an impulse to appear in output circuit 20 when T1 is passing current. C1 is connected across the circuit containing T1 and both are held at a potential somewhat below the breakdown voltage of T1 by a battery B1 or other source of constant potential.

The operation is as follows: Assume that uniform periodic impulses of magnitude just adequate to charge C1 above the voltage margin are impressed in aiding manner on the input circuit. T1 will be tripped by the first impulse and C1 will discharge through T1 down to the cutoff voltage of T1, whereupon T1 will be de-ionized. The discharge current of C1 through T1 will produce a brief impulse in the output circuit the form and duration of which is mainly controlled by R3. The discharge of C1 drops the voltage across T1, thereby materially increasing the voltage margin; hence if succeeding impulses arrive before the normal voltage margin is restored by the recharging of C1, T1 is not tripped, and such impulses are not transmitted to the output circuit. The charging rate of C1 is controlled by R1, hence if R1 is large, a considerable interval may be made to occur before C1 is again charged sufficiently to restore the normal voltage margin and permit T1 to be tripped by the signal impulses. By varying R1, the number of impulses missed before the tripping of T1 and the consequent passing of an impulse to the output circuit may be selected at will over a considerable range, which range may be further extended by varying C1. Since the elements controlling the charging of C1 are of stable character, the ratio of passed to excluded signals when established remains constant, provided the input signals are substantially uniform, and the circuit shown may be used to group or count periodic impulses or waves which are too rapid in occurrence for ordinary counting methods. The input signals may, for example, be produced by a photo-electric counting device actuated by rapidly moving objects, or by other preferred means generating uniform rapid impulses.

Referring next to Fig. 8, T2 is a vacuum tube biased below cutoff by potentiometer P2 via input circuit 10. In the plate circuit of T2 is a filter arrangement which comprises a capacitor C1, timing resistor R2, gaseous discharge tube T1, discharge limiting resistor R3, and output transformer 13. Potentiometer P1 supplies potential to the place circuit of T2.

The general operation of the circuit is as follows: Since T2 is biased below cutoff, the plate current which normally flows through T2 is negligible, and practically all the drop through the plate circuit of T2 occurs across the internal anode-cathode circuit of T2. Hence very little voltage exists across C1—R2, and T1 in shunt therewith. Now assume that a signal of sufficient amplitude to raise the grid of T2 above cutoff is applied to input circuit 10. The impedance of T2 is thus lowered, and plate current begins to flow, charging C1. The charging of C1 continues until its potential is raised above the breakdown voltage of T1, whereupon T1 is tripped and current flows therethrough until the voltage across its terminals falls below the cutoff voltage of T1. Since the primary of transformer 13 is in series with T1, an impulse is produced in output circuit 20 during the current discharge through T1, the wave form being dependent in part upon the electrical constants of the circuits, including transformer 13. The duration of this discharge may be controlled by adjustment of R3.

In case the signal applied to input circuit 10 is not of sufficient amplitude and duration to permit sufficient current to flow through T2 to cause C1 to be charged sufficiently to trip T1, no output impulse occurs between incoming signal impulses, and the charge on C1 leaks off through R2. Hence a filtering action similar to that provided by the arrangement shown in Fig. 1 is obtained.

Another type of action similar to that of the arrangement shown in Fig. 7 may be obtained by suitable adjustment of the circuit constants. Assume that a series of periodic impulses are applied to input circuit 10, each impulse being of sufficient magnitude to raise the grid of T2 above the cutoff point, but not of sufficient magnitude to charge C1 above the voltage margin. Under such conditions each impulse causes T2 to add an increment of charge to C1, part of which charge leaks off through R2 during the interval between impulses. After a certain number of such impulses, T1 is tripped and an impulse is transmitted to output circuit 20. It is thus evident that the arrangement shown in Fig. 8 can be caused to group or count rapid periodic impulses in the same manner as the arrangement shown in Fig. 7. Furthermore, the arrangement shown in Fig. 7 may be connected between the original impulse source and the arrangement shown in Fig. 8, thus providing a cascaded counting circuit of high ratio.

Referring now to Fig. 9, the arrangement of Fig. 5 is shown as applied to the receiving circuit of a single impulse printing telegraph system. Three stages of the receiving circuit are shown, namely the rectifier stage, limiting stage, and filter-amplifier stage, associated with electron tubes T3, T2, and T1 respectively.

T3 is shown as a triode vacuum tube, but represents any rectifier device. Its function is to apply unidirectional voltage variations to the grid of limiting tube T2, and may be omitted when unidirectional voltage variations are otherwise obtained. T3 is preferably supplied with a negative bias normally holding the grid at or near the cut-off potential, hence the plate current flowing through load resistor R9 is increased by received signals.

T2 is preferably a vacuum tube biased to provide a certain normal level of plate current, and has its grid circuit so coupled to rectifier tube T3 that an increase of plate current in T3 causes the plate current in T2 to fall below the normal level. As shown, T2 is self biased by cathode resistor R7, although other well known means may be used. C2 is the coupling condenser between the plate circuit of T3 and the grid circuit of T2, and R8 is the grid leak resistor for T2.

T1 is a triode gas discharge tube similar to that described in connection with Fig. 5. The input circuit to the grid of T1 is preferably coupled to the plate circuit of T2 by means of transformer 11. The input circuit of T1 thus comprises the secondary of transformer 11, integrating condenser C1, and resistor R1. For reasons presently to be described, the natural period of this circuit when connected as shown is preferably made twice the duration of the wanted signal impulses. The grid T1 is held at proper normal bias by potentiometer P2, while potentiometer P1 provides a steady source of potential for the anode-cathode circuit of T1. R4 is a grid current limiting resistor, while L is a cut-off relay, all as described in connection with Fig. 5.

The operation of the arrangement is as follows: The incoming signals, including interference signals, are applied to rectifier tube T3, and produce increased plate current through R9. The rise in current in R9 in response to incoming signal impulses is shown graphically as $i_1$ in the first line of Fig. 10. An increase in current through R9 causes a drop in potential at the connection of C2 with the plate circuit of T3, hence the grid of T2 is made more negative, and the plate current flowing through the primary of transformer 11 is diminished as indicated by $i_2$ of Fig. 10. It is to be noted that since $i_2$ can only vary between the normal value and zero, the current variations through the primary of 11 are limited to a certain range regardless of the strength of the signals rectified by T3, hence the designation of T2 as the limiting tube.

The input circuit to T1, having inductance and capacitance, is oscillatory in nature, and the voltage across C1 due to a current variation in the primary of 11 as indicated by $i_2$ will be of the general form indicated by $e$ of Fig. 10. It is well established that when an oscillatory circuit is excited by an impulse of the proper duration in relation to its natural period, the second alternation of the voltage surge across the capacitance may exceed the first alternation in amplitude, the theoretical limit being twice the amplitude of the first alternation. The secondary of transformer 11 is so connected to the input circuit that the first alternation produces a charge on C1 in a direction opposing the tripping of T1, while the second alternation is in an aiding direction. Referring to Fig. 10, let E represent the voltage margin, then when $e$ becomes equal to E, T1 is ionized or tripped. $i_3$ represents the outgoing impulse produced by tripping T1, and it will be observed that this impulse occurs after the expiration of the signal impulse.

Established theory shows that when the ratio of the duration of the exciting impulse to the natural period of an undamped oscillatory circuit is within the limits of .2 to .8, the second alternation will exceed the first alternation in amplitude. Damping of the circuit due to resistance will narrow the range of this ratio somewhat, and in practice it can be taken as a basis of design that the natural period of the input circuit to T1 should be approximately twice the duration of the wanted signal impulses. While R1 has some effect on the natural period of the input circuit, the main function of R1 is to provide a means of controlling the damping of the input circuit, and in established applications may be omitted, the correct amount of damping being obtained by proper design of transformer 11.

The arrangement shown in Fig. 9 is effective in filtering out interference signals of different time characteristics than the wanted signals even if much stronger than the wanted signal impulses since all signals are limited in effect by limiting tube T2, and signals materially differing in time characteristics from the wanted signal impulses will not produce sufficient voltage across C1 to trip T1. Limiting tube T2 also acts as an automatic volume control, and can be adjusted so that signal impulses weakened by fading or by other causes will be effective to trigger T1.

The arrangement shown in Fig. 9 is particularly adapted to printing telegraph systems operated over radio or carrier frequency channels.

It is to be observed that the various embodiments of the invention possess in common an integrating capacitor C1, a timing impedance Z1 controlling the charging of C1, a gaseous-discharge tube T1, a discharge limiting device Z3 controlling the discharge of T1, and a steady potential source. Also that each arrangement is capable of exercising a filtering or selective action on the signals passing therethrough, and is capable of amplifying the incoming signal. The arrangements shown also provide means for producing outgoing impulses of a wide variety of shapes and durations at will.

In the various arrangements, the impedance of the input circuit to C1 has an effect on the action of that combination, and in some instances, the input circuits may in themselves have sufficient capacity or impedance so that a separate timing element is not required. By the well understood principle of equivalent circuits it is clear, however, that such instances are special cases of the basic circuits herein disclosed, in which C and Z represent the equivalent capacitance and impedance of the input circuit, however distributed. In like manner, the function of discharge limiting impedance Z3 may in some instances be embodied in the output coupling device or circuit, and in such cases Z3 represents the equivalent discharge limiting device applied to gaseous discharge tube T1.

What is claimed is:

1. An electronic filter system comprising an input circuit receiving electrical signals, capacitor means charged responsively to said electrical signals, means for controlling the charging of said capacitor means, a gaseous discharge electronic tube energizable upon the application, to said capacitor means, of a predetermined potential, a steady potential source of electrical energy for supplying energy to said electronic tube, a discharge circuit for said electronic tube, and control means for limiting the current discharge through said discharge circuit, said control means comprising a discharge circuit cut-off relay.

2. An electrical impulse filter arrangement comprising an input circuit including a normally unexcited oscillatory circuit, an electron discharge device having an input and output circuit associated therewith, a grid control element included in the input circuit and means normally to bias the grid element to render the device non-conductive, and means to impress the discharge of the oscillatory circuit upon the input circuit of the device upon excitation of the oscillatory circuit by signal conditions includng means whereby the second alternation of the oscillatory circuit discharge is effective solely to overcome the bias of the grid element thereby rendering the electron discharge device conductive.

3. An electrical impulse filter arrangement comprising an input circuit including a normally unexcited oscillatory circuit, an electron discharge device having an input and output circuit associated therewith, said device being characterized by continued operation unaffected by grid potential after starting, means to impress normally a grid bias potential upon the device to render it non-conductive, means to impress the discharge of the oscillatory circuit upon the input circuit of the device upon excitation of the oscillatory circuit by signal conditions including means whereby the second alternation of the oscillatory circuit discharge is effective solely to overcome the grid bias potential thereby rendering the electron discharge device conductive, and means in the output circuit of the device to restore the device upon operation thereof to a non-conductive state.

4. The invention set forth in claim 3 wherein the last mentioned means comprises relay means.

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