

Sept. 28, 1943.

W. LEHFELDT

2,330,499

CONTROL CAPACITY CIRCUITS

Filed Nov. 19, 1940.

2 Sheets-Sheet 1

Fig. 1.

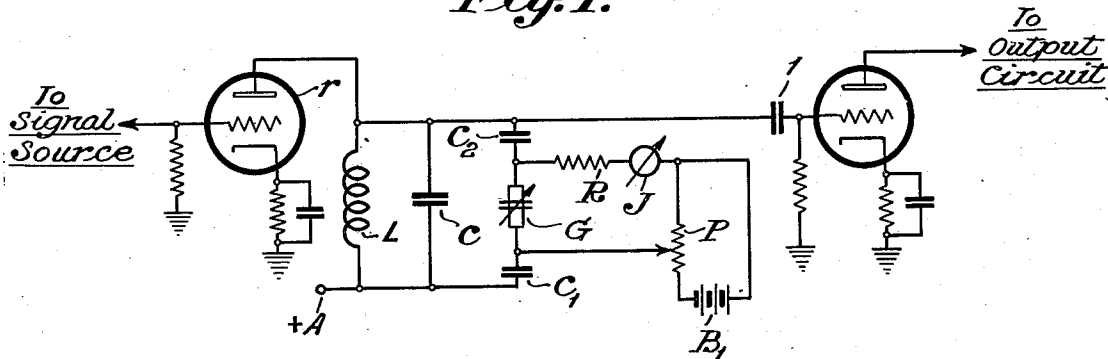


Fig. 2.

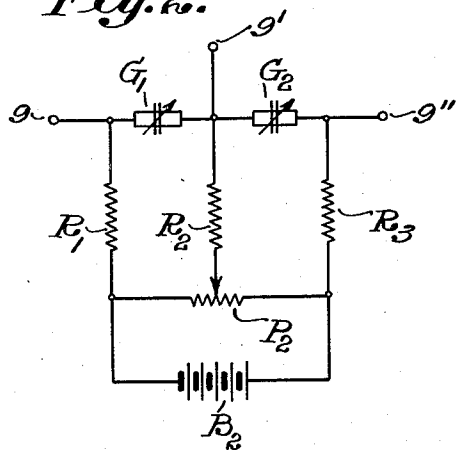


Fig. 3.

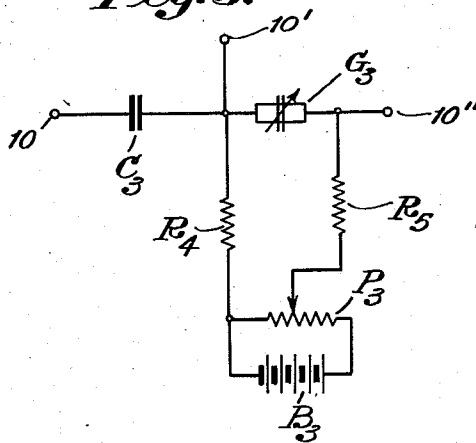
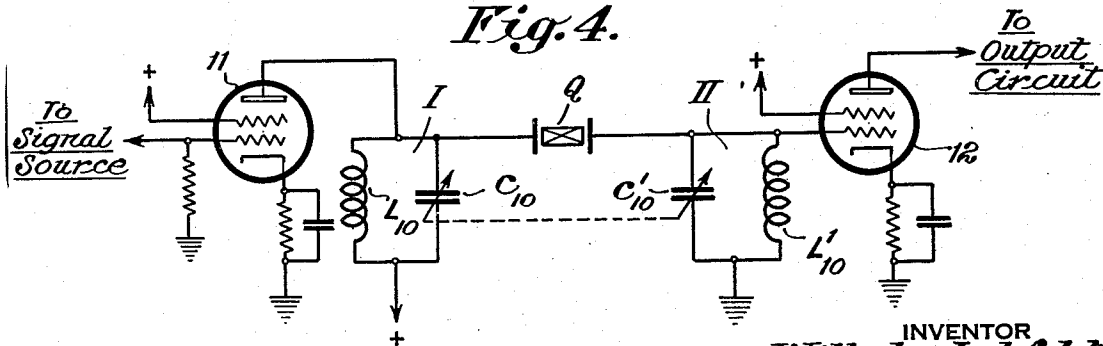


Fig. 4.



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2 Sheets-Sheet 2

Fig. 4a.

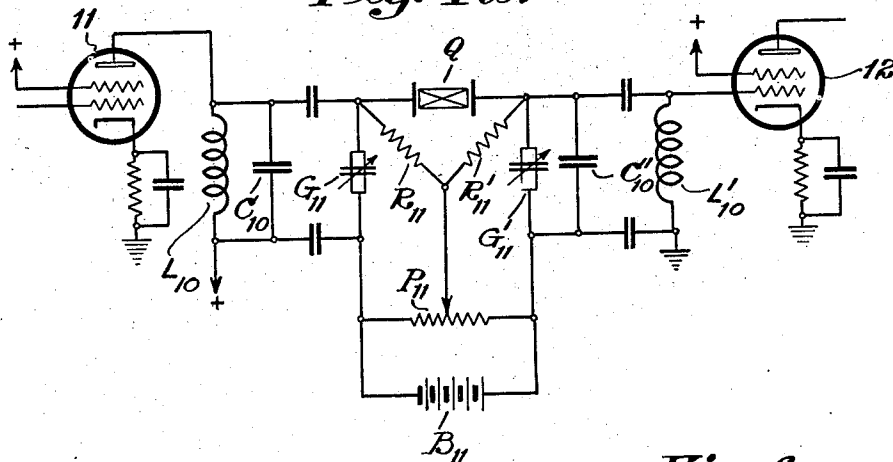


Fig. 5.

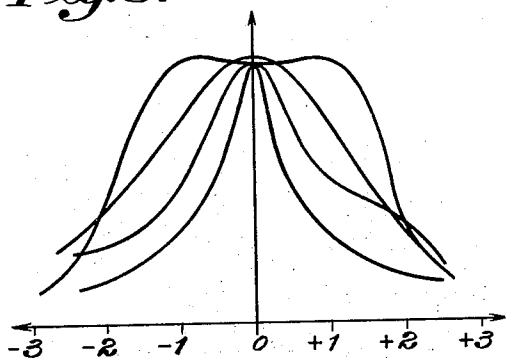


Fig. 6.

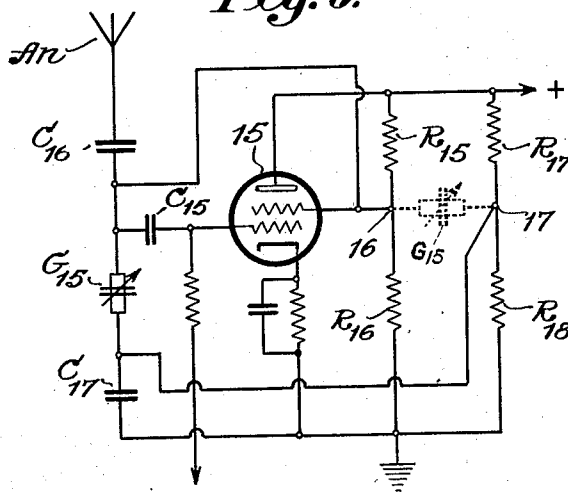
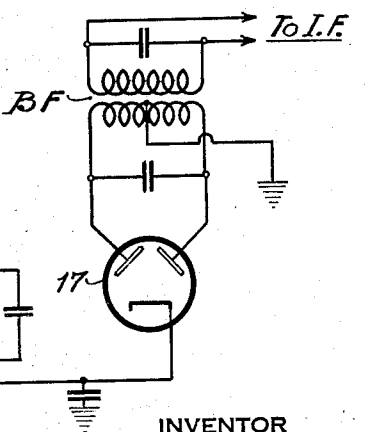
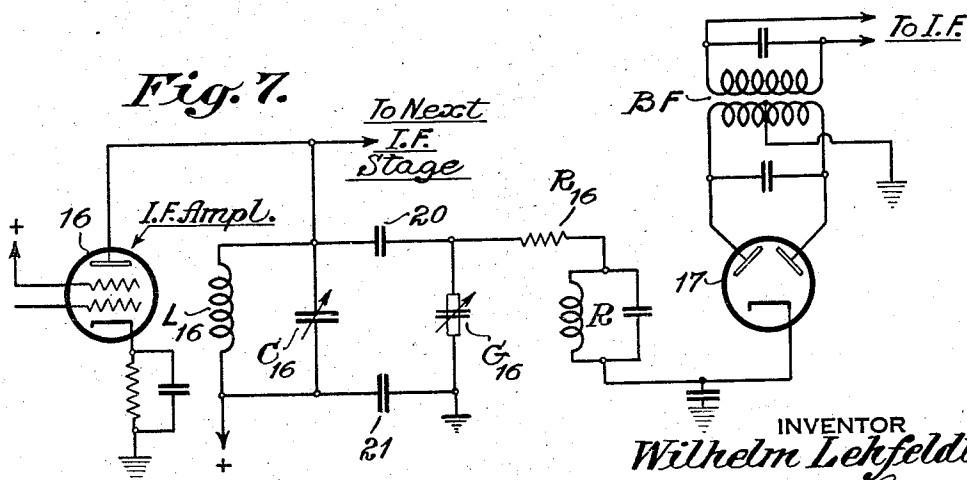


Fig. 7.



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CONTROL CAPACITY CIRCUITS

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8 Claims. (Cl. 179—171)

Voltage-dependent complex resistances such as silicon carbide resistances or dry (copper oxide type) rectifiers the resistance value of which is a function of an applied direct current (D. C.) voltage, or of the D. C. flowing therethrough or of a controlling alternating current (A. C.) of substantially lower frequency, are well known in the art. Resistances of this kind mostly involve an appreciable wattless or reactive component.

According to the invention the regulating condenser to be used, especially for radio frequency (R. F.) currents, consists of a complex resistance, the resistance value of which is varied as a function of the impressed D. C. voltage, or of the direct current flowing therethrough, or of an A. C. of a frequency lower than that to be regulated or controlled.

The A. C. resistance, for instance, of a dry copper oxide type rectifier measured in a bridge arrangement with low alternating voltage amplitude as a function of a superposed D. C. voltage, exhibits the well-known resistance characteristic. If such measurements are made at different frequencies (first without a superposed D. C.) there results the well-known equivalent circuit diagram for the dry rectifier. Heretofore it has only been known that the effective, or ohmic, resistance varies as a function of the impressed D. C. voltage. But it was discovered that in reality in the presence of a superposed D. C. voltage the capacity is also altered; that is, it grows as the resistance declines.

Now, this property according to the invention makes it possible to use the dry rectifier (dry condenser as hereinbefore defined) as a variable condenser, especially for R. F. work. It has also been ascertained that in the presence of high frequencies, that is, frequencies over 50 kilocycles (kc.) for which the phase angle difference of the condenser should be less than 10-1, the resistance and capacity become smaller so that the equivalent circuit diagram no longer quite holds good. It has moreover been ascertained that in the direction of flow (or low resistance), in so far as concerns the dry rectifiers under investigation being particularly suited for R. F. and having electrodes consisting of colloidal graphite (known in the trade as "Aquadag" electrodes), and electrodes consisting of silver thermally vaporized thereon, the capacitive phase slightly predominates in the neighborhood of 100 kc.

In the backward, or high-resistance, direction the behavior of the investigated dry rectifiers is still more favorable, for it has been found that for a frequency of around 3000 cycles they assume

the nature of a capacity whose phase angle difference, at 50,000 cycles becomes less than 0.1. Also, this capacity varies with the D. C. voltage impressed thereon.

5 The physical explanation of this new effect is approximately as follows:

The construction or structure of a resistance having voltage effect (that is to say, being a function of voltage) is generally as follows: Metal, barrier layer, semi-conductor. The dependence of a resistance upon the size and direction of an impressed potential in all likelihood is based upon a concentration drop of the free electrons inside a boundary layer under conditions of absence of voltage. Now, according to the value and the sense of an applied potential, the said concentration drop is shifted one way or the other. Incidentally, symbolically speaking, the thickness of the barrier layer, and thus the resistance thereof, is altered. In the case of a rectifier, when acted upon in the forward or low-resistance direction, free electrons are urged from the semi-conductor to flow towards the barrier or stopper layer with the result that in an advanced stratum thereof the conductance is raised, and the barrier becomes "thinner." This explanation will be much more plausible if it is kept in mind that the transition from the semi-conductor to the barrier is continuous, and that in the production of most dry rectifiers known in the art and practice, the barrier is formed out of the semi-conductor. Therefore, if the barrier is attenuated, this means a decrease of the resistance of the same, while its capacity value grows.

This theory not only explains quite easily and plausibly the well-known rectifier effect, but over and above that also the newly discovered capacity effect. In other words, by these actually observed capacity changes, what has heretofore been a rather symbolical and hypothetical attempt at an explanation of the rectifier effect is also confirmed or supported. Whether surplus electrons or deficiency electrons, that is, apparently positive electrons would be responsible for conductivity, is immaterial in the light of present day notions held in physics. All that it implies is a reversal in sign.

For a better understanding of the present invention reference will be had to the accompanying drawings wherein Fig. 1 illustrates an embodiment in which a dry rectifier is used as a remote-controlled capacity for the tuning of an oscillation circuit, Fig. 2 shows the use of two series-connected rectifiers in a capacitive voltage

divider system; Fig. 3 is a modification of Fig. 2 utilizing a single rectifier acting as a regulating condenser; Fig. 4 is a quartz crystal filter circuit according to the prior art for regulating the band width; Fig. 4a is a filter circuit similar to Fig. 4 but modified in accordance with the present invention; Fig. 5 illustrates the characteristic curves obtained with the circuit of Fig. 4a; Fig. 6 shows the application of the invention to a radio receiver in which overloading due to automatic control is avoided; and Fig. 7 shows application of the invention to a radio receiver for obtaining automatic sharp tuning or frequency control.

To symbolize such a regulating, or control, capacity of the kind here disclosed, the conventional symbols used for a resistance and for a condenser in superposition and in conjunction with an arrow shall be used in what follows. Referring to Fig. 1 it will be seen that the oscillatory circuit comprising inductance L and capacity C is included in the plate circuit of a grid-controlled tube r , coupling relation with the grid of another amplifier tube being established by means of a condenser I . In parallel relation to the said oscillation circuit L, C is arranged a copper oxide rectifier G in series between the two blocking condensers C_1 and C_2 . The chemical symbol for copper oxide is Cu_2O . According to the setting of the central tap of the potentiometer P (100,000 ohms) which is associated with the battery B_1 , the rectifier G alters its capacity thereby resulting in different resonance curves. The measuring instrument J connected in series with the resistance R of 1 megohm indicates the control current between 1 and 50 micro-amperes. The following constants may be used: $C=200 \mu F$; $C_1=0.1 \mu F$; $C_2=100 \mu F$. In addition to the shift of resonance, the rectifier G causes a slight additional amount of damping which is ascribable to its effective resistance.

Now, the use of the dry rectifier as a regulating condenser offers the practical merit that the D. C. required for the control action is very small, say, of an order of magnitude of a few micro-amperes, so that the current may be supplied by way of a very high resistance. This resistance, in the circuit shown in Fig. 1, was 1 megohm in value. Without causing undue loss the frequency can be readily changed 10 per cent in the presence of a change in the capacity of 20 per cent.

Another field of practical application resides in the combination of two voltage-dependent complex resistances to form a capacitive voltage divider (differential condenser) as shown in Figs. 2 or 3. If the well known potentiometer condition is to be fulfilled, that is to say, that the sum total of the individual resistances is to be always equal to a constant, a circuit comprising impedances as shown in Fig. 2 may be employed. The capacities being adjustable according to requirements by shifting the center tap of the potentiometer P_2 are taken off at the terminals 9, 9', 9'' of the two rectifiers G_1, G_2 connected in series. The latter are connected by way of resistances R_1 to R_3 , each of an order of magnitude of 1 megohm, with the terminals of the potentiometer P_2 which is connected in parallel to the source of D. C. voltage supply B_2 .

Where complex resistances with voltage effect are used as capacitive voltage dividers, one dry rectifier or the like will often be found to be adequate and sufficient when the so-called potentiometer condition above indicated, namely, a constant aggregate resistance, need not to be satisfied. An arrangement of this kind is shown in

Fig. 3 in which rectifier G_3 as a function of the setting of the central tap of the potentiometer resistance P_3 acts as a regulating condenser.

By reference to Figs. 4 and 4a the use of a voltage-dependent complex resistance acting as a regulating condenser shall be explained in connection with the regulation of the band-width of a quartz crystal filter. Fig. 4 shows a known circuit organization comprising a quartz filter and two screen grid amplifier tubes 11 and 12, two oscillation circuits I and II which are intercoupled by means of the quartz crystal Q . The two capacities C_{10} and C'_{10} form part of an adjustable differential condenser, the mechanical coupling thereof being indicated by the dash-line.

The band-width variation of the quartz filter in an arrangement as shown in Fig. 4 may be accomplished either by variation of the coupling of the crystal Q , or else by detuning of the oscillatory circuit in symmetry to the natural resonance of the crystal. The disturbing parallel capacitance of the crystal, of course, must be neutralized in this scheme. If the band-width is to be altered not by a mechanically actuated switch, but by electrical ways and means, then the sole chance is to detune the oscillation circuits and this, according to the invention, is accomplishable most simply by utilizing the capacity variation of voltage-dependent resistances or dry rectifiers as illustrated in Fig. 4a.

Fig. 5 illustrates band-pass filter curves obtained by the detuning of two dry rectifiers. The variations of the capacity amount to around 12 μF .

Another application of the invention has been found for automatic remote control in broadcast receiver sets where overloading of the R. F. tubes is to be avoided as well known in the art. To this end, the use of so-called hot conductors (that is, resistances with negative temperature coefficient) has been suggested subject to control actions by the screen grid current. The advantage which dry rectifiers, or equivalent voltage-dependent complex resistances, offer according to the invention over hot conductors when used for the remote control as indicated resides in substantially lower power or current requirements, amounting to around 10 microamps. as compared with 1 milliamp., not to mention lower cost of the new arrangement.

An embodiment of a circuit arrangement according to the invention is shown in Fig. 6 where the antenna is indicated at A_n and a screen grid amplifier tube at 15. The resistances R_{15} to R_{18} form a bridge network. Across one of the diagonals thereof is applied the plate potential, while in the other diagonal is included the dry rectifier G_{15} which represents a regulating condenser being varied in dependence upon the potentials prevailing across the diagonal points 16 and 17 of the bridge. The condensers C_{15} to C_{17} block the regulating circuit containing the dry rectifier for flow of D. C. against the antenna, grid, and ground.

The operation of this circuit is as follows: In the case of weak signals being received on the antenna, no AVC voltage is applied to the control grid and the screen grid assumes a normal operating potential. The potential of point 17 is so chosen that under these conditions the potential difference between points 16 and 17 impressed across element G_{15} is such as to result in a high impedance of G_{15} . Thus, substantially the full antenna voltage is impressed upon the control grid of the tube. On the other hand, in

the case of strong signals a large AVC voltage is impressed upon the control grid with the result that the potential of point 16 rises and thereby greatly reduces the impedance of element G_{15} . Since this latter element forms a portion of an impedance potentiometer which includes C_{15} and the antenna impedance as its other portion, the grid of the tube receives only a much diminished fraction of the total antenna voltage so that the tube is not overloaded by the assumed strong signals. The plate of the tube may be connected through a conventional output circuit, not shown in the drawings, to a source of positive potential.

For instance, in broad band systems modulation in the case of R. F. has been applied for a long while with the use of dry rectifiers, that is in the form of what has been known as "ring modulation" arrangements, without it being known, however, that capacity changes attendant upon, and accompanying resistance changes, play a part therein. By choosing suitable dry rectifiers, the frequency characteristic may here be altered by the variation of the capacitive phase component as a function of the voltage.

Fig. 7 illustrates a circuit arrangement for automatic (sharp) tuning in which, according to the invention, a dry rectifier G_{15} acting as a regulating condenser operating as a function of the potential is employed. Screen grid tube 16 feeds the oscillation circuit L_{15} , C_{15} . Re-adjustment of the oscillatory circuit is effected by means of a parallel circuit arrangement comprising the band pass filter BF and the diode 17 and which is fed with control energy from an intermediate frequency (I. F.) stage of the amplifier. The D. C. voltage furnished from the said diode controls in this scheme the capacity of the rectifier. The two condensers 20, 21 between the oscillation circuit and the control, or regulator, rectifier G_{15} keep D. C. away from the control circuit and the oscillatory circuit, while the resonance circuit R precludes the alternating potential from the diode.

According to another object of the invention the voltage-dependent complex resistance acting as a regulating condenser may also be used for automatic dynamic expansion. In this scheme the amplification of the R. F. amplitude is controlled in the desired manner. According to the invention a voltage divider comprising dry rectifiers and arranged in the R. F. portion is controlled by the audio amplitude.

Although in the discussion of exemplified embodiments of the invention reference has been made only to the use of dry (that is, copper oxide-type) rectifiers for the complex resistances having voltage effect (that is, being a function of potential), it will be understood that what has been set forth above applies broadly in a similar manner to all voltage-dependent, complex resistances such as silicon carbide or boron carbide resistances.

What is claimed is:

1. In a high-frequency electrical system, an electron discharge tube having a plurality of electrodes, in put and output circuits connected to said electrodes, a rectifier of silicon carbide constituting a regulating condenser and a voltage-dependent resistance included in at least one of said circuits, a source of direct current and means for utilizing said source to control

the capacitive and resistive effect of said regulating condenser on said tube circuit.

2. In an electrical system, an electron discharge tube having a cathode, an input control grid, a screen grid and an anode, a resistance bridge having one pair of diagonals connected between the anode and cathode, a regulating condenser comprising a voltage-dependent resistance connected between the other pair of diagonals of said bridge, said regulating condenser being included also in the input circuit connected between the input control grid and cathode, and a connection from one of the latter pair of diagonals to the screen grid.

3. An electrical system according to the invention defined in claim 2 wherein the voltage-dependent resistance is constituted by a copper oxide rectifier.

4. An electrical system according to the invention defined in claim 2 wherein the voltage-dependent resistance is constituted by a rectifier of silicon carbide.

5. In an electrical system, an electron discharge tube having a cathode, an input control grid, a screen grid and an anode, a resistance bridge having one pair of diagonals connected between the anode and cathode, a regulating condenser comprising a voltage-dependent resistance connected between the other pair of diagonals of said bridge, said regulating condenser being included also in the input circuit connected between the input control grid and cathode, and a connection from input grid side of the regulating condenser to the screen grid.

6. In an electrical system, an electron discharge tube having a cathode, an input control grid, a screen grid and an anode, a regulating condenser comprising a voltage-dependent resistance connected between the input control grid and cathode through blocking condensers, a source of voltage connected between anode and cathode, a voltage dropping resistor connected between anode and screen grid, and a connection from the input grid side of the regulating condenser to the screen grid.

7. In an electrical system, an electron discharge tube having a cathode, an input control grid and an anode, a resistance bridge having one pair of diagonals connected between the anode and cathode, and a regulating condenser comprising a voltage-dependent resistance connected between the other pair of diagonals of said bridge, said regulating condenser being included also in the input circuit connected between the input control grid and cathode.

8. A radio frequency amplifier stage, adapted to be operated with input voltages having a wide range of amplitudes without overloading on large amplitudes, comprising a source of signals, a tube, a transmission network coupling said source to the grid of said tube, an element of said network consisting of a rectifier having an effective impedance dependent upon a direct current bias across its terminals, and means to control the transmission of signals through said network inversely as the strength of said signals comprising signal rectifying means and connections for impressing rectified voltage of said signals across said variable impedance element.

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