Aug. 11, 1942. R. GOLICKE 2,292,439

STABILIZED ELECTRON DISCHARGE DEVICE CIRCUIT

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Fig. 1

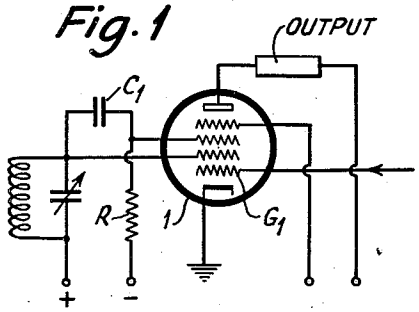


Fig. 2

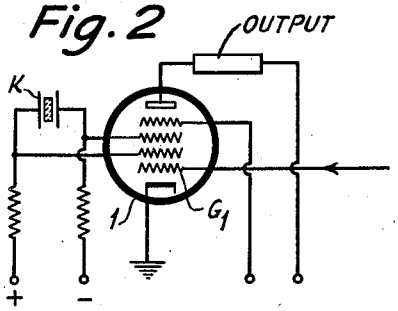


Fig. 3

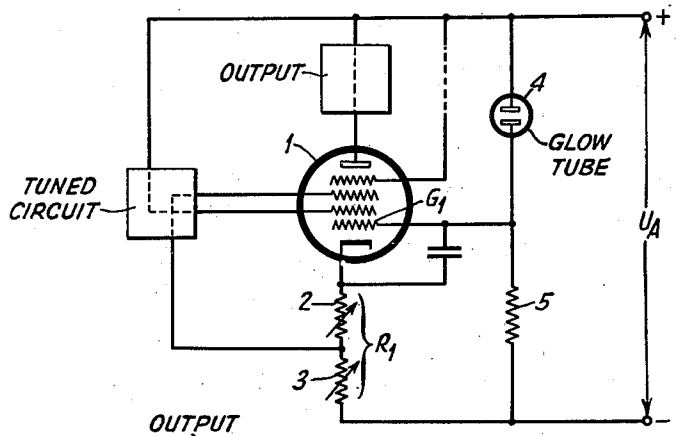
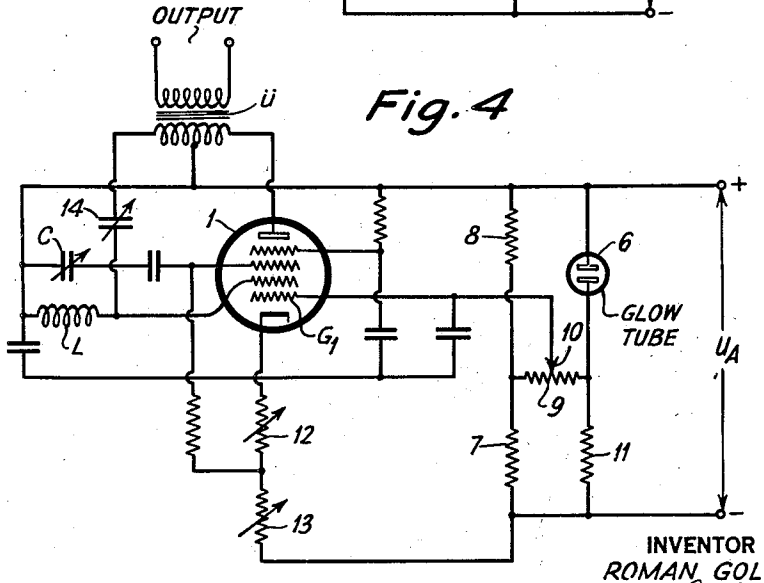


Fig. 4



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Fig. 5

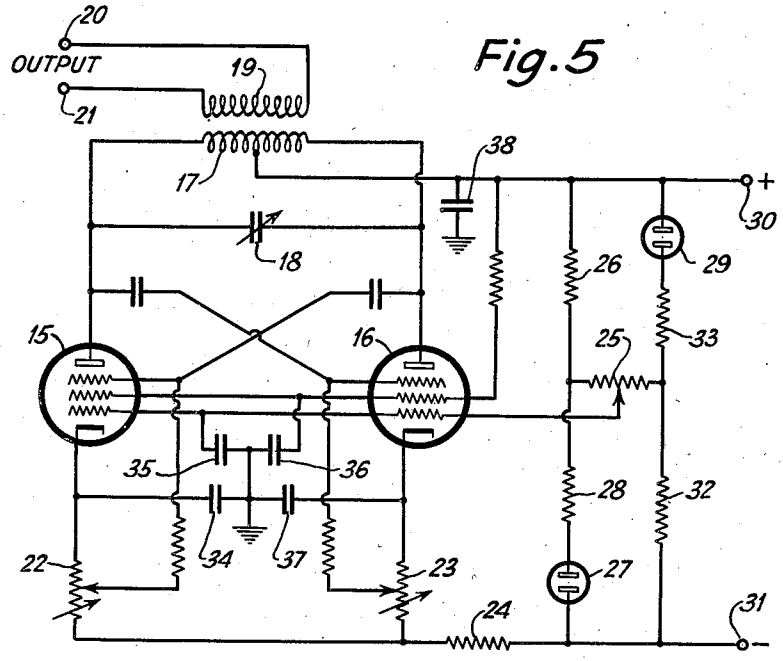
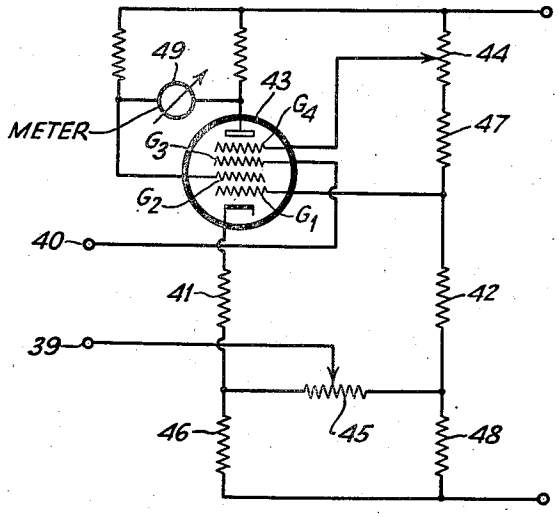


Fig. 6



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STABILIZED ELECTRON DISCHARGE DEVICE CIRCUIT

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6 Claims. (Cl. 250—36)

(Granted under the provisions of sec. 14, act of March 2, 1927; 357 O. G. 5)

This invention is concerned with a circuit arrangement designed to reduce the actions of fluctuations of the operating potentials and variations in tube data as a result of aging, particularly upon frequency stability in multi-grid tubes. It is known that great constancy of frequency in a generator tube is obtainable by insuring feedback under favorable phase conditions and by operating the oscillator so that distortion is avoided. In order to satisfy these demands to be made in operating a transmitter of stable frequency in so far as the tube itself is concerned, circuit schemes have been developed in which the real tube quantities variable under routine operating conditions will affect the frequency only to an extremely insignificant degree. However, it has been ascertained that variations of the working voltages may nevertheless react upon the frequency. These residual influences, for instance, are ascribed to variable components of the internal tube capacitance which are acted upon by the potentials prevailing at the electrodes and by the emission of the cathode by way of the space charge.

It has been ascertained that variations or fluctuations of the working voltages at the various electrodes of the oscillator will, in part, affect the frequency in contrary directions. In the circuit organization of this invention which is especially designed to insure constant and stable frequency in a multi-grid oscillator tube, the variations of the plate potential are distributed among the various tube electrodes in such proportions that mutual compensation of the working voltage variations will be insured. The compensating potential is preferably applied to one or more electrodes adjacent to the cathode and which have a potential which is negative in respect to the cathode so that control free from dissipation is feasible. The working voltage fluctuations which affect the electrodes are so assessed in reference to one another that frequency fluctuations will offset one another.

The voltage or voltages required for compensation may be advantageously obtained in a bridge circuit scheme. The compensating potentials are most suitably derived from the plate lead, the tube and a resistance, on the one hand, and two resistances, on the other hand, constituting the arms of a bridge arrangement. One of the diagonals of the bridge is fed from the plate potential, whereas the other diagonal accordingly results in a controlling direct current voltage which may be impressed, for instance, upon the grid of the tube adjacent to the cathode. Inserting in the bridge resistances of a type having voltage effect, that is to say, resistances being a function of potential, then conditions may be shaped in such a way that upon variations of the plate potential the voltage impressed upon the first grid will change in such a way that frequency fluctuations are compensated. The sign of the variations reaching the first grid may, according to requirements, be chosen at will by choosing the arrangement of the voltage-dependent resistances in the bridge accordingly. Among the resistances comprised in the bridge scheme, all or merely a part thereof may be of the kind which in their operation are a function of the potential. In order that the plate potential variations may be regulated or eliminated as far as feasible in the absence of inertia, it is expedient and advantageous to use a glow-discharge tube, for instance, for one of the voltage-dependent resistances. Inasmuch as the grid adjacent to the cathode has preferably potentials that are negative to the cathode, the control action may be made non-dissipative (wattless). Hence, for regulation only extremely small currents are required so that the voltage-dependent resistance may consist of a small signal glow tube.

Simultaneously with the compensation of the plate potential variations, it is possible also to obtain compensation and equalization of the fluctuations of cathode emission. These fluctuations of emission of the cathode may be occasioned, for instance, by fluctuations in the heating as well as by aging of the cathode. For stabilization of the emission, a control potential counteracting the fluctuations of emission may be impressed upon the grid or the same electrodes which serve for compensating the plate potential fluctuations. Such stabilization is accomplishable, for instance, by the drop of voltage across a resistance included in the lead brought to the cathode. In order to maximize the effectiveness of this scheme, the resistances are preferably so proportioned that a large part of the plate potential will be in the drop of potential across the cathode resistance. The first grid must then be impressed with a positive counteracting potential.

A circuit organization as here disclosed is generally suited for multi-grid tube circuits in which only part of the tube electrodes is used for signal circuit purposes, while other electrodes, for instance, the first grid; are available for compensating or stabilizing purposes. For example, generators operating with series resonance cir-

cuits (also low-ohm oscillator crystals) may be designed. Since in such schemes the resonance circuit is in low-ohm connection with the tube, the reactions of the tube upon the frequency are anyway low. Hence, crystal stabilized oscillators of the said sort may be expected to insure high frequency constancy.

The invention shall now be explained in more detail by reference to the drawings, wherein Figs. 1 and 2 illustrate, by way of example, two oscillator circuits of the type which can be stabilized as to frequency by means of the invention, and Figs. 3, 4, 5 and 6 illustrate different embodiments of the invention.

Fig 1 shows a generator comprising a multi-grid tube in which by means of a feed back condenser C_1 and grid leak resistance R of suitable value, regeneration of strict phase is assured. The compensating potential in this generator may preferably be impressed upon the grid G_1 adjacent to the cathode. For it has been ascertained that voltage fluctuations at the first grid influence the frequency more strongly and in the opposite sense as compared with most other electrodes.

Fig. 2 illustrates an oscillator which works in combination with a series resonance circuit. The frequency is here determined by a crystal K. Compensation of the plate potential fluctuations is effected also by way of the grid G_1 which is adjacent to the cathode.

An exemplified embodiment of a simple circuit arrangement for compensation of plate potential influences upon the frequency is schematically shown in Fig. 3. What is here used is a bridge scheme, tube 1 and the resistance R_1 comprising the two fractional resistances 2 and 3, on the one hand, and the resistances 4 and 5, on the other hand, constituting the four arms of the bridge. One of the diagonals of the bridge is fed with plate potential U_A, while the other diagonal feeds a controlling direct current voltage to the first grid G_1 of tube 1. Inserting in the bridge voltage-dependent resistances, then conditions may be made so that upon variation of the plate potential U_A the voltage acting upon the first grid is so altered that frequency variations are eliminated and compensated. It has been found to be advantageous to apply almost the entire fluctuation of the plate potential upon the first grid G_1. Hence, the resistance 4 (or resistances 2 and 3) must be of such nature that current variations will occasion only slight potential variations, and/or resistance 5 is to exhibit the opposite behavior. In a great many instances it is sufficient to make only one of the three resistances voltage-dependent. In order that potential variations of the plate may be eliminated as far as feasible without inertia, it is of advantage to use a glow-tube in lieu of the resistance 4. Since the first grid is at a negative potential in reference to the cathode, the control action may be non-dissipative and wattless. The bridge arms consisting of the resistances 4 and 5, as a consequence, have to carry only very small currents; hence, small signal lamps could be used, for instance.

Fig. 4 shows an exemplified embodiment for a regenerative oscillator of very high frequency stability. One pair of bridge arms for the regulating potential is here divided into two parallel portions, one of these containing the glow tube 6 and element 11, while the other one is formed by the resistances 7 and 8. The control grid for the first grid G_1 of the tube 1 is derived from a potentiometer 9 by way of a slide contact 10, this potentiometer uniting the two parallel portions of the bridge arm. By the aid of the potentiometer 9 it is possible to regulate the proportion of the plate potential fluctuations which is impressed upon the first grid, this proportion being greater the closer the slider 10 comes to be placed to that end of the potentiometer turned towards the glow-tube.

Aside from the effects of the plate potential upon the frequency, also the reactions of the cathode whose emissivity fluctuates as a function of the heating and the age, are neutralized. For stabilizing the space current there is provided a cathode resistance which is formed by the resistances 12, 13.

In the case of an oscillation generator as shown in Fig. 4, frequency stability is enhanced further on account of the fact that the coupling of the consumer or load is made as low as possible in reaction. This is readily feasible in the case of multi-grid tubes, without it being necessary to provide a special isolation stage. For instance, the oscillation circuit means may be connected to grids which are shielded from the plate serving as the output by an electrode being at zero alternating potential. It has been ascertained that in hexodes the screening effect afforded by the fourth grid is not quite adequate to insure complete decoupling. In the case of the generator shown in Fig. 4, therefore, neutralization is provided by deriving from the output transformer or output oscillation circuit alternating voltage presenting a phase shift of 180° to the plate potential, the said potential by way of a small neutralizing condenser 14 being impressed upon the oscillatory circuit consisting of the inductance coil L and capacity C. If the neutralization is accurately adjusted by the aid of the variable condenser 14, actions upon the frequency by fluctuations of the output load will be largely avoided.

In the exemplified embodiments of circuit arrangements shown in Figs. 3 and 4, one or two of the cathode resistances 2, 3, and 12, 13, respectively, may be made variable within certain limits. Thus the cathode current to which stabilization becomes adjusted can be altered. And this, in turn, will vary the slope of the characteristics of the utilization or signal circuit organization.

In the case of oscillators, such regulation is of advantage in order that the feed back by way of the slope may be so adjusted that operation will be only inside the steeper portion of the doubly curved characteristic, and this portion lies inside the region of negative potentials. Grid current flow together with its harmful effects upon frequency stability are thus avoided.

Fig. 5 shows a frequency stabilized generator. For frequency generation there are here used two multi-grid tubes 15 and 16 operating in push-pull. Between the plates of these tubes there is inserted the oscillation circuit comprising the inductance 17 and the capacity 18. The output end is in coupling relation with the said oscillation circuit by way of the coil 19. The utilization or signal voltage is taken off across the terminals 20 and 21. In this circuit arrangement it is advantageous to use separate cathode resistances 22 and 23, for in this manner each cathode can be stabilized separately. These resistances are most conveniently made variable. For joint regulation of the cathode current and thus of the slope or mutual conductance of both

tubes may serve a common portion of the cathode resistances, say, the variable resistance 24.

Potentiometer 25 is inserted between two voltage dividers which are a function of potential in opposite directions. One of the said voltage dividers comprises the resistance 26 and the glow tube 27, the latter preferably having in series another resistance 28, while in the case of the other, voltage divider and glow tube are transposed.

In this arm, the glow tube 29 is connected with the positive terminal 30 of the plate potential. Connected with the negative terminal 31 is the resistance 32. Glow tube 29 may besides have connected in series with it a resistance 33. Owing to the fact that the potentiometer 25 is included between two voltage dividers being a function of potential in contrary directions, it is possible to adjust the compensating potential both as to amount as well as of sign. The condensers 34 to 38 are so proportioned that they result in a block for the working frequency.

Fig. 6 illustrates by way of example a measuring organization comprising the use of stabilizing means according to the invention. This arrangement may serve, for instance, for the measurement of small direct current powers under conditions free from dissipation. The instrument 49 in this scheme is connected in a bridge between two tube paths. The instrument current is only a small fraction of the tube currents; for instance, for full deflection it may amount to 100 μ amp., as contrasted with 5–10 milliamp. electrode current. By virtue of this ratio between instrument current and tube current changes of tubes become very manifest and must be eliminated by the adoption of special measures to this end.

The direct current voltage to be measured is impressed upon the terminals 39 and 40. Adjustment of zero of the instrument is roughly possible by choosing suitable fixed resistances 41 and 42. Fine adjustment is accomplishable by variation of the positive potential impressed upon the fourth grid G_4 of tube 43 by way of the potentiometer 44. Potentiometer 45 serves for compensation of the plate or heating potential variations. While by resistances 41 and 46 stabilization of the cathode is attained, the residual influences of the cathode are eliminable by the aid of a compensating voltage impressed upon the third grid in series with the utilization (signal) control potential which may be taken off from a potentiometer 45. At this potentiometer 45 acts the stabilization potential for the first grid G_1. Resistance 42 in this connection may be chosen of small value; it merely serves the purpose to provide a drop of potential which corresponds to the difference of the biasing potentials of grids G_1 and G_3. Compensation of the cathode actions can be secured to a large degree if a suitable fraction of the stabilizing potential is tapped on the potentiometer 45 and impressed upon the grid G_3.

By suitable adjustment it would also be possible to compensate at the same time plate potential fluctuations if the plate potential and the heating or cathode potential originate from the same source of energy supply so that their fluctuations would be similar. However, such a step would fail to take care of such cathode fluctuations as are caused by aging of the cathode. Hence, it is expedient to insure cathode stabilization or compensation and compensation of the plate potential fluctuations independently of each other.

Compensation of the plate potential fluctuations is feasible because of the fact that plate current and grid current of grid G_2 are made to like measure a function of the plate potential. The plate and G_2 paths are mostly resistances which are a function of potential to unequal extents. Thus, in order to render their voltage dependence alike, the path involving the greater voltage dependence has an ohmic resistance of suitable size connected in parallel with it.

Resistances 41 and 42 are suitably so chosen that when operating the potentiometer 45, the shifts in the operating point will be as small as possible. The potentiometer 44 is preferably chosen so large that shifts in the operating point as well as disparities in tube data and characteristics can be aligned and compensated. Through arm 44, 47, 42 and 48 roughly the same current may flow as through the tube. In this instance, resistance 46 becomes approximately equal to resistance 48. In order that the amplification may be made as high as possible, the resistances 46 and 48 may be made as low as compensation will just permit. The potentiometer 45 may be one order of magnitude approximately higher in ohmage than these resistances; for instance, of a value of 500 to 100 kohm.

What is claimed is:

1. An oscillator circuit comprising a multi-grid electron discharge device having a cathode, a first grid adjacent said cathode and separated therefrom solely by space, an anode, and a plurality of intermediate electrodes; an oscillatory circuit coupled between two electrodes of said device other than the first grid; a source of potential connected between said anode and cathode; a non-linear resistance network bridged across said anode and cathode; and a connection from the first grid of said device to a point on said network so chosen that changes in the potential of said source tending to produce a change in the frequency of oscillation will apply to said first grid potentials of such magnitude and sign as to substantially neutralize the tendency to frequency change caused by the changes in potential of said source.

2. An oscillator circuit comprising a multi-grid electron discharge device having a cathode, a first grid, an anode, and a plurality of intermediate electrodes; an oscillatory circuit coupled between two electrodes of said device other than the first grid; means for biasing said first grid negatively relative to said cathode; a source of potential connected between said anode and cathode; a non-linear resistance network bridged across said anode and cathode; and a connection from the first grid of said device to a point on said network so chosen that changes in the potential of said source tending to produce a change in the frequency of oscillation will apply to said first grid potentials of such magnitude and sign as to substantially neutralize the tendency to frequency change caused by the changes in potential of said source.

3. An oscillator comprising a multi-grid electron discharge device having a cathode, first, second, third grids and an anode; means for biasing said first grid at a negative potential relative to said cathode independently of the generated oscillatory currents; an oscillatory circuit coupled between said second and third grids; a source of potential connected between said anode and cathode for maintaining said anode at a positive po-

tential relative to said cathode; a resistance network connecting together said anode, cathode and first grid, the point of connection from said first grid to said network being so chosen and the resistors of said network having such values that changes in the potential of said source tending to produce a change in the frequency of oscillation will apply to said first grid potentials of such magnitude and sign as to substantially neutralize the tendency to frequency change caused by the changes in potential of said source.

4. An oscillator in accordance with claim 3, characterized in this that said oscillatory circuit comprises a parallel tuned circuit connected between said second grid and said cathode, there being a feed-back reactor coupling said third grid and said oscillatory circuit.

5. An oscillator in accordance with claim 3, characterized in this that one of the resistors of said network is voltage-dependent and comprises a glow tube.

6. An oscillator circuit comprising a multi-grid electron discharge device having a cathode, a first grid, an anode and a plurality of intermediate electrodes; an oscillatory circuit coupled between two electrodes of said device other than the first grid; a source of potential connected between said anode and cathode; a resistor network including a first pair of resistors connected in series between the positive and negative terminals of said source and a second pair of resistors connected in series between the cathode and the negative terminal of said source; and a connection from said first grid to the junction point of said first pair of resistors, the values of said resistors being so chosen that changes in the potential of said source tending to produce a change in the frequency of oscillation will apply to said first grid potentials of such magnitude and sign as to substantially neutralize the tendency to frequency change caused by the changes in potential of said source.

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