July 26, 1938. J. H. O. HARRIES 2,125,003

ELECTRON DISCHARGE TUBE CIRCUITS

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*Fig. 1.*

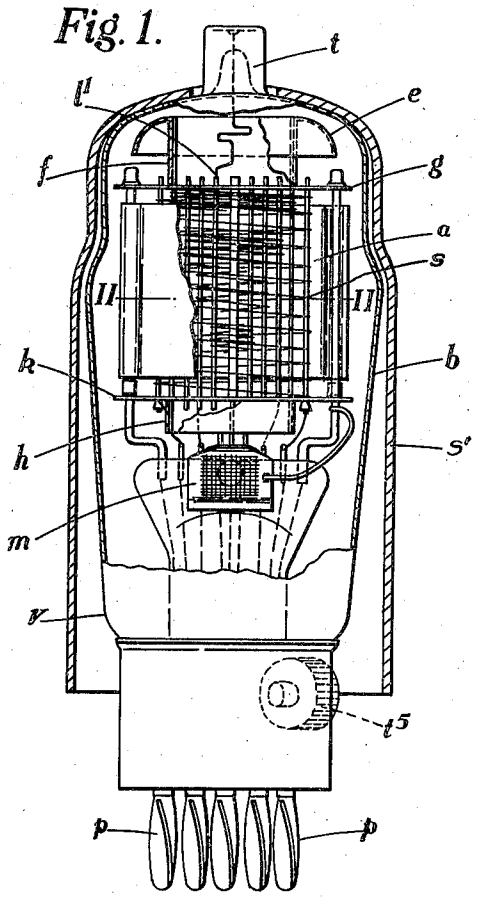
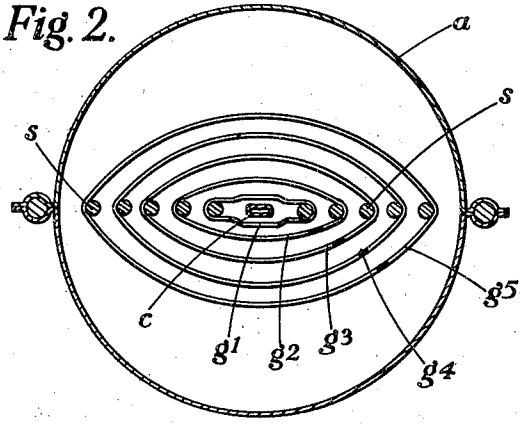



*Fig. 2.*




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Fig. 3.

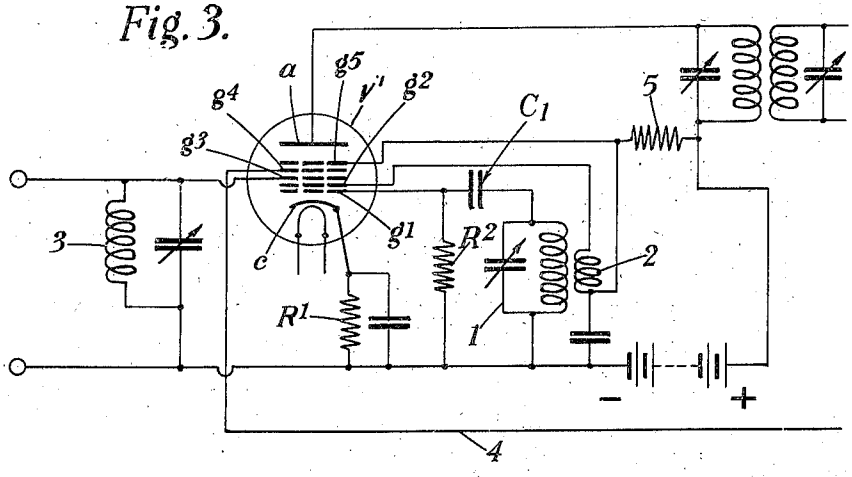



Fig. 4.

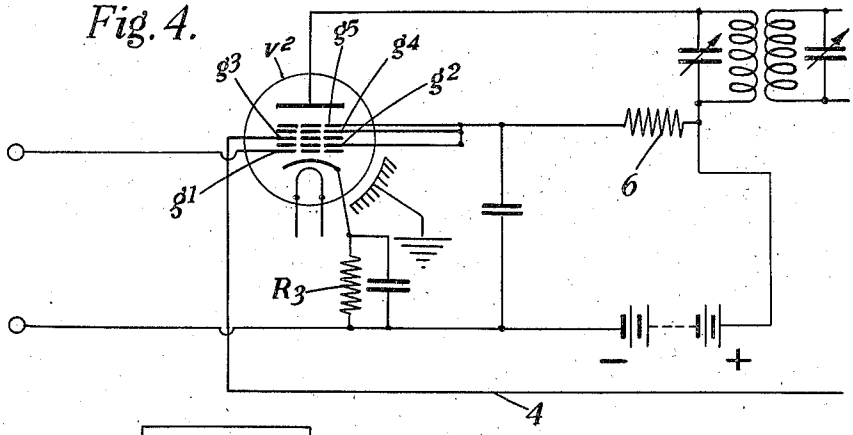
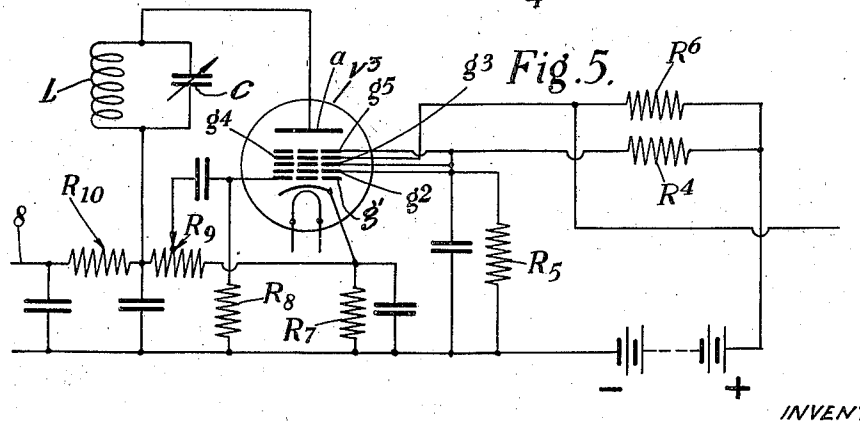



Fig. 5.




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ELECTRON DISCHARGE TUBE CIRCUITS

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Fig. 6.

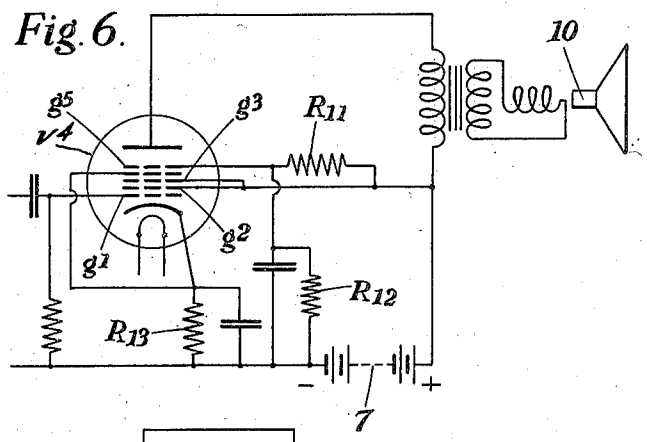



Fig. 7.

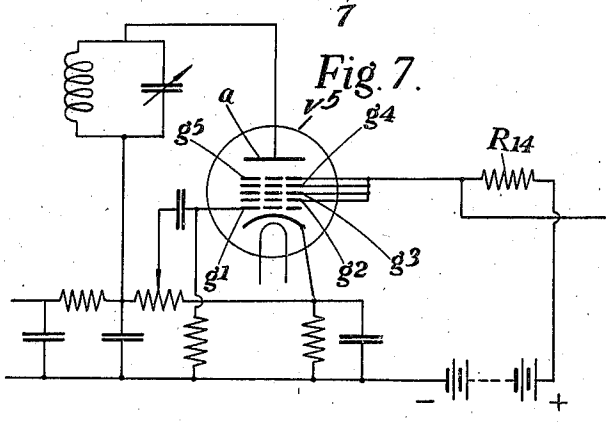
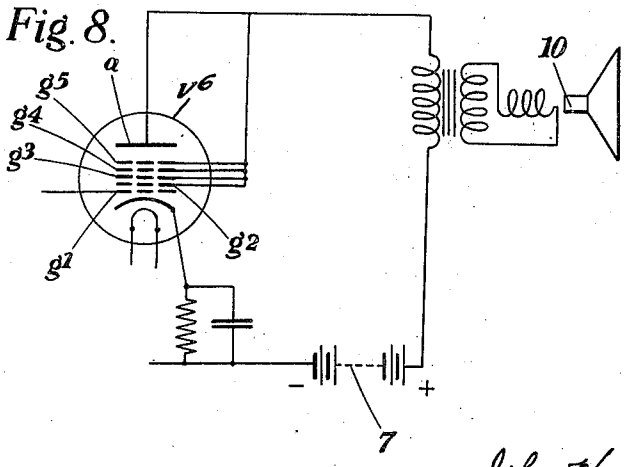



Fig. 8.




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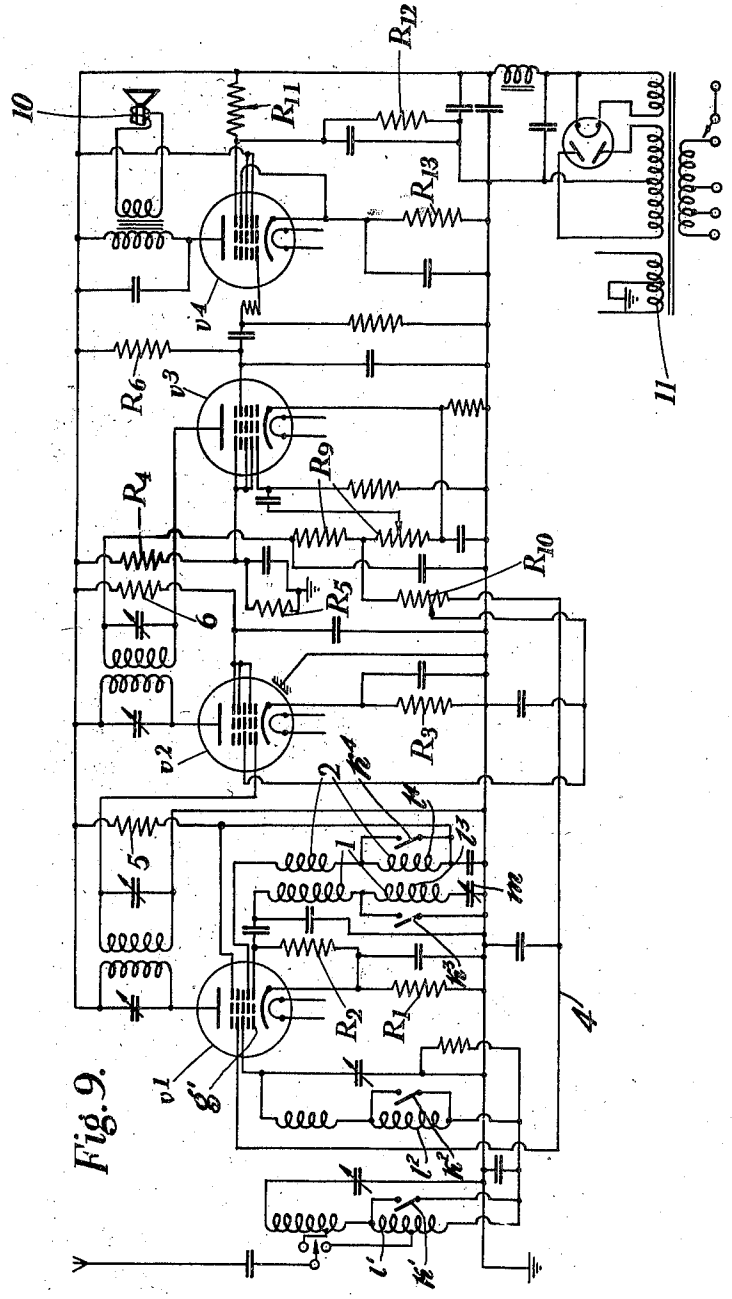



Fig. 9.

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Patented July 26, 1938 2,125,003

# UNITED STATES PATENT OFFICE

2,125,003

## ELECTRON DISCHARGE TUBE CIRCUITS

John Henry Owen Harries, Frinton-on-Sea, Essex, England

Application October 28, 1935, Serial No. 47,042
In Great Britain August 24, 1934

37 Claims. (Cl. 250—20)

The present invention relates to electron discharge tubes or thermionic valves and to circuit arrangements for use with such tubes.

The present invention has a double purpose; first of all to produce a form of discharge tube which is very convenient for use in a single valve frequency converter, such as that employed in supersonic heterodyne receivers and which enables a circuit to be used in such a converter free from the drawbacks of known arrangements, and secondly to provide such a tube that it is capable of use in other stages of a radio receiver and of similar apparatus, such as thermionic amplifiers for television work and indeed in the extreme case to provide a tube which may be employed so to speak as a universal tube, that is to say so that a single form of construction without any alteration may be employed in each of the several stages of a multi-valve radio receiver.

In a single valve frequency converter stage of a supersonic heterodyne receiver, the one valve has to provide for detecting as well as generating the local oscillations. In particular it has been found necessary to provide for very complete electrical separation between the oscillator and signal frequency circuits. The oscillator must be stable and there must be negligible frequency shift with gain control. It is desirable to provide for automatic gain control which can be regulated to approximately zero gain without disturbing the local oscillations. Yet again the anode impedance should not be less than 1 million ohms, while the initial anode current should be as small as possible, preferably not greater than 1.5 to 2.0 milliamperes at maximum gain. Finally, the conversion conductance should be as high as is compatible with low cross-modulation which should be a minimum at high gain.

Considering now again the need of very complete electrical separation between the oscillator and signal frequency circuits, hitherto attempts have been made to attain this object by providing screening in the valve itself of the grid connected to the signal frequency circuits from the grids connected to the oscillator circuits. This method, however, is found to be unsatisfactory, especially at high signal and oscillator frequencies, because the capacity which remains in spite of the screening, even with the best form of screening which has so far been possible in commercial practice, is sufficient to provide an appreciable degree of coupling between the circuits. Thus, the present invention aims at providing effective separation of the oscillator and signal frequency circuits by means independent of screening and thus largely, if not entirely, independent of frequency changes.

Thus according to the present invention, a thermionic valve having at least four grids in addition to an anode and a cathode is employed in a single valve frequency-changer circuit, a pair of grids being connected respectively, one as an oscillating control grid to an oscillatory circuit and the second grid to reaction means coupled to that oscillatory circuit, while another grid is connected as a radio frequency injection grid to a radio frequency input circuit and the capacity of the oscillating control grid to the radio frequency injection grid is made less than the capacity of the second grid to the same radio-frequency injection grid. Thus, advantage is taken of the fact that the voltage across the tuned oscillatory circuit is greater than that across the reaction coil and of approximately opposite phase. The undesirable coupling between the oscillatory and radio frequency circuits is therefore reduced to the smallest possible amount because the voltage applied to the second grid from the reaction coil is less than that applied to the oscillating control grid by the tuned oscillatory circuit, whereas the capacity of the said second grid to the radio frequency injection grid is, on the other hand, larger than that of the oscillating control grid to the said radio frequency injection grid. Thus, the radio frequency injection grid tends to be at a node of potential with respect to the second grid and the oscillating control grid. The two capacities mentioned above are preferably adjusted so that the radio frequency injection grid is, in fact, substantially at a node of potential with respect to the oscillating control grid and the second grid and the relative values of these capacities may be obtained by providing the said grids with suitably shaped conducting surfaces within the envelope of the valve, but in practice an approximation to these conditions is frequently sufficiently satisfactory. The potentials for controlling the magnification of the frequency changer may be applied to a fourth grid nearer to the anode than the oscillating control grid and the second grid.

The grid nearest to the cathode may be connected as the oscillatory control grid and has its lead taken out of the valve envelope at the opposite end to that at which the rest of the electrode leads are taken out. Two of the grids may have such configurations that for the grid

nearer to the cathode, the mutual conductance is not less than of the order of one milliampere per volt and, for the other grid, it is not less than 0.25 milliampere per volt. The arrangement may be such that in the absence of a metal screen placed outside of and close to the envelope of the valve, the capacity between the grid nearest the cathode and the anode is greater than of the order of 0.007 mmfd.

A dished electrostatic screen extending into close proximity with the inner wall of the envelope is attached to the outer end of the grid assembly so as to shield the grid nearest to the cathode from the outer surface of the anode.

In solving the problem set out above it has been found convenient to employ valves in which the anode is set at a distance from the nearest grid electrode which is substantially the "critical" distance in the sense set forth in the specifications of United States Letters Patent No. 2,045,525 and No. 2,045,526. In those specifications it is explained that, if the anode of a valve be placed at various distances from the electrode nearest to it, the positions and spacings of the other electrodes and the operating constants otherwise being unchanged, a curve could be plotted showing the relation between the varying distance of the anode and what was called the break-down voltage, that is the anode voltage at which the anode current reaches saturation value. Such curve shows that if the anode distance is reduced from rather a large value, the break-down voltage decreases to a minimum but that it increases again as the anode is moved nearer to the electrode nearest to it. It is explained that this increase is due to the effect of secondary electron emission from the anode. The distance apart of the anode and the next electrode for the minimum break-down voltage is termed the critical distance and this expression will be used hereinafter in this sense.

A further advantage of a valve as set forth above lies in the fact that the valve may be utilized for shielded amplification, as well as for frequency conversion, since the first grid being at the top of the valve may readily be shielded from the anode. This enables the same type of valve to be used in all stages of a multi-stage valve receiver. This may be appreciated more clearly from a brief consideration of the principal requirements which must be met by such a universal valve which has to operate efficiently in all stages. Apart from the question of the frequency converter stage dealt with above, the requirements in a valve to enable it to act satisfactorily in the intermediate frequency and radio frequency amplifier stages are briefly as follows: The anode to control grid capacity should be very small. It is found that with modern high gain valves the anode to control grid capacity should certainly not be greater than 0.02 mmfd. to 0.005 mmfd. for operation at intermediate frequencies of the order of 110 kilocycles per second. At higher intermediate frequencies of the order of 450 kilocycles per second, instability commences to appear, then the anode to control grid capacity should not be greater than about 0.0015 mmfd. Again the anode impedance should be not less than one million ohms. Theoretically it should not be less than five times the anode load. If it is less than one million ohms, selectivity and amplification are adversely affected in practice. The initial anode current should be of the order of 7.5 milliamperes. The screen current should be as low as possible and not more than about a quarter to one third of the initial anode current. Mutual conductances much greater than about 2 milliamperes per volt are not desirable in intermediate frequency amplifiers owing to commercial limitations and difficulties in screening in radio receivers. It is particularly important in radio frequency stages that cross modulation should be a minimum when the gain is maximum, that is to say, at low automatic gain control voltages. The considerations here are the same as apply to the frequency converter stage.

For audio frequency amplifier stages, high impedance operation is often necessary and the possibility of gain control at audio frequency by varying the function of one of the grids in the valve is desirable.

For detection purposes it is desirable to provide a triode or high impedance low frequency amplifier stage in the same envelope with the diode. If low frequency amplifier stages are used in the case of a triode, the magnification should be five or six times and in the case of a high impedance valve as much as forty or more times. However, small separate diodes are very easily made and are very cheap and have certain circuit advantages so that they may be used instead of employing a combined detector amplifying valve.

In a power stage the valve must give an adequate output to operate a loud speaker with a voltage on the control grid of not more than about 15 to 20 volts peak. Distortion must be as low as possible, which in practice implies that in the output stage the undesirable effects of secondary electron emission from the anode to the next electrode is reduced as far as possible.

Finally as regards automatic gain control, the circuit should be capable of controlling the output and maintaining the diode voltage at a value not greater than 10 volts. Higher values tend to produce whistling and involve overloading the intermediate frequency amplifier. Distortion and cross-modulation must be kept at a minimum. As indicated above it is sometimes useful to apply the automatic gain control to an audio frequency valve as well as to the radio frequency valves. Cost and relibility are basic considerations so that receivers generally employ extremely simple automatic gain control circuits. They must operate adequately from the lowest input voltage to the receiver which will operate the diode effectively up to an input of as much as two or three volts due to a strong local station. Quiescent automatic gain control circuits giving inter-channel suppression are desirable. From the above it will be appreciated that the factors to be taken into consideration in producing a satisfactory universal valve for the purposes indicated are numerous and complicated, but nevertheless the problem has been satisfactorily solved in accordance with the present invention.

It has already been explained that the effect of the secondary emission from the anode and therefore the critical spacing of the anode can be modified by modifying the effect of secondary electron emission from the anode. This emission may be reduced according to the present invention by blackening the anode surface or corrugating the anode and so forth.

Minor modifications may be made in the valve to suit various characteristics. The mesh of the various grids, that is to say the number of turns per centimetre in the helices forming the grids, may be varied and the spacing may be

varied to suit different conditions. Thus, the grid nearest to the cathode may be of the sharp cut-off type and any of the other grids, particularly that used as an automatic gain control electrode may be, if desired, constructed to have a variable-mu characteristic.

In order that the invention may be clearly understood and readily carried into effect, some examples of construction and circuit connections in accordance with the invention will now be described as examples with reference to the accompanying drawings, in which:—

Figure 1 is an elevation with the external screening shield in section and parts of the other electrodes cut away to show the details of construction;

Figure 2 is a horizontal section on the line II—II in Figure 1 of the electrode assembly, Figure 1 being to an enlarged scale and Figure 2 to a still more enlarged scale, the electrodes in Figure 2 being shown approximately three times the actual size;

Figure 3 is a diagram of connections showing the valve connected as a single valve frequency changer;

Figure 4 shows the valve connected as an intermediate frequency amplifier;

Figure 5 shows the valve connected effectively as a tetrode acting as a detector amplifier;

Figure 6 shows the valve connected as a power output valve;

Figure 7 shows the valve connected effectively as a triode acting as a detector amplifier;

Figure 8 is a form of connection of a plain triode, while

Figure 9 is a complete circuit diagram of a supersonic heterodyne receiver having four of the universal valves connected respectively as in Figures 3, 4, 5 and 6.

In Figures 1 and 2 full details are shown of a tube $v$ with a cylindrical anode $a$, an indirectly heated cathode $c$ of the usual British type with a 4-watt heater, and five grids between these two electrodes, viz., $g^1$, $g^2$, $g^3$, $g^4$ and $g^5$. In the actual sample the cathode $c$ is rectangular in cross-section, the sides being 1.5 mms. and 1 mm. in length. The diameter of the anode $a$ may be taken as 27 millimetres and the rest of the dimensions in Figures 1 and 2 are to scale. It will be noted that in plan view the first grid $g^1$ is of flattened shape, while the rest of the grids appear as two circular arcs passing around the supports $s$, all of which are nickel rods of a diameter of 0.75 millimetre. The spacing of the electrodes may be varied to suit different conditions, but in the sample described the respective radii of curvature of the arcs of the grids $g^2$, $g^3$, $g^4$, $g^5$ are 10, 10.6, 11.5 and 14 mms. The distances from centre to centre of the grid supporting rods are respectively 10, 14, 18 and 22 mms., while in the case of grid $g^1$ this distance is 6 mms. The minor axes of grids $g^2$, $g^3$, $g^4$, $g^5$ are respectively 3.7, 7.4, 10 and 12 mms. and the parallel sides of the grid $g^1$ are 2 mms. apart. The mesh of the different grids may also be varied to suit different conditions. In the sample taken they vary from about 5.5 turns per centimetre in the grid $g^5$ to 15 turns per centimetre in the grid $g^3$, the spacing of the grid $g^2$ being 7.1 turns per centimetre, that of the grid $g^1$, 12 and that of the grid $g^4$, 14 turns per centimetre. All the grids are wound of molybdenum wire, the diameter of the wire of $g^1$ being 0.08 millimetre, that of the grids $g^2$, $g^3$, $g^4$, 0.1 millimetre and that of the grid $g^5$ 0.15 millimetre. The first grid $g^1$ has a lead $l^1$ going to the upper terminal $t$. The grid $g^5$ next to the anode is taken out at a side terminal $t^5$, whereas the other three grids, the anode, cathode and heater are taken out to the seven pins $p$. The side terminal may, of course, be omitted and a base used with one additional pin. The grids $g^1$, $g^2$, $g^3$, $g^4$, $g^5$, are wound uniformly, but if it is desired to produce a variable-mu or remote cut-off characteristic, one of the grids, for example, the grid $g^3$ may have some turns omitted along its length.

The screening is very simple and is effective because of its exact position and the wide spacings involved. When the valve is used as a voltage amplifier and the anode to control grid capacity must be a minimum, an external metal electrostatic screen $s^1$ is employed fairly closely conforming to the upper part of the glass bulb $b$. The internal screen consists of an upper screen $e$ of dished shape with a hollow central portion $f$ supported on a mica bridge plate $g$ extending across the electrode assembly. The dished screen $e$ extends approximately into the neighbourhood of the inner wall of the bulb $b$. There is also a lower hollow screen $h$ supported from a second mica bridge plate $k$ and surrounding the lower ends of the grid assembly. A getter support is shown at $m$. In such a valve, with the external screen $s^1$ in position, the anode to control grid capacity is about 0.001 mmfd. The anode is cylindrical and is widely spaced from the outermost grid $g^5$ as seen in Figure 2. It is of blackened nickel to reduce the secondary emission from it and this tends to flatten the lower limb of the distance curve as illustrated in United States Letters Patent No. 2,045,525. The anode is spaced substantially at the critical distance from the outermost grid $g^5$.

A valve constructed in the way described and illustrated in Figures 1 and 2 has the desirable properties of a universal valve as already set out above. In particular the capacity between the grids $g^1$ and $g^3$ is small compared with that between the grids $g^2$ and $g^3$, the ratio between these capacities being such that when the grids $g^1$ and $g^2$ are connected as oscillator electrodes as will be described with reference to Figure 3, the oscillator circuits are not coupled to the radio-frequency input circuit to an undesirable extent and "locking-in" is avoided. This desirable ratio is obtained because the grid $g^1$ is connected to the terminal $t$ at the top of the bulb $b$ whereas the leads from the grids $g^2$ and $g^3$ are taken out at the lower end of the bulb. When a universal valve is to serve without alteration as a screened amplifier as well as a frequency converter, the first grid $g^1$ must have its lead taken out at the opposite end from the other electrodes or the capacity between the grid $g^1$ and the anode $a$ under screened amplifier conditions will not be low enough.

In Figures 3 to 8 of the drawings, some possible forms of connection of the valve when used for different purposes are illustrated.

In Figure 3, the connections of the valve $v^1$ as a single valve frequency changer are shown. The grids $g^1$, $g^2$ operate respectively as the control grid and anode grid of the oscillator part of the valve, the tuned oscillator circuit 1 being connected to the grid $g^1$, the anode circuit feedback coil 2 being connected to the grid $g^2$. The grid $g^3$ is the input grid for the signal frequency and is connected directly to the tuned input circuit 3. The grid $g^4$ is the automatic gain control

grid separate from the input grid and is connected directly to an automatic gain control bus bar 4. Alternatively, the functions of the grids $g^3$ and $g^4$ may be interchanged. Either of these grids may be wound non-uniformly so as to give a variable-mu cut-off characteristic and then both the signal frequency and the automatic gain control voltages may be applied to the same grid. The anode $a$ is coupled to the next stage, for example the intermediate frequency amplifier in the ordinary way.

The grid $g^5$ is connected through a break-down resistance 5 and is a positive screening grid. The oscillator potentials on the grids $g^1$ and $g^2$ are in opposite phase and the ratios of the capacities between the grids $g^1$ and $g^2$ and the grid $g^3$—or $g^4$—are such that the oscillator circuits, 1, 2 are not coupled to the radio frequency circuit to an undesirable extent. This method of balancing out the feed back is found to be better than screening and is not affected by frequency. In this case, with the valve constants as described with reference to Figure 1, the operating conditions are as follows:—The anode voltage is 250 and the break-down resistance 5 has a value of about 60,000 ohms so that a steady potential of about 100 volts is applied to the grids $g^2$ and $g^5$. The cathode bias resistance $R^1$ is 200 ohms and the grid leak resistance $R^2$, 15,000 ohms. The condenser $C_1$ is 0.001 mfd. The anode current in the absence of an automatic gain control voltage is from 1.5 to 2.0 milliamperes. The cathode is at about 3 volts positive and the current flowing to the grid $g^2$ is about 9 milliamperes. The internal alternating current resistance of the valve is 1 million ohms. The conversion conductance with zero automatic gain control voltage is about 0.7 to 0.8 milliampere per volt.

In Figure 4, the connections are shown for a controlled gain voltage amplifier suitable for use in the intermediate frequency stage of a supersonic heterodyne receiver. The valve $v^2$ is in effect a tetrode as the first grid $g^1$ acts as the input grid, the third grid $g^3$ acts as the automatic gain control grid, and the other three grids $g^2$, $g^4$ and $g^5$ are connected directly together and through a resistance 6 to the high tension source so that they act as positive screening grids. The anode to control grid capacity with the external screen in position is about 0.001 mmfd. It will be noticed that here again separate grids are used for the gain control and for the input voltage. The mutual conductance is reduced proportionally to the reduction in anode current which occurs as the gain control grid is made more negative. This method avoids the amplitude distortion which accompanies the method of gain control by means of a variable-mu characteristic. If the valve has the dimensions described with reference to Figure 1, the following gives the operating conditions:—The anode voltage is 250. The break-down resistance 6 has a value of 60,000 ohms and the cathode bias resistance $R_3$ is 150 ohms. The voltage on the grids $g^2$, $g^4$, and $g^5$ is between 60 and 70 volts. If the grid $g^3$ is at the same potential as the cathode, the mutual conductance of the valve is of the order of 2.2 milliamperes per volt and the anode current about 7.5 milliamperes. The internal alternating current resistance of the valve is about 1 million ohms. It is important to note that as increasingly negative automatic gain control voltages are applied to the grid $g^3$, the current flowing to the grid $g^2$ will increase and therefore the screen voltage on the grid $g^2$ will be reduced. The total current taken by the valve will also fall owing to the reduced positive field acting on the cathode space charge with the particular configuration of the grids provided. Also, the cathode bias due to the voltage drop across the resistance $R_3$ will be reduced proportionally. In this way, the operating cathode bias remains at the correct value with respect to the screen voltage at all values of the negative automatic gain control voltage on the grid $g^3$. This is an important property of the valve when employed in this circuit. If methods of producing the necessary grid bias has been used, other than a cathode resistance, then the cathode or grid bias would not have taken automatically a suitable value for all values of the automatic gain control voltage.

In Figure 5, the valve $v^3$ is shown connected as a single valve detector audio frequency amplifier, the valve serving as a tetrode. The anode $a$ of the valve is connected to the tuned output circuit L, C, and operates as a diode on a virtual or floating space-charge cathode formed between the grids and anode. The grids $g^2$, $g^3$, and $g^5$ are connected together as positive screening grids, being connected to a potential divider $R_4$, $R_5$ across the high tension source, while the grid $g^4$ serves as the anode of the audio frequency amplifier part of the valve. This form of connection gives a magnification of up to the order of 40 times. The automatic gain control connection is made at 8, for example, to the line 4 in Figures 3 and 4. If, again, the valve has the dimensions as in Figure 1, the operating conditions are as follows:—The anode voltage is 250. The volage divider resistances $R_4$ and $R_5$ are respectively 250,000 and 50,000 ohms so as to produce a potential of about 40 volts on the grids $g^2$, $g^3$, $g^5$. The resistance $R_6$ which serves as the resistance coupling the valve to the next stage has a value of 30,000 ohms, while the cathode bias resistance $R_7$ is 1,000 ohms. The grid leak resistance $R_8$ may be 1 million ohms. The diode load resistance $R_9$ is 500,000 ohms and the automatic gain control filter resistance $R_{10}$, 1 million ohms. The efficiency of rectification is high, of the order of 96 per cent.

In Figure 6 the valve $v^4$ is shown connected to act as a power output valve. The external screen is not used but the valve so connected has a low anode to control grid capacity. The grid $g^1$ is the input grid and the grids $g^2$, $g^3$ and $g^5$ are positive screening grids connected to a potential divider $R_{11}$, $R_{12}$ connected across the high tension source 7. A loud speaker 10 is shown transformer-coupled to the anode circuit of the valve. With the valve illustrated in Figure 1, the operating conditions are as follows:—The steady potential of the anode $a$ and of the grids $g^2$ and $g^3$ is 250 volts and that of the grid $g^5$ is about 70 volts. The cathode bias resistance $R_{13}$ is 250 ohms. The anode current is 32 milliamperes and the mutual conductance of the order of 3 milliamperes per volt. The cathode bias is about 12 volts and the valve should be capable of giving a power output of the order of 2 to 3 watts with a load of about 6,000 ohms.

In Figure 7, the valve $v^5$ is shown connected as a single valve detector amplifier actually operating as a triode. $g^1$ is the input grid, the anode $a$ acts as a diode and the output is taken off from the remaining four grids $g^2$, $g^3$, $g^4$ and $g^5$ connected together. With the valve shown in Figure 1, the operating conditions are much the same as stated in connection with Figure 5, except that the potential divider $R_4$, $R_5$ is omitted and the coupling resistance $R_{14}$ may conveniently

have a high value, for example, of 50,000 to 100,000 ohms.

Figure 8 shows the valve $v^6$ connected as a plain triode employed for example as an output valve. The grid $g^1$ is the input grid, the remaining four grids $g^2$, $g^3$, $g^4$ and $g^5$ are all connected direct to the anode $a$ and with it form the output electrode.

Figure 9 shows the circuit connections of a complete supersonic heterodyne receiver. The valve $v^1$ is connected as a single valve frequency changer precisely as shown in Figure 3, with the exception that the resistance $R_2$ is connected between the grid $g^1$ and the cathode of the tube $v^1$. The valve $v^2$ is an intermediate frequency amplifier connected exactly as shown in Figure 4. The valve $v^3$ is a combined detector and amplifier connected as a tetrode in precisely the manner shown in Figure 5, while the valve $v^4$ is a power output valve connected exactly as shown in Figure 6. The circuit is shown with the ordinary aerial tuning arrangements and the ordinary mains power unit for the high tension supply with a winding 11 supplying the current to the heaters of the cathodes of the valves. Also, the frequency changer valve $v^1$ and its associated circuits are shown provided with switching arrangements for changing from one wave length range to another. Thus in the antenna circuit the switch $k^1$ can be closed to short circuit inductance $l^1$ and in the input circuit to the tube $v^1$, the switch $k^2$ can be closed to short circuit inductance $l^2$. Furthermore, in the oscillator grid circuit there is a switch $k^3$ which can be closed to short circuit inductance $l^3$ and condenser $m$ and finally in the oscillator anode circuit a switch $k^4$ is arranged when closed to short circuit an inductance $l^4$. The circuit connections will be apparent after examination of Figures 3 to 6 since the same reference characters have been used for corresponding parts.

It will be easily appreciated that the same form of valve could not be used in all the circuits if they had not the following characteristic features. In the case of the frequency changer valve $v^1$, the first grid $g^1$ has its lead taken out at the top of the bulb $b$ and is prevented from producing serious "lock-in" by means of the capacity ratio of the grids as described instead of by shielding. Since the first grid $g^1$ is connected to the terminal $t$ at the top of the bulb $b$, that is to say, at the opposite end to that at which the anode $a$ is connected, the same construction of valve can therefore be used as the intermediate frequency amplifier $v^2$. By the provision of several grids it is possible to employ the same construction of valve as the combined diode and tetrode amplifier $v^3$. The potential of the grid $g^5$ while sufficiently high to serve as an anode break-down voltage low compared with the voltage of the high tension source used in the receiver and compared with the voltage of the anode $a$ and the other positive grids, is nevertheless low enough to allow of a critical anode distance within the dimensions of a bulb of convenient size so that the advantages of the anode critical distance as regards power output and low distortion level are retained. Furthermore, owing to the provision of a number of grids, there is a grid in the case of the frequency converter and intermediate frequency valves, which is nearer the anode than the control or oscillatory grids and is available as an automatic gain control electrode.

I claim:—

1. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacities of said input grid to said oscillating control grid and to said third grid are so related that said input grid is substantially at a node of potential as regards the potentials of said oscillating control grid and said third grid.

2. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit, and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said third grid, and two of said grid electrodes having such configurations, that the mutual conductance of said tube with respect to the grid electrode nearer the cathode is, at least, of the order of one milliampere per volt and with respect to the other of said two grids is at least 0.25 milliampere per volt.

3. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said third grid, and said oscillating control grid and said third grid having such configurations, that the mutual conductance of said tube with respect to said oscillating control grid is at least of the order of one milliampere per volt, and with respect to the third grid at least 0.25 milliampere per volt.

4. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes of which one is operative as an oscillating control grid and another as an input grid and a dish-shaped electrostatic screen connected to one

of said grid electrodes, attached to one end of the grid assembly and extending into close proximity with the inner wall of the envelope so as to shield the grid electrode nearest to the cathode from the outer surface of said anode, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is lesss than its capacity to said third grid.

5. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes of which one is operative as an oscillating control grid and another as an input grid and a dish-shaped electrostatic screen connected to one of said grid electrodes attached to one end of the grid assembly and extending into close proximity with the inner wall of the envelope so as to shield the grid electrode nearest to the cathode from the outer surface of said anode, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said third grid, and the electrostatic capacity between the anode and the grid electrode nearest the cathode of said electron discharge tube, being greater than the order of 0.007 micro-micro-farad when uninfluenced by the presence of an external conductive screen in close proximity to the envelope of said tube.

6. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid of the variable mu type and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said third grid whereby said input grid is substantially at a node of potential as regards the potentials of said oscillatory control grid and said third grid.

7. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid of the variable mu type and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacities of said input grid to said oscillating control grid and to said third grid are so related that said input grid is substantially at a node of potential as regards the potentials of said oscillating control grid and said third grid.

8. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode having its surface treated to reduce secondary electron emission and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said third grid.

9. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode with a blackened surface and a cathode, at least four grid electrodes, of which one is operative as an oscillating control grid and another as an input grid, an oscillatory circuit connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid, said input grid having electrostatic capacity to said oscillating control grid and said third grid, the dimensions and positions of said input grid, oscillating control grid and third grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said third grid.

10. A supersonic heterodyne signal frequency changing circuit arrangement comprising an electron discharge tube having an anode with a blackened surface, a cathode and at least four grid electrodes of which the grid electrode nearest the cathode is operative as an oscillating control grid and another of said grid electrodes as an input grid, an oscillatory circuit connected to said oscillating control grid, back-coupling means coupled to said oscillatory circuit and connected to a third of said grid electrodes, and a radio-frequency input circuit connected to said input grid electrode, said oscillating control grid having its leading-in conductor extending through the envelope of said discharge tube at the end opposite to that through which the leading-in conductors of said other electrodes extend.

11. A supersonic heterodyne signal frequency changing circuit arrangement, comprising an electron discharge tube having, in addition to an anode and a cathode, at least four grid electrodes, of which the grid electrode nearest to the cathode is operative as an oscillating control grid, another of said grid electrodes as an input grid and a third of said grid electrodes constructed to have a variable mu characteristic, is operative as an automatic gain-control electrode, an oscillatory circuit

connected to said oscillatory control grid, back-coupling means coupled to said oscillatory circuit and connected to a fourth of said grid electrodes, a radio-frequency input circuit connected to said input grid and an automatic gain control bus-bar connected to said automatic gain control electrode, said input grid having electrostatic capacity to said oscillating control grid and said fourth grid, the dimensions and positions of said input grid, oscillating control grid and fourth grid being such that the capacity of said input grid to said oscillating control grid is less than its capacity to said fourth grid.

12. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and five successive grid electrodes therebetween, at least one tube being connected to operate as a frequency converter, a source of positive potential connected to one grid electrode for operation thereof as a positive screening grid, an input circuit connected to a secod grid electrode, an oscillating circuit connected to a third grid electrode for operation thereof as an oscillation control electrode, back coupling means coupling said oscillating circuit to a fourth grid electrode connected for operation as an anode grid; a second tube connected to operate as an intermediate frequency amplifier, an external screen surrounding said second tube, one second tube grid electrode being coupled to the output of said first tube and operating as a control electrode, means maintaining the remaining second tube grid electrodes at positive potentials for operation as screen electrodes; a third tube connected for operation as a detector, means for applying potential between the third tube cathode and a third tube electrode to produce rectified current, circuit connections for applying automatic volume control potentials from the output of said third tube respectively to one first tube grid electrode and one second tube grid electrode; a fourth tube operating as an audio frequency amplifier and having one grid electrode coupled to the third tube; a fifth tube operating as a power output tube, means connecting one fifth tube grid electrode as a control grid, means coupling said fifth tube control grid to the output of said fourth tube, and means for maintaining the remaining fifth tube grids at positive potentials for operation as screening grids.

13. Apparatus according to claim 12 characterized by the fact that in each of the electron discharge tubes the first grid counting from the cathode is spaced therefrom by a distance of the order of about 0.3 mm. and has a mesh closer than the order of 10 turns per centimeter of 0.1 mm. wire, the third and fourth grids having meshes closer than the order of 10 turns per centimeter of 0.1 mm. wire, the second grid being of mesh not closer than about the order of 10 turns per centimeter of 0.1 mm. wire, the fifth grid having a mesh not closer than the order of about 8 turns per centimeter of 0.1 mm. wire and the distance between successive grids beginning with the second grid being approximately equal and of the order of 1 to 2 mms.

14. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and five successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter and having two of its grid electrodes operating respectively as an oscillation control electrode and an anode, a further grid electrode connected to automatic volume control potential and the remaining grid electrode connected as a positive screening grid, an oscillatory circuit connected to said oscillator control electrode, back coupling means coupled to said anode grid and coupled to said oscillator circuit; a further tube operating as an intermediate frequency shielded amplifier cooperating with external screening means and having one grid electrode operating as a control electrode, one other grid electrode having automatic volume control voltages applied thereto, the remaining grid electrodes connected for operation as screening electrodes; detecting means and a still further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

15. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and five successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter and having two of its grid electrodes operating respectively as an oscillation control electrode and an anode, a further grid electrode connected to automatic volume control potential and the remaining grid electrode connected as a positive screening grid, an oscillatory circuit connected to said oscillator control electrode, back coupling means coupled to said anode grid and coupled to said oscillatory circuit; detecting means and a still further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

16. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and five successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter and having two of its grid electrodes operating respectively as an oscillation control electrode and an anode, a further grid electrode connected to said automatic volume control potential and the remaining grid electrode connected as a positive screening grid, an oscillatory circuit connected to said oscillator control electrode, back coupling means coupled to said anode grid and coupled to said oscillator circuit; a further tube operating as an intermediate frequency shielded amplifier cooperating with external screening means and having one grid electrode operating as a control electrode, one other grid electrode having automatic volume control voltages applied thereto, the remaining grid electrodes connected for operation as screening electrode, a still further tube operating as a detector input, and means for applying potential between the cathode and anode to produce rectified current; detecting means and a still further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

17. In a wireless receiving apparatus or the like, a plurality of electron discharge tubes, each having a cathode, an anode and five successive grid electrodes therebetween, at least one tube

operating as a radio frequency amplifier and having its first grid electrode counting from the cathode connected to the input circuit with the second and fifth electrodes connected as positive screening electrodes and one of the third and fourth grid electrodes connected to automatic volume controlling potentials and the remaining grid electrode being connected as a screening electrode; detecting means and a further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

18. In an electron discharge amplifier, an electron discharge tube having a cathode, an anode and at least five grid electrodes therebetween, a signal input circuit, means for connecting the first grid counting from the cathode to said input circuit for operation as a control electrode, and means for maintaining the remaining electrodes at positive potentials relative to said cathode for operation as screen electrodes.

19. In an electron discharge amplifier, an electron discharge tube having a cathode, an anode and at least five grid electrodes therebetween, a signal input circuit, means for connecting the first grid counting from the cathode to said signal input circuit for operation as a control electrode, means for maintaining the electrode nearest the anode at a positive potential relative to said cathode, and means for maintaining said remaining electrodes at a higher positive potential than said last-named electrode for operation as screening electrodes.

20. An electron discharge combined detector amplifier tube circuit comprising an electron discharge tube having an anode, a cathode and at least five grid electrodes therebetween, a high frequency input circuit connected between one electrode and said cathode in series with a load resistance to render said one electrode and cathode operative as a diode detector, means connecting one of said grid electrodes as a control electrode and for impressing thereon rectified potentials from said load resistance, an output circuit connected to at least one of said grid electrodes nearer to said anode than the grid electrode last mentioned, and a source of positive potential connected to said output circuit whereby said last-mentioned grid electrode is operative as the anode with respect to said grid electrode connected as a control electrode.

21. An electron discharge amplifier circuit comprising an electron discharge tube having an anode, a cathode and at least five electrodes therebetween, one grid electrode operating as a control electrode and having its lead passing out of the tube envelope at the end thereof opposite to that at which the anode lead passes out, a signal input circuit connected to said control electrode, another grid electrode connected for operation as a positive screen grid, a detector tube having its output connected to a further grid electrode for supplying automatic volume control potentials thereto, screening means within said tube envelope and screening means external of said tube envelope and cooperative with said internal screening means for screening said control electrode from said anode.

22. An electron discharge amplifier circuit comprising an electron discharge tube having a cathode, an anode, and at least five electrodes therebetween, a signal input circuit means for connecting the first grid counting from the cathode to said input circuit for operation as a control grid, a load resistance, a source of positive potential, means for connecting said load resistance to said source, and means for connecting the remaining grids and the anode to said load resistance for cooperative operation as an anode with respect to said control electrode and cathode.

23. In a wireless receiving apparatus or the like a plurality of like electron discharge tubes, each having an anode, a cathode and at least four successive grid electrodes therebetween, at least one tube operating as a frequency converter; a further tube operating as an intermediate frequency shielded amplifier co-operating with external screening means and having one grid electrode operating as a controlling electrode, one other grid electrode having automatic volume control voltages applied thereto, and the remaining grid electrodes connected for operation as screening electrodes; detecting means and a still further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

24. A wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having an anode, a cathode and at least four successive grid electrodes therebetween, at least one tube operating as a radio-frequency amplifier and having its first grid electrode counting from the cathode connected to the input circuit with one of the remaining grid electrodes connected to automatic volume controlling potentials and the remaining grid electrodes being connected as screening electrodes; a detecting means and a further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

25. In a wireless reeciving apparatus or the like, a plurality of like electron discharge tubes, each having an anode, a cathode and five successive grid electrodes therebetween; at last one tube operating as a radio frequency amplifier and having its first grid electrode counting from the cathode connected to the input circuit with the second and fifth grid electrodes connected as positive screening electrodes and one of the third and fourth grid electrodes connected to automatic volume controlling potentials and the remaining grid electrode being connected to the screening electrode, detecting means and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

26. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having an anode, a cathode and five successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter; detecting means and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

27. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes

each having a cathode, an anode and four successive grid electrodes therebetween, at least one tube being connected to operate as a frequency converter, a source of positive potential connected to one grid electrode for operation thereof as a positive screening grid, an input circuit connected to a second grid electrode, an oscillating circuit connected to a third grid electrode for operation thereof as an oscillating control electrode, back coupling means coupling said oscillating circuit to a fourth grid electrode connected for operation as an anode grid; a second tube connected to operate as an intermediate frequency amplifier, an external screen surrounding said second tube, one second tube grid electrode being coupled to the output of said first tube and operating as a control electrode, means maintaining the remaining second tube electrodes at positive potential for operation as screening electrodes, a third tube connected for operation as a detector, means for applying potential between the third tube cathode and a third tube electrode to produce rectified current, circuit connections for applying automatic volume control potentials from the output of said third tube respectively to one first tube grid electrode and one second tube grid electrode; a fourth tube operating as an audio frequency amplifier and having one grid electrode coupled to the third tube; a fifth tube operating as a power output tube, means connecting one fifth tube grid electrode as a control grid, means coupling said fifth tube control grid to the output of said fourth tube and means for maintaining the remaining fifth tube grids at positive potentials for operation as screening grids.

28. Apparatus according to claim 27 characterized by the fact that in each of the electron discharge tubes the first grid counting from the cathode is spaced therefrom by a distance of the order of about 0.3 mm. and has a mesh closer than the order of 10 turns per centimeter of 0.1 mm. wire, the third grid having meshes closer than the order of 10 turns per centimeter of 0.1 mm. wire, the second grid being of mesh not closer than about the order of 10 turns per centimeter of 0.1 mm. wire, the fourth grid having a mesh not closer than the order of about 8 turns per centimeter of 0.1 mm. wire and the distance between successive grids beginning with the second grid being approximately equal and of the order of 1 to 2 mms.

29. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and four successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter; a further tube operating as an intermediate frequency shielded amplifier cooperating with external screening means and having one grid electrode operating as a control electrode, one other grid electrode having automatic volume control voltages applied thereto, the remaining grid electrodes connected for operation as screening electrodes; detecting means and a still further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

30. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and four successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter; detecting means and a further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

31. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having a cathode, an anode and four successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter; a further tube operating as an intermediate frequency shielded amplifier cooperating with external screening means and having one grid electrode operating as a control electrode, one other grid electrode having automatic volume control voltages applied thereto, the remaining grid electrodes connected for operation as screening electrode, a still further tube operating as a detector input, and means for applying potential between the cathode and anode to produce rectified current; detecting means and a still further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

32. In a wireless receiving apparatus or the like, a plurality of electron discharge tubes, each having a cathode, and anode and four successive grid electrodes therebetween, at least one tube operating as a radio frequency amplifier; detecting means and a further tube operating as an audio-frequency amplifier with one grid electrode connected as a control electrode and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

33. In an electron discharge amplifier, an electron discharge tube having a cathode, an anode and at least four grid electrodes therebetween, a signal input circuit, means for connecting the first grid counting from the cathode to said input circuit for operation as a control electrode, and means for maintaining the remaining electrodes for operation as screen electrodes at positive potentials relative to said cathode.

34. In an electron discharge amplifier, an electron discharge tube having a cathode, an anode and at least four grid electrodes therebetween, a signal input circuit, means for connecting the first grid counting from the cathode to said signal input circuit for operation as a control electrode, means for maintaining the electrode nearest the anode at a positive potential relative to said cathode, and means for maintaining said remaining electrodes at a higher positive potential than said last-named electrode for operation as screening electrodes.

35. An electron discharge combined detector amplifier tube circuit comprising an electron discharge tube having an anode, a cathode and at least four grid electrodes therebetween, a high frequency input circuit connected between one electrode and said cathode in series with a load resistance to render said one electrode and cathode operative as a diode detector, means connecting one of said grid electrodes as a control electrode and for impressing thereon rectified potentials from said load resistance, an output circuit connected to at least one of said grid elec-

trodes nearer to said anode than the grid electrode last mentioned, and a source of positive potential connected to said output circuit whereby said last-mentioned grid electrode is operative as the anode with respect to said grid electrode connected as a control electrode.

36. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes, each having an anode, a cathode and four successive grid electrodes therebetween; at least one tube operating as a radio frequency amplifier and having its first grid electrode counting from the cathode connected to the input circuit with the second and fourth grid electrodes connected as positive screening electrodes and the third grid electrode connected to automatic volume controlling potentials and the remaining grid electrode being connected to the screening electrode, detecting means and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

37. In a wireless receiving apparatus or the like, a plurality of like electron discharge tubes each having an anode, a cathode and four successive grid electrodes therebetween, at least one of said tubes operating as a frequency converter; detecting means and at least one further tube operating as a power output tube with one grid electrode connected as a control grid and the remaining grids connected to operate as screening grids.

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