

March 7, 1939.

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2,149,328

SPACE DISCHARGE TYPE OF APPARATUS

Filed Dec. 27, 1935

2 Sheets-Sheet 1

FIG. 1

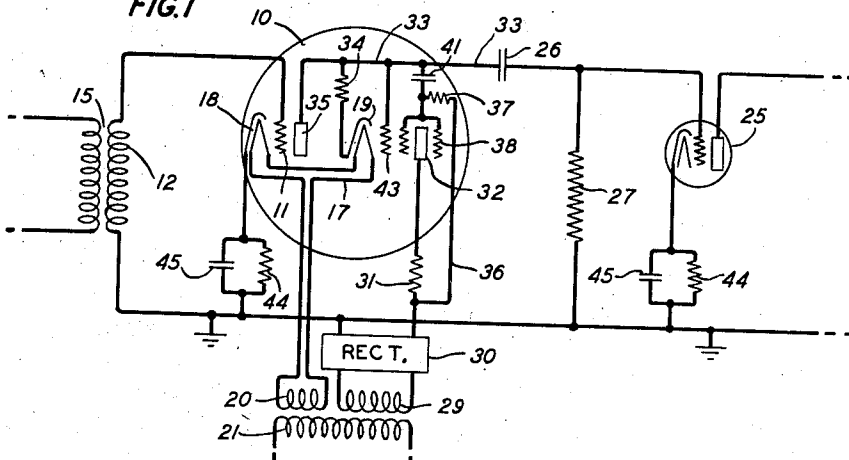


FIG. 2

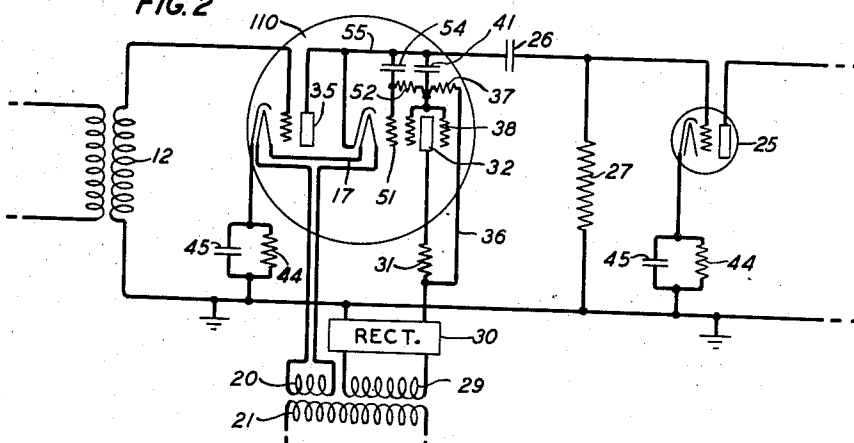
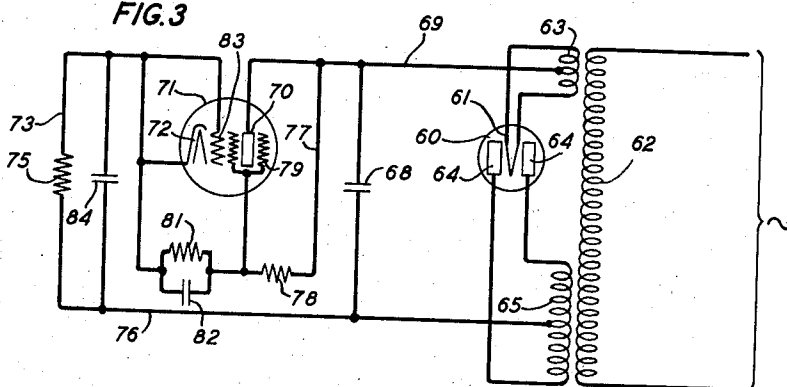


FIG. 3



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FIG. 4

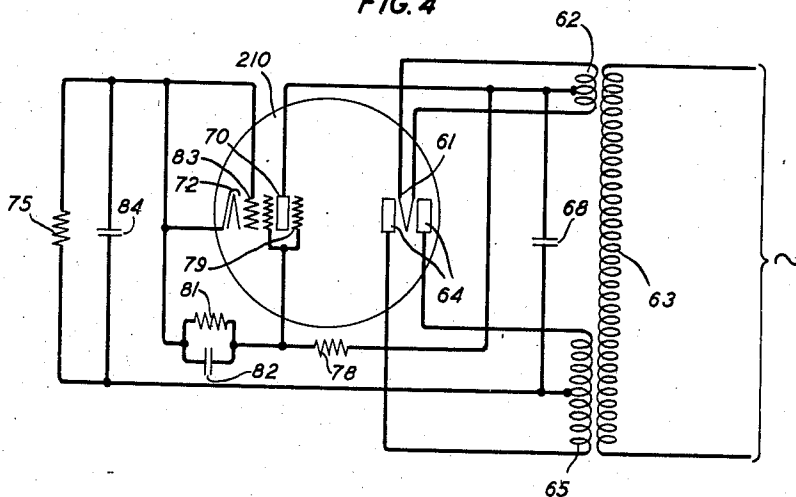
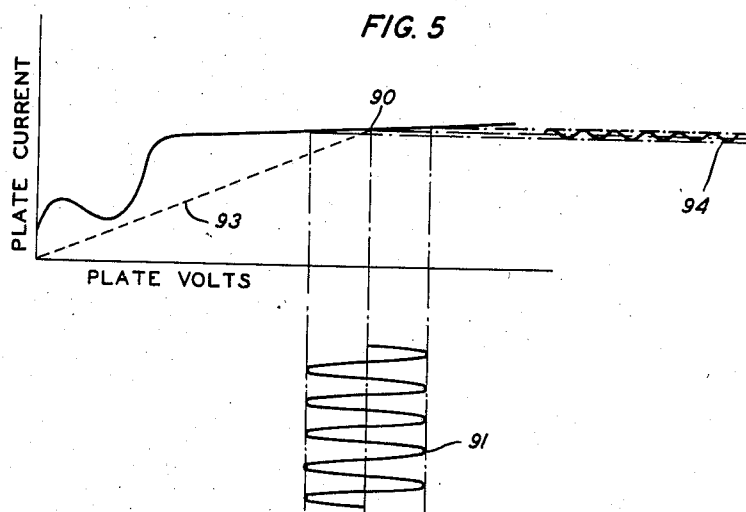


FIG. 5



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SPACE DISCHARGE TYPE OF APPARATUS

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4 Claims. (Cl. 179—171)

The present invention is related to electronic devices and to circuits employing such devices.

One known type of amplifier circuit has a thermionic stage coupled to a preceding stage through a choke furnishing the anode voltage. This choke has an impedance to varying currents of a value higher than its resistance to direct current. The ideal coupling choke would be one having an approximately infinite impedance to varying currents and a low direct current resistance. One difficulty in getting a suitably high resistance to varying currents in the prior art has been in an unduly high direct current resistance in the coupling, calling for a high B battery voltage to insure sufficient plate voltage through the choke or coupling circuit. Furthermore, distortion has often been introduced by circuit elements in this choke which in some cases give undue distortion to higher frequencies of interest. It has been known to use thermionic diodes or triodes in a choking or coupling circuit. The diode or the triode devices have a downwardly curved characteristic giving a low ratio of alternating current impedance to direct current resistance in the device. Thermionic coupling so far known to have been proposed while useful for low frequency ranges, has caused marked or prohibitive non-linearity of response in the higher frequencies. The present invention permits the use of a type of thermionic device as a coupling choke giving a high ratio of alternating current impedance to direct current resistance and without objectionable distortion in any frequency range of interest.

An object of the present invention is to provide a choke of high efficiency in a coupling circuit which will not give undue distortion in the amplifier characteristic in some range of the frequency band of interest.

A further object of the invention is the employment of an electron discharge device having a suitable filter characteristic in a power network.

A further object of the invention is the provision of a new tube structure adapted for an amplifier stage and for coupling the amplifier stage to a later amplifying stage in a manner to avoid the distortion caused by circuit elements known in the prior art which have a large capacity to ground.

Further objects and features of the present invention will be noted in connection with the accompanying specification and drawings illustrative of embodiments of this invention.

In these drawings

Fig. 1 represents a composite amplifier tube

having its own coupling arrangement to a later stage in the same envelope with the amplifier;

Fig. 2 illustrates a modification of the tube structure in Fig. 1;

Fig. 3 illustrates a composite full-wave rectifier tube and filter structure for directly supplying filtered alternating current having a low ripple;

Fig. 4 shows a composite tube in a full-wave rectifier circuit using the elements of a tetrode; and

Fig. 5 shows the characteristic of a four-element or tetrode tube and its mode of employment for the purposes and functions of the present invention.

Fig. 1 discloses circuits employing a new type of amplifying tube 10 for the purposes of this invention. The tube 10 has its input grid 11 associated with the secondary winding 12 of an input transformer 15 connected to a source of signals, such as radio frequency signals, carrier telegraph signals, audio signals or the like. The filament 17 of this composite tube which is shown to be of the heater type carries two cathodes 18 and 19, the filament being energized from a secondary winding 20 of a power transformer having a primary winding 21 connected to a source of alternating current. The plate coupling arrangement connecting this stage of amplification to a later disposed amplifying tube 25 is through elements within the envelope of the tube itself and through the known resistance condenser connection shown as a condenser 26 and a high resistance 27.

The plate current for the amplifying portion of the tube 10 is received through a plate coupling filter arrangement from the alternating current source 21 over a transformer secondary 29, the positive terminal of rectifier 30, a branch circuit including an optionally used resistance 31 external to the envelope connecting to the auxiliary anode 32 within the tube. The plate current path for the amplifying triode continues through the space within the electrode area of the tube to the cathode 19 of the tetrode and to a lead wire 33 within the tube over a resistance 34, passing over the lead wire 33 to the anode 35 of the amplifying triode. A conductive connection 36 including a series resistance 37 of high value within the tube envelope shunts a portion of the anode-cathode circuit of the amplifying triode, including the resistance 31, external to the tube envelope, and the space path between the anode 32 and the screen grid 38 in series. The voltage drop in the resistance 37 produced by the plate current causes the screen grid 38 to be biased to a

positive potential with respect to the cathode 19, which is lower than that of the anode 32. As the resistance 37 is effectively in parallel with the plate resistance of the tetrode, it tends to lower the magnitude of the total effective coupling resistance which in turn has the effect of reducing the amplification. The smaller the value of the resistance 37 is, the more pronounced this effect will be. It is desirable, therefore, that the value of resistance 37 be made high. The presence of the resistance 31 in series with the anode 32 in the portion of the anode circuit shunted by resistance 37 enables a higher value for resistance 37 to be used.

The screen grid 38 is connected to the interior portion of lead wire 33 as shown through a condenser 41 primarily to insure that the screen grid 38 is maintained at the alternating potential of the cathode. The thermionic coupling device (19, 43, 38, 32) is meant to function as a resistance which develops alternating current voltages across the cathode and plate only. Were the condenser 41 to be omitted, the alternating current voltages impressed on the anode 32 would also appear on the screen grid 38 with somewhat reduced amplitude, which would tend to lower the effective anode-cathode resistance of the tetrode and thus impair its efficiency as a coupling element. The cathode 19 is connected to the interior portion of lead wire 33 either directly or as shown through a resistance 34. This latter connection through the resistance 34 causes the space charge grid 43 in the tetrode portion of the tube 10 to be negative with respect to the cathode 19. The path for the plate current in the case of tube 10 may be traced from the rectifier to the anode 32, through the interelectrode space within the tube to the cathode 19, over the resistance 34 and lead wire 33 to the anode 35, through the interelectrode space of the amplifying triode to the cathode shield 18 and back to the negative terminal of the rectifier through a filtering network. The network in the connection of the cathode 18 to the rectifier circuit consists of a resistance 44 designed to furnish the proper bias in well-known manner to the control grid 11 in the amplifying triode of the tube 10, and a shunting condenser 45.

The tetrode tube device as here employed within the envelope holding the elements of a thermionic triode used as an amplifier effects a smoothing action on the plate rectified power and as well gives a highly efficient plate coupling for the triode employed as an amplifier. Slight modifications may be made in the disposal of these elements of the compound tube while still employing the advantages of the tetrode tube characteristic shown in Fig. 5.

A slight modification of the compound tube structure of Fig. 1, is shown in Fig. 2 where the amplifying triode and the thermionic tetrode plate coupling circuit for the triode are likewise enclosed in the envelope of tube 110. Slight changes are made in the plate coupling circuit of the tetrode to secure the desired working conditions in a slightly different way. The circuit of Fig. 2 employs the same power supply circuits as are used in Fig. 1 for filament heating and for furnishing a rectified source of power to the filtering elements within the envelope of tube 110. The positive terminal of the rectified power is connected as previously to the anode 32 in the tetrode device through an exterior resistance 31. The branch connection including lead 36 shunting the resistance 31 connects as before to the

screen grid element through a resistance 37. The space charge grid 51 is connected to the screen grid by means of a resistance connection 52 to give the space charge grid a definite positive voltage somewhat less than the voltage of the screen grid surrounding the anode 32 of the tetrode. This space charge grid 51 is connected through a condenser 54 to the lead wire 55 within the tube extending to the anode 35 of the amplifying triode. This condenser 54 serves to maintain the screen grid 38 at the same alternating potential as the cathode of the tetrode. Since the space charge grid 51 receives its bias from the screen grid 38, the cathode 19 associated with the elements of the tetrode structure is connected directly to the lead wire 55 without the need for an intervening resistance connection. Other elements in the circuit of Fig. 2 may be quite similar to those of the circuit of Fig. 1.

Fig. 3 shows the use of a tetrode tube as a series resistance in a π section filter employed in this case as a part of a filtering circuit of a push-pull rectifier. The use of a tetrode tube as the series element in the filter materially diminishes the residual ripple received from the rectifying device. A rectifying device in this application of the present invention is shown as a thermionic rectifier tube 60 which has its filament 61 heated from an alternating source of power connected to the primary winding 62 of a power transformer, through secondary winding 63 of the transformer. The balanced anode structures consisting of anodes 64 are connected for full rectification to secondary transformer windings 65 associated with the alternating current source of power 62. The output circuits through this push-pull rectifier are shunted by a condenser 68 to remove a material portion of the power ripple. The path for the rectified current from the positive side of the thermionic rectifier extends from the filament lead 69 to the anode 70 in the tetrode tube 71. The circuit continues through the interelectrode space of the tetrode to the cathode 72 and over lead 73 to the load indicated at 75 and over lead 76 back to the mid-point of the secondary winding 65. A lead 77 from the lead wire 69 connects to a resistance 78 connected in turn to the screen grid 79 of the tetrode. The screen grid 79 is connected to the cathode 72 through a resistance 81 shunted by a condenser 82. The cathode and grid 83 are strapped together. The resistances 78 and 81 act as a voltage divider to maintain a predetermined voltage condition on the screen grid 79 relative to the main electrodes of tube 71. The condenser 82 is provided to prevent alternating current potentials appearing between the screen grid and the cathode of the tetrode tube. It aids in removing a material portion of the ripple in by-passing the high frequencies or harmonics. The resistance 81 may be omitted under certain conditions as where resistance 78 has a suitable value for a particular case. The load 75 may be of any character such as a battery under charge or the terminals of a radio set, signal transmission apparatus or the like. The load 75 is shunted by a condenser 84 for improving the filtering effect by the removal from the power current of residual ripple such as that of harmonics of the power frequency. In this rectifier circuit the parts of the rectifier device 60 may be in the same envelope with the elements of the tetrode device 71, the two devices employing, however, different filaments as is seen in Fig. 4.

Fig. 4 shows the thermionic rectifier and the

tetrode series filtering element placed in the same envelope of a tube 210. The filament 61 for the rectifier element with the two balanced anodes 64 are within the same evacuated area as the anode 70, screen grid 79, control grid 83, cathode 72 and associated elements of the tetrode series filtering structure. This particular arrangement is of advantage where compactness is desirable as in aeroplane radios.

Fig. 5 shows the characteristic of the tetrode tube which permits the advantageous plate coupling and filter arrangement by apparatus made according to the present invention. It is intended to operate the tetrode tube element at about point 90 on the most nearly horizontal portion of the curve of the tetrode tube characteristic. A ripple 91 to be filtered out is indicated diagrammatically in exaggerated manner. The tangent to the curve at the point 90 gives a measure of the value of the impedance of the tube around the point 90 to alternating current which is equal to the reciprocal of the slope of the tangent line. In contrast the direct current resistance of the tube at the operating point 90 is much less, being equal to the reciprocal of the slope of a line 93 joining the point 90 to the origin of the curve. The reciprocal of the slope of the trigonometric tangent of the characteristic line at point 90 is seen to be a very large figure. The reciprocal of the slope or the trigonometric tangent of the angle to the line 93 joining the point 90 to the origin is seen to be very much lower in value.

Diode or triode thermionic tubes have been employed as a plate coupling but are not as satisfactory since in contrast to the tetrode tubes their characteristic is curved oppositely or is dished downwardly. Even at saturation the diode or triode does not have as flat a characteristic curve or a characteristic tending to remain as flat. The downwardly curved characteristic for the diode or triode reverses the impedance relationship characteristic from that for the tetrode tube. This reversal makes the direct current resistance of the diode or triode higher than the alternating current impedance over the working range.

It is apparent with the characteristic curve for a tetrode so nearly flat at the point 90 that slight variations in the curve of voltage impressed on the tube as shown in the rippled line 91 will produce almost no appreciable ripple change in the plate current output or direct current going to the triode plate or to the load. The ripple passing through the tetrode as plate current is illustrated in highly magnified manner in line 94. The tube, therefore, has a high choking value against alternating current ripple used as a plate coupling and at the same time it has a material value as a filter to smooth out series ripple and pass a more nearly pure direct or rectified current. The higher choking value of this type of plate coupling over the known inductance choke permits a higher efficiency and a lower consumption of direct current voltage or of rectified current.

The connection of the tetrode tube to the amplifying triode tube within the same envelope materially reduces the necessary connections between the elements and their capacity to ground. The prior placing of a thermionic coupling element in an envelope separate from the elements of the amplifying triode necessitates the presence of batteries and other circuit elements having a large capacity to ground. This gives a material

disadvantage to high frequency signals which are materially distorted due to the high capacity-to-ground of the connections. There is an improved high frequency characteristic made possible with this tetrode plate coupling and B power circuit within an amplifying tube as in Fig. 1 or Fig. 2. With the increasing interest in ever higher frequencies in transmission the unified coupling disclosed is of material value in extending the admissible frequency range without the hitherto unavoidable distortion or high power loss. Further advantage resides in the avoidance of an inductance choke with its stray magnetic fields and objectionable weight.

The advantage in avoiding a magnetic choke by the use of the tetrode according to this invention is nearly as great in the power supply circuits of Fig. 3 or 4 as in those of Figs. 1 and 2. Compactness results from the substitution of a tetrode filtering element in place of the known magnetic choke in permitting reduction in the number of parts and the closer association of parts. This closer association of parts of a power supply circuit does not give rise to the need for having the complicated prior art magnetic shielding necessary with a power supply circuit including a magnetic choke. Material economy is effected in weight as well as in space and this economy of both space and weight more than offsets even a possible high direct current drop in power circuits employing a tetrode filtering element as in Fig. 3 or Fig. 4.

What is claimed is:

1. An amplifying circuit comprising a space discharge amplifying device having as electrodes, a cathode, an anode and a control grid, and circuits therefor, an output coupling circuit for said device comprising a second space discharge device having as electrodes a cathode, an anode, a control grid and a shield grid, and having its space path connected in series with the anode-cathode circuit of the first device with the cathode of said second device connected to the anode of said first device, the electrodes of the two devices being housed in the same envelope, a source of space current connected in said anode-cathode circuit between the cathode of said first device and the anode of said second device, a conductive connection between the anode and the shield grid of said second device, including a series resistance of high value within said envelope, for positively biasing said shield grid with respect to the cathode and the control grid of said second device, means to maintain said shield grid and said control grid of said second device at the same alternating potential as the cathode thereof, and means to positively bias the control grid of said second device with respect to the cathode thereof.

2. The amplifying circuit of claim 1, in which the last-mentioned means comprises a resistance within said envelope connected directly between the shield grid and the control grid of said second device, said source comprises a source of rectified alternating current and said means for maintaining said shield grid and said control grid at the same alternating potential as the cathode comprises capacitive connections between the cathode and the two grid electrodes.

3. In combination, two electron space discharge devices, each having electrodes including a cathode, an anode and a control grid, and circuits therefor, and a circuit for coupling the anode-cathode circuit of one of said devices to the control grid-cathode circuit of the other device, including a third electron space discharge device

having electrodes including a cathode, an anode, a space charge grid and a shield grid, and having its space path in series with the cathode-anode circuit of said one device with the cathode of said third device conductively connected to the anode of said one device, the electrodes of said one and said third device being housed in the same envelope, a conductive connection between the anode of said third device and the shield grid thereof including a resistance within said envelope, to positively bias said shield grid with respect to the cathode of said third device, means to maintain said shield grid and said space charge grid at the same alternating potential as the cathode of said third device, and means to apply a positive bias to said space charge grid which is less than the positive bias applied to said shield grid.

4. An amplifying circuit comprising a space discharge device having as electrodes a cathode, an anode and a control grid, and circuits there-

for, the plate current supply for said device comprising a source of rectified alternating current, an output coupling for said device comprising a second space discharge device having as electrodes a cathode, an anode, a control grid and a screen grid, and having its space path connected in series with the anode-cathode circuit of the first device between said source and the space path of said first device, with the cathode of said second device connected to the anode of said first device, the electrodes of the two devices being housed in the same envelope, a series resistance in said anode-cathode circuit connected between said source and the anode of said second device, a highly resistive conductive connection shunting the anode-shield grid space path of said device and said resistance in series, and means for maintaining said screen grid at the same alternating potential as the cathode of said second device.

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