

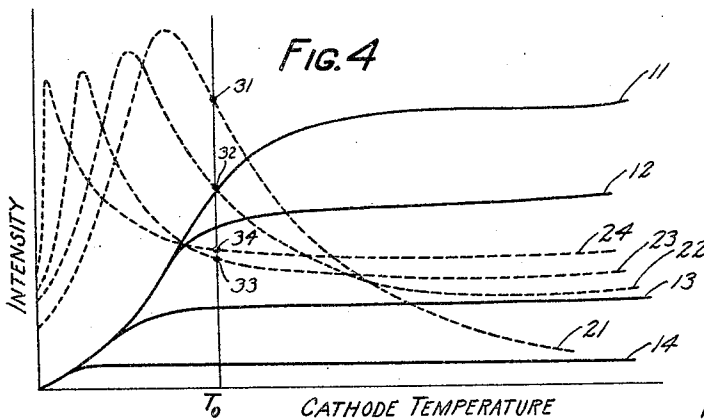
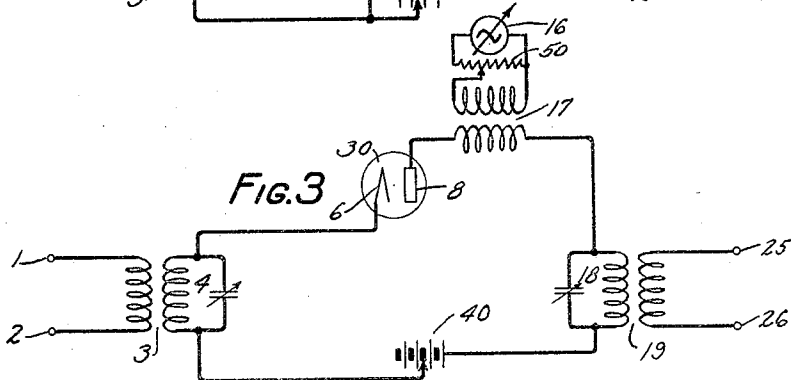
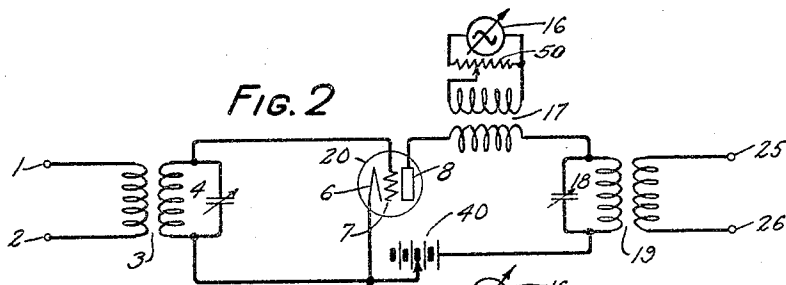
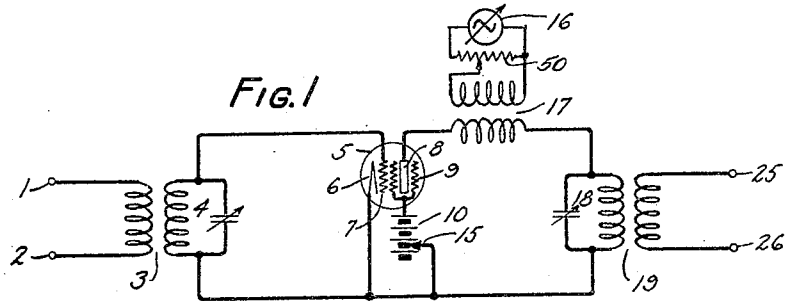
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CONTROL CIRCUITS FOR SPACE DISCHARGE DEVICES

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CONTROL CIRCUITS FOR SPACE DISCHARGE DEVICES

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This invention relates to circuit arrangements for the efficient and quiet operation of space discharge devices and particularly to the operation of these devices as modulators and detectors.

In the operation of a space discharge device it is generally desirable to secure a high degree of amplification and a large output of useful power together with relatively little generation of disturbing currents which will give rise to noises in a receiver connected to the device.

It is well known that the disturbing effect of noise producing currents is dependent upon their relative intensity compared with the intensity of the useful currents with which they are commingled in a receiving device. It is evident that any measures taken to reduce noises which originate in space discharge devices and their attached circuits must, in order to be effective, either increase the intensity of the useful currents or not reduce them to the same extent that the noise producing currents are reduced.

In the present invention the desired efficient and quiet operation of a space discharge device is secured by a particular adjustment of the direct current biasing potentials which are applied to the various electrodes of the device together with a readjustment of the intensities of the alternating currents applied to the device. The manner in which these adjustments provide for increased efficiency and quiet operation will be pointed out more particularly hereinafter.

In the proceedings of the Institute of Radio Engineers for February 1930, Volume 18, No. 2, pages 243 to 265, I have published the results of a study of the causes of noise in vacuum tubes and attached circuits. The principal sources of noise which I have found and those which are most susceptible of control are the "small shot effect" in vacuum tubes and the thermal agitation of conductors.

The small shot effect is due to the existence of slight irregularities in the stream of electrons passing from the cathode to the anode of a vacuum tube, giving rise to fluctuations in the plate current. The fluctuations are due to the arrival of electrons at the plate at a

non-uniform rate. This effect is most pronounced when a vacuum tube is operated in a condition in which temperature saturation is not complete.

The thermal agitation of electricity in a conductor is a state due to the irregular motion of the electric charges in the conductor and is produced by the heat energy in the conductor. This irregular motion of the charges produces slight irregularities in the current through the conductor and gives rise to noises in the receiver. The effect of thermal agitation is greater in large resistances than in small ones and increases with the temperature at which the resistance is operated.

In many commercial tubes the amount of noise is reduced to a satisfactory amount by operating the tube in a condition of temperature saturation to reduce the small shot effect and by using fairly large direct current plate potential to reduce the plate filament resistance and its accompanying thermal agitation to a small value.

In certain tube structures it has been found that the condition of temperature saturation is not readily obtained with the high values of direct current plate potential commonly used. The four-electrode type or screen grid tube which is at present available commercially is particularly disadvantageous in this respect. Tubes of this type are generally sufficiently quiet in operation when employed as amplifiers, for then the useful currents are amplified to a sufficient intensity so that the noise producing currents are relatively weak and hence unobjectionable. When the tube is used as a modulator or detector, however, the degree of amplification obtainable is less and the noise producing currents are relatively strong, requiring the use of special measures to reduce their relative intensity.

In order to improve the temperature saturation in a tube of the type above mentioned and thereby decrease the small shot effect I reduce the value of the direct current potentials employed. I use a relatively small positive bias on the screen grid electrode and preferably apply no direct current potential whatever to the plate. In reducing the direct current biasing potentials the degree of am-

plification obtained in a tube is decreased. It is possible, however, to compensate to a large degree for this decrease of amplification by correspondingly increasing the intensity of the alternating current input of the tube, but in the case of a modulator or a detector this loss of amplification is not of great importance. While the reduction of amplification necessarily means that the intensity of the useful currents is reduced, it has been found that the intensity of the noise producing currents is reduced to a still greater extent. The result is a net improvement in the ratio of useful currents to noise producing currents.

The invention will now be described in detail with reference to the drawing in which Fig. 1 shows an embodiment of the invention employing a four-electrode space discharge device. Fig. 2 shows the application of the invention to a three-element tube and Fig. 3 shows its application to a two-element tube while Fig. 4 shows theoretical curves which will be employed in explaining the invention.

Referring to Fig. 1, the terminals 1 and 2 are input terminals to which may be connected a source of incoming electrical waves or currents. The input circuit 1, 2 is coupled by means of a transformer 3 to an input tuned circuit 4. The tuned circuit 4 is connected to the input side of a four-electrode space discharge device 5, having a cathode 6, a control grid 7, an anode or plate 8, and a screen grid 9. One side of the circuit 4 is connected to the cathode 6 and the other side is connected to the control grid 7. The screen grid electrode 9 is connected to the positive terminal of a battery 10. An adjustable connector 15 is connected to another portion of the battery 10 and to the cathode 6. By adjustment of the connector 15 a positive direct current potential of any desired value may be impressed upon the screen grid 9.

A local source of alternating currents for use in heterodyne reception of the incoming waves is provided at 16. This source is adjustable as to frequency by any suitable means as indicated by the arrow in the diagrammatic representation. The source 16 is connected to the plate circuit of the tube 5 through an adjustable potentiometer 50 and any suitable coupling means, which latter is represented by the transformer 17. An output circuit 18 is provided which is tuned for the frequency of the useful current to be derived from the tube 5. The circuit 18 is coupled by means of a transformer 19 to the output terminals 25 and 26.

The plate 8 is preferably operated without any direct current potential being applied thereto, but a small potential may be applied without departing from the scope of the invention. By varying the position of the contact 15 in the screen grid circuit and the intensity of the alternating current from the

local source 16 by means of the potentiometer 50, an adjustment may readily be found which gives a large degree of amplification and a large output of useful current together with a relatively small amount of disturbing currents or noises.

The circuit shown in Fig. 2 is similar to that shown in Fig. 1 except that a three-electrode tube 20 is employed in place of the four-electrode tube 5. The plate 8 of the tube 20 is provided with an adjustable biasing battery 40 and is preferably operated with relatively little or no direct current biasing potential. The effective potential of battery 40 and the intensity of the alternating current from the local source 16 may be adjusted to such values that the circuit will give a maximum amplification and a large amount of useful current with a minimum amount of noise.

In Fig. 3 a two-element tube 30 is illustrated. The input circuit 4 is connected in series with the output circuit 18. As in the case of the circuit shown in Fig. 2 the effective potential of battery 40 and the intensity of the current from the local source 16 may be adjusted to obtain the most quiet and efficient operation of the system.

The principle underlying the adjustment of the direct current biasing potentials to secure a reduction in the relative amount of noise produced by a space discharge device will be explained by reference to Fig. 4. The curves 11, 12, 13 and 14 represent the intensity of the space current as a function of the temperature of the cathode. The various curves 11, 12, 13 and 14 show this relation for different values of the direct current biasing potential of the tube in decreasing order.

Each of these curves has a rising portion for the small values of the cathode temperature and a nearly horizontal portion for the higher cathode temperatures. The rising portion of the curve represents a condition in which the plate electrode is drawing electrons directly from the cathode and is a condition in which temperature saturation does not exist. In this condition any irregularity in the emission of electrons from the cathode produces a corresponding irregularity in the plate current. In other words, this region is one in which the small shot effect is most pronounced and gives rise to noise in the plate circuit.

The horizontal portion of the curve represents a condition of temperature saturation. In this condition a change in the cathode temperature has practically no effect upon the intensity of the plate current. At these high temperatures the cathode emits electrons greatly in excess of the number required to constitute the plate current. The excess electrons accumulate in the region of the cathode and constitute what is called the space charge. It is believed that the plate current under

these circumstances is composed of electrons drawn from the space charge and not directly from the cathode. The irregularities in the stream of electrons emitted from the cathode are not transmitted directly to the plate and consequently it appears that the plate current is made more uniform by operating the tube under the condition of temperature saturation.

The curves 21, 22, 23 and 24 represent the manner in which the tube noises depend upon the cathode temperature. Curve 21 corresponds to the same direct current plate potential as the curve 11. In the same way curves 22 and 12 correspond and also 23 corresponds with 13 and 24 with 14. Each of the curves 21, 22, 23 and 24 shows a maximum amount of noise in the region where the plate current curve is rising and each of these curves also falls to a relatively small value at the higher cathode temperatures.

The maximum value of noise is in each case due to the small shot effect while the noise observed at the higher cathode temperatures, that is, in the region of temperature saturation depends principally upon the thermal agitation within the tube. Since the noise of thermal agitation increases when the plate filament resistance increases, the noise curve 21 which corresponds to the smallest value of plate filament resistance falls to a lower value than the curves 22, 23 and 24. The latter curves, in order, come down to increasingly higher final values because they correspond to larger values of plate filament resistance.

A tube which cannot be operated in a condition of temperature saturation will have its normal operating temperature represented approximately by the value T_0 . The vertical line corresponding to the temperature T_0 intersects the noise curves 21, 22, 23 and 24 at the points 31, 32, 33 and 34 respectively. It will be seen that as the direct current biasing potential is reduced the values of noise obtained in the tube will correspond to the ordinates of the points 31, 32, 33 and 34. A minimum amount of noise is obtained in the region of the points 33 and 34. By adjusting the effective potential of the battery 10 in Fig. 1 or battery 40 in Figs. 2 and 3 an operating condition corresponding to the point 33 may readily be obtained.

As hereinbefore mentioned, the decreased values of direct current biasing potential corresponding to the operating conditions of points 33 and 34 are accompanied by a reduction of amplification and a lower intensity of useful current. The noise, however, is reduced in a greater degree than is the useful current so that there is a material improvement, that is, a diminution in the net disturbing effect of the noise.

What is claimed is:

1. A circuit comprising a space discharge

device having an anode, a cathode, a control grid and a screen grid, the anode being at the same direct current potential as the cathode, means for applying a positive direct current bias to said screen grid, a source of alternating current coupled to said anode, and means for adjusting the intensity of said alternating current whereby the ratio of useful currents to noise producing currents in said device is increased.

2. A circuit comprising a space discharge device having an anode, a cathode, a control grid and a screen grid, the anode being at the same direct current potential as the cathode, means for applying a positive direct current potential to said screen grid, a source of alternating current coupled to said anode, and means for adjusting the intensity of alternating current from said source.

3. A circuit comprising a space discharge device having an anode, a cathode, a control grid and a screen grid, the anode being at the same direct current potential as the cathode, means for applying a positive direct current bias to said screen grid, a source of alternating current coupled to said anode, input and output circuits for said space discharge device, and means for adjusting the bias of said screen grid whereby the ratio of useful currents to noise producing currents in said output circuit is increased.

4. A circuit comprising a space discharge device having an anode, a cathode, a control grid and a screen grid, the anode being at the same direct current potential as the cathode, means for applying a positive direct current bias to said screen grid, a source of alternating current coupled to said anode, input and output circuits for said space discharge device, means for adjusting the bias of said screen grid, and means for adjusting the intensity of the alternating current from said source, whereby the ratio of useful currents to noise producing currents in said output circuit is increased.

5. A modulating system comprising a space discharge device having an anode, a cathode, a control grid and a screen grid, a source of carrier current to be modulated, means for coupling said source to said anode, a source of modulating current connected to said control grid, an output circuit for utilizing modulated currents, the anode of said discharge device being at substantially the same direct current potential as said cathode, and the screen grid having such a value of direct current potential with respect to said cathode that the ratio of useful currents to noise producing currents in said output circuit is substantially a maximum.

6. A modulating system comprising a space discharge device having an anode, a cathode, a control grid and a screen grid, a source of carrier current to be modulated, means for coupling said source to said anode, a source

of modulating current connected to said control grid, an output circuit for utilizing modulated currents from said device, said anode being at substantially the same direct current potential as said cathode, and the direct current potential of said screen grid and the alternating current potential of said anode being at such values respectively that the ratio of useful currents to noise producing currents in said output circuit is substantially a maximum.

In witness whereof, I hereunto subscribe my name this 11th day of April, 1930.

FREDERICK B. LLEWELLYN.