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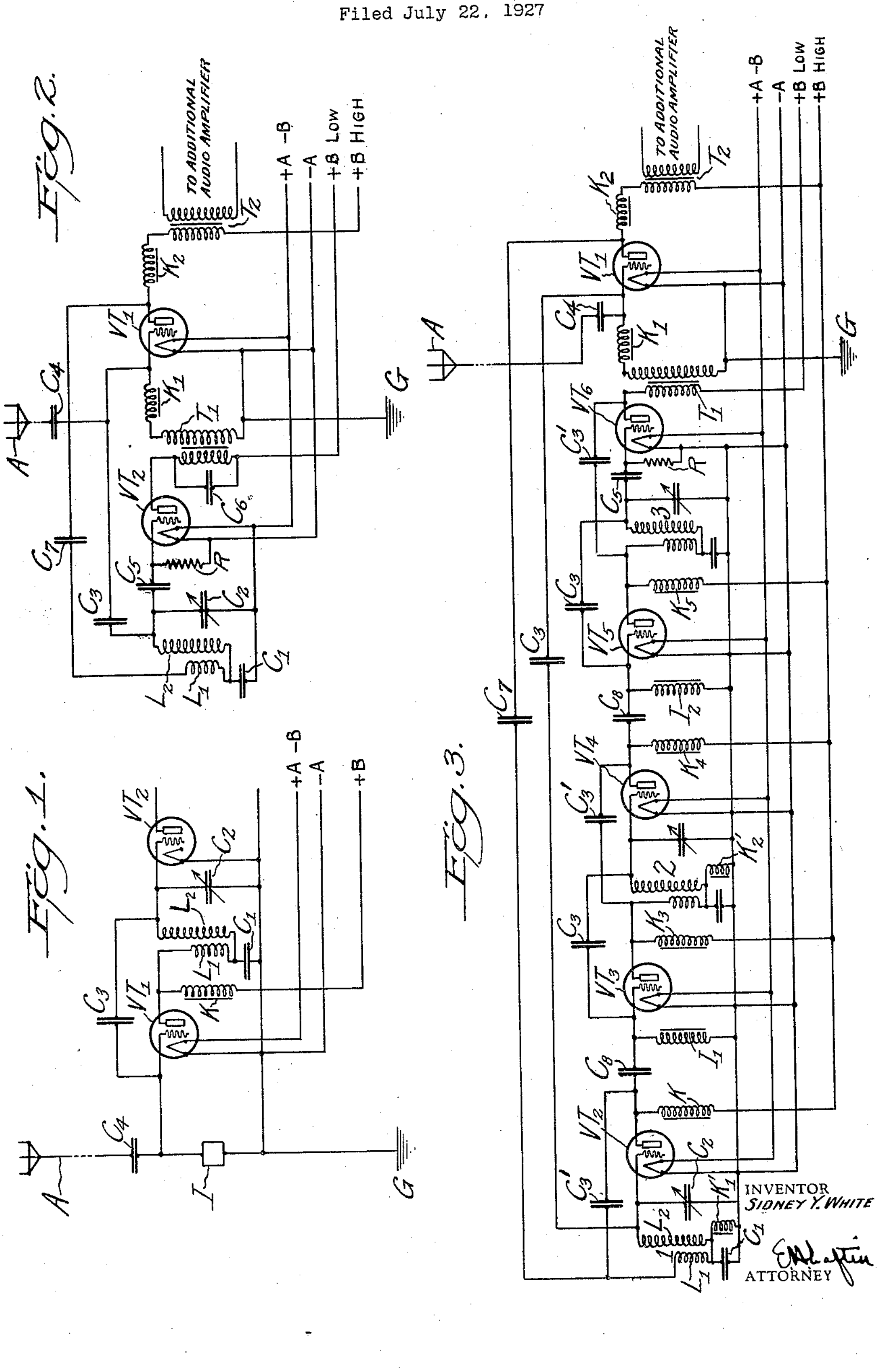

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AMPLIFIER SYSTEM, METHOD, AND APPARATUS

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While my invention relates generally to amplifier systems, it has for a particular object the selective amplification of more or less high frequency alternating currents in systems employing three electrode vacuum tube or like amplifying devices.

An object is to secure selective amplification over a wide range of frequencies while employing a minimum of variable period apparatus and a substantial amount of non-selective apparatus. A further object is to secure a high order of amplification with a minimum of apparatus.

Another object is to secure more or less uniform amplification over a very wide range of frequencies, such as the range employed in radio broadcasting.

A still further object is to obtain a very high order of amplification on a one-frequency basis at high frequency without developing the unstable conditions heretofore accompanying such attempts.

Other uses and benefits of my invention will be obvious to those skilled in the art from the following description and accompanying drawings, in which Fig. 1 diagrammatically illustrates a simple application of my invention that lends itself to ready explanation. Fig. 2 diagrammatically illustrates another application of unique form to a radio receiver. Fig. 3 shows a combination of uses in a more or less elaborate and highly efficient form of radio receiver. Like reference symbols represent like parts as far as possible throughout the several figures.

In Fig. 1 a source of more or less wide range of high frequency alternating currents, indicated as an ordinary radio receiving antenna A grounded at G, is shown coupled to the input electrodes of a three-electrode vacuum tube VT_1 through an indicated non-selective impedance I, which may therefore be a resistance, a condenser, or a so-called choke or capacitively reacting coil, and therefore substantially equally non-selective for all frequencies of a given wide range of radio frequencies. The tube is indicated as energized for operation from sources +A −B, −A and +B in a manner too well known to require explanation, the anode of tube VT_1 being energized through a choke coil K to more or less confine high frequency currents to other circuit paths of the system.

A second tube VT_2 is shown coupled to the output circuit of the first tube through a variable period circuit L_2C_2, and a combined electromagnetic and electrostatic coupling including the inductive relation between coils L_1 and L_2 and the coupling condenser C_1, by means of which combined coupling the coupling relation can be controlled in any desired manner with frequency, and the reaction of the variable circuit on the output circuit also so controlled, as more fully described in my copending applications Serial Nos. 48,936 of August 8, 1925, and 49,521 of August 11, 1925, patented November 4, 1930, No. 1,780,611. The output connections to tube VT_2 are not completed as this part of the system is not required for the present explanation.

The system as so far described is one in substantial use in radio receivers, being commonly termed a "coupling tube", and has for one object permitting the design and adjustment of the constants of variable period circuit L_2C_2 in the factory, and not having the circuit thereafter materially disturbed by whatever length and disposition of antenna the ultimate user of the receiver may employ, as would be the case if the antenna were more or less directly associated with the variable circuit. This precaution is of particular importance in the present day practice of providing so-called "single dial" control for a plurality of such variable circuits included in the same system.

It is quite generally recognized that this coupling tube, with its non-selective input, adds nothing to the over-all amplification of the system. In fact, it generally imposes a slight loss in amplification over that which would be obtained by efficiently associating the antenna more or less directly with the variable circuit.

It is the purpose of my invention to overcome this difficulty such that the coupling tube can be called upon for the additional function of materially and selectively amplifying in spite of the non-selective coupling impedance, and I accomplish this result by the simple expedient of connecting the grid lead of coupling tube VT_1 to a point of suitable potential and polarity in variable circuit L_2C_2 through condenser C_3, it being possible to choose the polarity relation between coils L_1 and L_2 such that this can be done, which relation happily happens to be that required for the electromagnetic and electrostatic energy transfers in the combined coupling to be assisting, the condition necessary to employing this coupling in its invaluable ability to secure uniform results over a remarkably wide range of frequencies. In fact I find that to attempt to cover the radio broadcast band with any degree of effectiveness without this so-called "constant coupling" effect would be hopelessly impossible.

By adjusting the relative values of condenser C_3 and the combined coupling I find that I can secure any degree of selective amplification desired, as variable condenser C_2 is operated, from below the natural amplifying ability of the tube even through to oscillation generation, and by properly adjusting the combined coupling can keep the degree of amplification constant with frequency, or vary it in any predetermined way. It so happens that for a coupling that provides a suitable practical energy transfer from tube VT_1 to VT_2 I can rely on adjustment of condenser C_3 to obtain the degree of amplification desired, so that my addition to the system does not interfere with its normal operation. For good radio broadcast reception I do not recommend an amplification beyond the natural amplification of the tube, this to avoid the distortion that accompanies regenerative amplification.

It will be noted that the addition of condenser C_3 couples the variable period circuit L_2C_2 somewhat more closely to the antenna system than would be had through the internal capacity of the tube alone, so that in cases where influences due to varying antenna conditions are important it is desirable to insert a condenser C_4 of more or less small capacity in the antenna. Such a condenser will slightly reduce the efficiency, but with the gain due to making the tube effectively amplifying this precaution can well be afforded.

Fig. 2 illustrates an adaptation of my present invention to the invention contained in my copending application, Serial No. 24,088 of April 18, 1925. In that application I provided for the use of one of the tubes of the audio frequency portion of a radio receiver as a coupling tube for the radio frequency portion without any suggestion for securing useful or selective amplification of the radio frequency currents in the audio stage. In Fig. 2 such result is had, thereby giving a triple function to the one tube, namely, audio amplification, coupling tube and selective radio amplification.

In Fig. 2 tube VT_1 is shown as the first audio tube of the audio system coupled to the radio system including tube VT_2 through indicated audio frequency transformer T_1, the primary of which is shown by-passed by the usual condenser C_6. The antenna A, grounded at G, is shown connected across the secondary of audio transformer T_1, which should preferably have a radio frequency choke K_1 in series if the distributed capacity of the secondary does not offer sufficient reactance. There is thus provided for audio tube VT_1 a non-selective impedance input for radio frequency currents. The output circuit includes a radio frequency choke k_2 if the primary of audio frequency transformer T_2 does not offer sufficient impedance to radio frequency current flow to make the choke unnecessary. The impedance so created in the output circuit forces the radio frequency currents through the path including condenser C_7 and a coupling, preferably combined electromagnetic and electrostatic, with variable period circuit L_2C_2, the radio frequency currents being thus selectively delivered to tube VT_2, which is indicated as connected to operate as a rectifier by reason of grid condenser C_5, grid leak R, and low anode exciting potential, all as well understood in the art. The modulations of the rectified radio frequency currents are filtered through audio transformer T_1, and pass forward without appreciable opposition from radio frequency choke K_1 to be amplified by tube VT_1, and passed on, or otherwise utilized, through transformer T_2. The tubes are indicated as energized in the manner mentioned in connection with Fig. 1.

So far as described the system is substantially the same as that of my copending application referred to. It will be noted that, as in the case of Fig. 1, I connect a condenser C_3 between the grid lead of the non-selective input tube, in this case the first audio tube, and the variable period circuit L_2C_2 which is constant coupled to the output system of the first audio tube. By adjusting as before described I can secure the same described selective amplification effects for the radio frequency currents in this audio stage tube. In a system of this type it is particularly desirable to include a condenser C_4 in the antenna to reduce any low frequency disturbances which the antenna might be subject to, such as location near a power transmission line. Without such precaution the low frequency disturbances would be impressed directly into the audio amplifying system and be sufficiently amplified to be annoying. Using the last audio tube as the coupling tube would aid to minimize this effect.

Fig. 3 shows diagrammatically an arrangement for a radio receiver to obtain an extremely high degree of selective amplification at any one of a wide range of frequencies, such as a broadcast receiver, embodying for this purpose the present invention as illustrated in both Figs. 1 and 2, combined electromagnetic and electrostatic coupling for constant coupling and constant amplification control, as well as the arrangement disclosed in a copending joint application of E. H. Loftin and myself Serial No. 207,618 of July 22, 1927, for securing selective amplification in a system of two vacuum tubes linked through a non-selective impedance. It adds the further feature of improving the performance of the detector stage tube in a manner to be later described.

The diagram well illustrates the simplified form to which the system can be reduced and yet contain so many features contributing towards high selective amplification without operating interferences, and in addition maintain this performance over an extremely wide band of frequencies with stable operation and a minimum of variable period circuits so electrically disposed as not to suffer undue disturbing influences from each other, the operator or the antenna with which used. Such a receiver is ideally adapted to the severest of all construction problems in radio, namely "single dial control".

Tube VT_1 may be any audio frequency stage tube, but is shown in Fig. 3 as the first stage. This tube is so associated with antenna A and variable period circuit L_2C_2 that it selectively amplifies and delivers radio frequency currents to first radio frequency tube VT_2 in the manner fully described in connection with Fig. 2. Tube VT_2 is coupled to tube VT_3 through non-selective impedance I_1, shown as a choke coil, and by reason of the coupling of its output circuit to variable period circuit L_2C_2 through condenser C'_3 and combined electromagnetic and electrostatic coupling shown, its plate circuit reactance is selectively controlled with frequency to overcome the capacitive reactance of impedance I_1 to cause this tube to selectively amplify the desired signal, as more fully described in the copending application previously referred to, and thus deliver twice selectively amplified desired signal energy to tube VT_3. At this point the system of my present invention, explained in connection with Fig. 1, is injected into the system. Tube VT_3 has a non-selective input in the form of non-selective impedance I_1, but a variable circuit 2 is coupled, as described in connection with Fig. 1, to the output of tube VT_3, and connected back to the grid lead through condenser C_3, so that this tube is made to selectively amplify the desired signal energy. Three times selectively amplified energy is therefore delivered to tube VT_4, and since tubes VT_4 and VT_5 are a repetition of the system of tubes VT_2 and VT_3, two more stages of selective amplification take place in them, thus delivering five times selectively amplified energy to tube VT_6 of the detector stage. However, I need not stop the selective amplification at this point. In general the tubes of detecting stages are operated most inefficiently from the amplifying point of view by reason of the audio transformer in the output reacting capacitively to the radio frequency currents to produce a capacitive plate circuit reactance which, acting through the tube capacity, destroys its amplifying ability. By making the same connection for tube VT_6, through condenser C'_3, to the coupling of the preceding variable circuit (circuit 3) as was done for tubes VT_2 and VT_4, a substantial degree of selective amplification can be injected through the intermediary of the detecting stage tube, thus making six steps of selective radio frequency amplification possible with but three variable circuits and four radio frequency tubes per se.

By way of comparison manufacturers of receivers having three stages of radio frequency amplification of the type having successive variable circuits linked through tubes, and requiring four such circuits for the three tubes, often claim amplification as high as eight per stage with tubes whose natural amplification average but the eight claimed. Allowing a coupling and loss factor of certainly at least 50% such claims, if true, necessarily mean that the tube is actually amplifying at least 16 times, or is operating on the highly regenerative and critical side of operation. Three stages of such amplication is equal to eight to the third power, or an overall amplification applied to the detector tube of approximately 500. In my system of Fig. 3 I can accept the natural amplification of eight of each tube, and thereby eliminate all regeneration with its distortion and instability, and accepting a loss and coupling factor of 50%, have a net gain of 4 per stage, and with the six gaining stages described the overall amplification will be the sixth power of four, or approximately 4000, a ratio of 8 to 1 in favor of my system operated under less difficult and harmful conditions. Now since the detector action is not directly proportional to the strength of the radio frequency currents, but as the square, my detected signals under the extremely stable conditions outlined will be 64 times as strong as the successive circuit system operated under decidedly critical and distorting conditions. Furthermore three stages appears to be the practical limit of the successive circuit system with any useful gain per stage. I see no theoretical or practical reason why with my system the amplification cannot be carried on indefinitely as long as well known precautions to prevent distant stage feed backs are employed, such as shielding, angulation of coils and the like.

The detector stage output is passed on to the audio system through transformers T_1 and T_2 in a conventional manner. The tubes are shown energized in well known conventional manner, choke coils K, K_3, K_4 and K_5 being used in connection with plate energizing as previously outlined. Condensers C_8 prevent the plate potential from reaching the grids of tubes VT_3 and VT_5. Choke coils K'_1 and K'_2 provide conductive grid bias paths around their respective coupling condensers. Also the variable condensers of variable circuits 1, 2 and 3 are connected to a common conductor of ground potential, satisfying a practical requirement for single dial control, and the high potential sides of these three circuits are so generously electrically isolated from each other as to substantially eliminate all of the difficulty encountered in successive circuit systems where it is the very operation of the succeeding circuit that overwhelmingly controls the amplifying ability of the tube to which the preceding circuit is connected.

No limitations are intended by reason of having described my invention in connection with radio receivers.

I claim:

1. The method of selectively highly amplifying alternating currents of a maintained one-frequency which comprises selectively amplifying said currents, non-selectively impressing said amplified currents upon the input electrodes of an amplifier, selectively absorbing at the same frequency energy of the output currents of said amplifier, and reimpressing a portion of said selectively absorbed energy upon said input electrodes.

2. The method of selectively highly amplifying alternating currents at a maintained one-frequency without deleterious reaction of succeeding selective circuits on preceding selective circuits which comprises selectively impressing said currents upon an amplifier, non-selectively transferring the amplifier output of said currents to the input electrodes of a second amplifier, selectively controlling the amplifying ability of said first amplifier to accord with the selective impressing of currents thereon, selectively absorbing the energy of the output currents of said second amplifier to accord with the preceding selective amplification in the first amplifier, reimpressing a portion of said absorbed energy upon the input electrodes of said second amplifier, and repeating the operation or any portion of it at the same frequency a desired number of times with the remainder of said selectively absorbed energy.

3. A system for amplifying alternating currents including an amplifier means connected between the input electrodes of said amplifier for non-selectively impressing said alternating currents upon the input electrodes of said amplifier, a second amplifier, a variable period circuit coupled to the output circuit of said amplifier and connected to the input electrodes of said second amplifier, and a condenser connected between the control input electrode of said amplifier and a point of such polarity in said variable circuit that a portion of the selected frequency energy in said circuit is transferred to said control electrode whereby the alternating current corresponding to said selected frequency is selectively amplified.

4. A system for amplifying alternating currents including an amplifier and means for non-selectively impressing alternating currents upon the input electrodes thereof, a variable period circuit, a two-element coupling between said variable circuit and the output circuit of said amplifier, one of said elements transferring energy increasingly with frequency increase and the other of said elements transferring energy decreasingly with frequency increase, said elements being so poled as to transfer energy in phase, and means for impressing a portion of the energy selectively absorbed by said variable period circuit upon the input electrodes of said amplifier.

5. A radio receiver including a radio frequency amplifying portion and an audio frequency amplifying portion, a radio frequency collecting antenna non-selectively connected to the input of one of the amplifiers in said audio frequency portion, a radio frequency coupling between the output circuit of said amplifier and a variable period radio frequency circuit in said radio frequency portion, and a radio frequency energy transmitting connection between the input of said audio amplifier and said variable period circuit whereby said audio amplifier is caused to selectively regeneratively amplify radio frequency currents collected on said antenna for delivery through said coupling to said radio frequency portion.

6. A system for the multiple selective amplification of alternating currents at a maintained one-frequency including an amplifier and means for non-selectively impressing the alternating currents upon the input electrodes thereof, means for selectively absorbing energy from the output circuit of said amplifier, means for delivering a portion of said selectively absorbed energy to said input electrodes, a second amplifier connected to receive the remainder of said selectively absorbed energy from said circuit, a non-selec-

tive impedance associated with the output circuit of said second amplifier to transfer energy therefrom, and means for altering the reactance upon said output circuit of said non-selective impedance in frequency consonance with the selective absorption of energy from the output circuit of said first amplifier.

7. A system for the multiple selective amplification of alternating currents at a maintained one-frequency including an amplifier, a non-selective impedance coupling said amplifier to a second amplifier, means causing said first amplifier to selectively amplify said alternating currents in spite of said non-selective impedance, and means associated with the output circuit of said second amplifier for causing selective amplification therein in consonance with the selective amplification in said first amplifier.

8. A system for multiple repeated selective amplification of alternating currents at a maintained one-frequency without deleterious reaction of succeeding selective circuits on preceding selective circuits including an amplifier, means for selectively impressing said alternating currents thereon, a second amplifier, a non-selective impedance coupling said amplifiers, means for causing said first amplifier to selectively amplify in spite of said non-selective impedance, a variable period circuit associated with the output circuit of said second amplifier, means associated with said circuit for causing said second amplifier to selectively amplify in consonance with the selective amplification of said first amplifier, and one or more additional such systems receiving initial energy from said variable period circuit to repeat the provided for multiple selective amplification.

9. In a system for selected amplification of alternating current of any one frequency over a wide range of frequencies including a pair of multi-electrode electron discharge tubes connected in cascade the method of selecting, amplifying and transferring energy of any one of the desired current frequencies which consists of non-selectively impressing the currents on the input of the first tube, selectively absorbing energy from the output currents of the first tube and impressing it upon the input electrodes of the second tube, and impressing a portion of said selectively absorbed energy on the input electrodes of said first tube.

10. A system for the selection and amplification of any one of the current frequencies of a wide range of frequencies including a multi-electrode space discharge tube, non-selective impedance means for impressing all of the current frequencies upon the input electrodes of said tube, a second tube, a variable period circuit tunable over said wide range of frequencies connected across the input electrodes of said second tube and coupled to the output circuit of said first tube, and means including a path independent of the first tube for impressing some of the selected frequency energy in said circuit back onto the input electrodes of said first tube in phase with the energy of said frequency therein.

11. A system for the selection and amplification of any one of the current frequencies of a wide range of frequencies including a three electrode vacuum tube, non-selective impedance means connected between the grid and filament of said tube for impressing all of the current frequencies upon the input electrodes of said tube, a second three electrode vacuum tube, a variable period circuit tunable over said wide range of frequencies connected across the input electrodes of said second tube and coupled to the output circuit of said first tube, and a condenser linking said circuit to the control electrode of said first tube of such value that the feed-back of energy therethrough is sufficient to produce amplification of the current frequency selected by said circuit to a desirable degree short of oscillation production.

12. A system for the selection and amplification of any one of the current frequencies of a wide range of frequencies including a three electrode vacuum tube, non-selective impedance means for impressing all of the current frequencies upon the input electrodes of said tube, a second three electrode vacuum tube, a variable period circuit tunable over said wide range of frequencies connected across the input electrodes of said second tube, an impedance linking a potential point in said circuit to the control electrode of said first tube, and a coupling between said circuit and the output circuit of said first tube including means for controlling the degree of coupling with the tuning of said circuit whereby the energy effect from frequency to frequency on the input electrodes of said second tube is controlled in a predetermined way with frequency.

13. A system for the selection and amplification of any one of the current frequencies of a wide range of frequencies including a three electrode vacuum tube, non-selective impedance means connected between the grid and filament of said tube for impressing all of the current frequencies of said range upon the input electrodes of said tube, a responsive device, a variable period circuit tunable over said wide range of frequencies associated with said responsive device and coupled to the output circuit of said tube, and an impedance means linking the control electrode of said tube to a potential point associated with said variable circuit.

14. In a system for selected amplification of alternating current of any one frequency over a wide range of frequencies including at least two space discharge devices connected in cascade, the method of selecting, amplify-

ing and transferring energy of any one of the desired current frequencies which consists in non-selectively impressing the currents on the input of the first device, selectively absorbing energy from the output currents of the first device and impressing it upon the input electrodes of the second device, and impressing a portion of said selectively absorbed energy on the input electrodes of the first device through a path independent of the latter.

In testimony whereof I affix my signature.

SIDNEY Y. WHITE.