

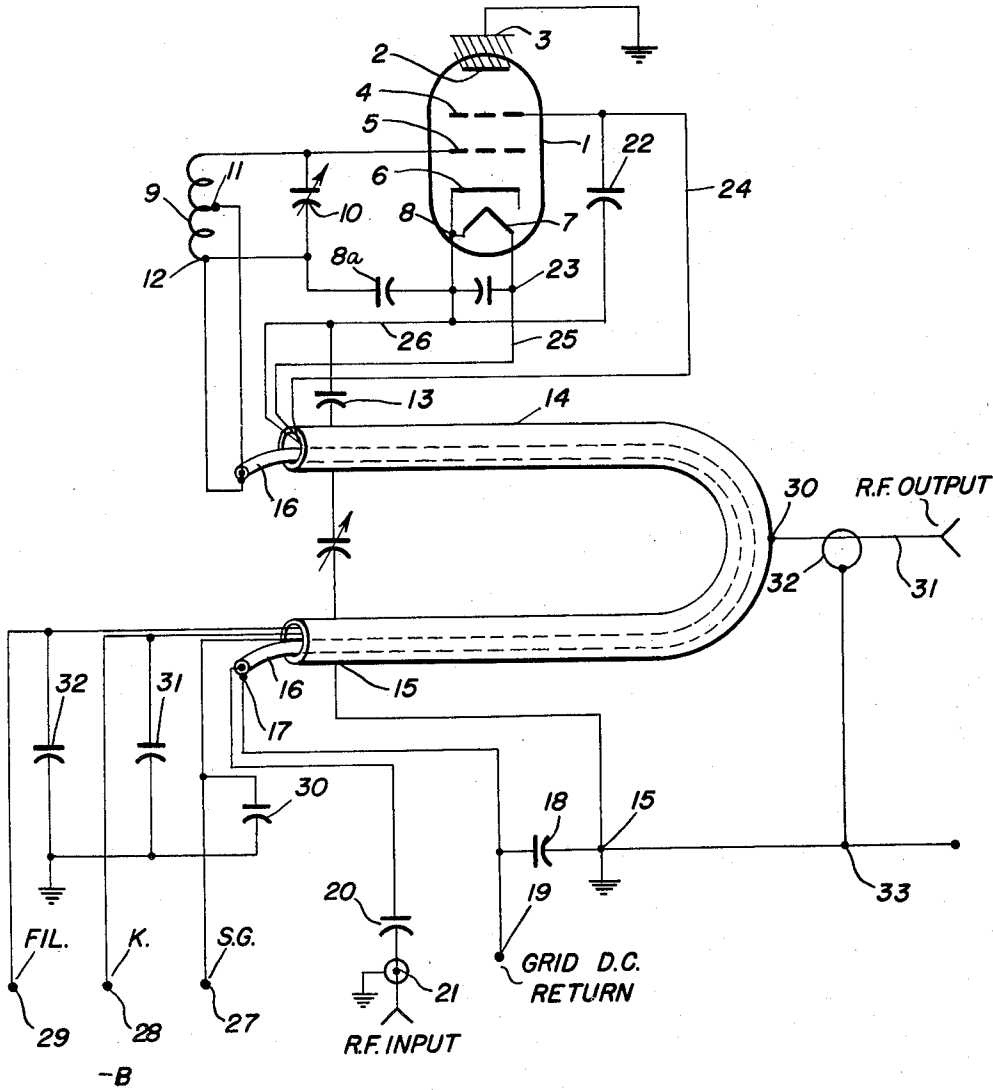
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VACUUM TUBE CIRCUIT

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VACUUM TUBE CIRCUIT

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The present invention relates generally to vacuum tube circuits, and more particularly, in a preferred field of use, to radio frequency amplifiers capable of stable operation under extreme environmental conditions, and operating with anode grounded for both direct current voltage and radio frequency voltage, whereby the anode may be connected physically to a heat sink.

In amplifiers designed for operation under extreme environmental conditions, and wherein a large quantity of heat is developed in a vacuum amplifier tube of the amplifier, provision is usually made for either liquid or air flow cooling the amplifier tube. Such provision is preferably avoided, where possible since it leads to auxiliary equipment, circuits and the like, to effect cooling, and generally also to safety provisions to assure that the amplifier tube will not be destroyed if the cooling system fails.

Ultra high frequency tubes are available in which part of the tube envelope is metallic and constitutes the anode of the tube. The anode of such a tube may be connected directly to a heat sink, constituting preferably a metallic element having extensive radiating surface. Sufficient heat dissipation may be obtained in this manner to obviate any necessity for liquid or air flow cooling, with consequent simplification of equipment, and reduction of space and weight. Systems of this type require, however, that the tube anode be operated at both D.C. and R.F. ground.

It is a primary object and feature of the present invention to provide a novel R.F. amplifier employing a vacuum tube which permits operation with an anode grounded for both D.C. and R.F. voltage.

It is another object of the present invention to provide a system of radio frequency amplification in which the anode of a vacuum tube operates at D.C. and R.F. ground, wherein the plate to cathode load is a transmission line in the form of a hollow tube which is utilized internally as a conduit for input signal leads, and D.C. and A.C. power leads, for energizing the various electrodes of the tube and the outer surface of which provides a cathode load for said vacuum tube.

It is another object of the present invention to provide a system of radio frequency amplification in which the anode of a vacuum tube operates at D.C. and R.F. ground and the tube is driven by an input R.F. voltage applied between control grid and cathode, and in which output R.F. voltage is developed between cathode and anode across a load impedance consisting of a transmission line in the form of a hollow tube which is utilized as a conduit for input signal leads, and D.C. and A.C. power leads for energizing the various electrodes of the vacuum tube.

A further object of the present invention relates to a system for providing a tuned anode to cathode load for a vacuum tube, in the form of a hollow conductive tube.

It is another object of the present invention to provide a tetrode circuit having a tuned input and a tuned output

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circuit, the output circuit consisting of a hollow conductor having, by virtue of its length, a high impedance as seen from the cathode, and devices for supplying R.F. signal between cathode and grid in superposition of cathode R.F. voltage, which shall be extremely economical and simple of in construction and adjustment to frequency.

A further object of the invention resides in the provision of a vacuum tube tetrode circuit having provision for a transmission line cathode load, consisting of a hollow tube of appropriate R.F. impedance as seen from the cathode of the tube, within which extend power leads for the heater of the tube, leads for supplying bias voltage to the screen grid and control grid, and a transmission line for supplying R.F. signal between control grid and cathode.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

The single figure of the drawings is a schematic circuit diagram of the system according to the invention.

In the single figure of the accompanying drawings, the reference numeral 1 denotes a vacuum tube having an anode 2, which is physically in contact with a heat sink 3, and which is connected directly to ground. It may be assumed for example, that the heat sink 3 is at ground voltage, and that the anode 2 being directly connected with the heat sink 3 is similarly at ground voltage, for both A.C. and D.C. voltages.

The vacuum tube 1 includes a screen grid 4, a control grid 5, a cathode 6 and a heater 7, the latter connected at one terminal 8 to the cathode 6.

A low reactance coupling capacitor 8a is connected in series between terminal 8 and the cathode side of a grid tuning inductance 9. Connected across the grid tuning inductance 9 is a grid tuning condenser 10. A signal input tap 11 is connected to an intermediate point of tuning inductance 9, and a further signal input terminal 12 is provided at the cathode side of tuning inductance 9.

The terminal 8 is coupled via a coupling capacitor 13 to the outside of a hollow conductor 14, at one end thereof, the remaining end being directly grounded at 15. The hollow conductor 14 in conjunction with the tube capacitance and tuning capacitor 34 forms a parallel resonant circuit at the operating frequency of the amplifier. The cathode 6, accordingly, sees a high R.F. impedance to ground and the anode, and the amplifier operates as a conventional amplifier.

Running internally of the hollow conductor 14 is a coaxial transmission line 16. One end point 17 of the outer conductor of the coaxial transmission line 16 is connected to ground for R.F. via a coupling capacitor 18, and this outer conductor extends within the hollow conductor 15, but insulated therefrom, and is connected to terminal 12, i.e., to the cathode 6, for R.F. and to the control grid 5 via inductance 9 for D.C. A D.C. grid return terminal 19 is connected to the end point 17 of the outer conductor of coaxial line 16, and bias voltage may be applied thereby.

The inner conductor of the coaxial line 16 is connected adjacent its end point 17a, via a coupling capacitor 20, to a grid signal input terminal 21, and at its other end to the tap 11 of tuning inductance 9. Accordingly, the transmission line 16 is a signal input line, and its outer conductor also serves to convey grid bias to control grid 5.

Screen grid 4 is R.F. coupled to the cathode 6 via low reactance capacitor 22. Screen grid 4, cathode terminal 8, and filament terminal 23, are connected via separate

leads 24, 25, 26, through the interior of hollow conductor 14, to screen grid, cathode or —B, and filament terminals, 27, 28 and 29, respectively. Each of these leads is connected to ground for R.F., by capacitors 30, 31 and 32, respectively. However, the fact that the leads are co-extensive with the outer conductor 14, implies that each of the cathode, screen grid and filament are at the same impedance above ground, for R.F. and the same is implied for the control grid return by its connection to the outer conductor of the transmission line 16. A suitable —B voltage supply is applied to the terminal 28, and provides the necessary anode voltage by bringing cathode voltage below ground level.

Output signal is derivable from a tap 33, on hollow conductor 14, taken intermediate to its ends at a point of suitable impedance, and extending to the inner conductor 34 of a coaxial transmission line 35, having its outer conductor grounded at 36.

In operation, R.F. signal is applied between terminal 21 and ground, the signal being applied via transmission line 16 between terminals 11 and 12, thereby driving the amplifier. At the same time, the D.C. level of the grid may be set by a suitable D.C. source connected to terminal 19. Heater voltage may be applied between terminals 28 and 29, and the heater as well as the cathode are maintained at high R.F. impedance to ground, by virtue of the transmission line 14, and particularly of the effective electrical length of the latter in relation to the operating frequency of the amplifier.

As R.F. signal is applied to the control grid 5, the grid to cathode circuit being tuned to the R.F. frequency, cathode current varies at R.F., and this current develops a relatively high voltage along the length of hollow conductor 14, and on its outer surface. A portion of this voltage is tapped off by transmission line 32.

No R.F. coupling exists between the outer surface of the hollow conductor 14 and the conductors internally thereof. Moreover, the control grid circuit is doubly shielded, since it is a coaxial line, and is in its entirety located internally of hollow conductor 14. Accordingly, no tendency to instability exists in the system.

While the description has proceeded on the basis that the present invention will operate as an amplifier, operation as a frequency multiplier or oscillator, is also feasible, and when operated as an amplifier, operation may be Class A, Class AB, Class C, or the like.

While we have described and illustrated one specific embodiment of our invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What we claim is:

1. A vacuum tube circuit, including a vacuum tube having an anode, a cathode, a heater and a control electrode, means connecting said anode to a point of reference potential for both direct current and radio frequency current, a tuned driving circuit connected between said cathode and said control electrode, a tuned output tank circuit coupled between said cathode and said point of reference potential, said tuned output tank circuit comprising a hollow tube having a length such that said hollow tube presents a high impedance as seen from said cathode, a first low reactance capacitor connected between a point adjacent one end of said hollow tube and said cathode, a second direct connection between the other end of said hollow tube and said point of reference potential, and means extending internally of said hollow tube in insulated relation thereto and having the same electrical length as said hollow tube for supplying voltages to said heater, said cathode, and said control grid, and for supplying radio frequency driving signal to said tuned driving circuit.

2. The combination according to claim 1, wherein said means for supplying radio frequency driving signals to

said driving circuit is a coaxial line having an inner and an outer conductor.

3. The combination according to claim 2, wherein said means for supplying D.C. voltage to said control grid is the said outer conductor of said coaxial line.

4. The combination according to claim 1, wherein said means for supplying voltage to said heater comprises a pair of conductors extending internally of said hollow tube, and wherein said heater is directly connected to said cathode.

5. An amplifier, including a tetrode vacuum tube having a cathode, a heater for said cathode, a control grid, a screen grid and an anode, means directly connecting said anode physically to a point of R.F. and D.C. ground potential, a tuning condenser connected at one terminal to said control grid, a tuning inductance connected in parallel with said tuning condenser, a first low reactance capacitor connected between said screen grid and said cathode, a second low reactance capacitor connected between the other terminal of said tuning condenser and said cathode, two separated taps on said tuning inductance, a transmission line load having a high impedance at the operating frequency of said amplifier, said transmission line load comprising a hollow metallic tube, low impedance means coupling said hollow tube externally at one end to said cathode and at the other end to a point of reference potential, and conductors for supplying R.F. signal to said taps, and heater voltage, —B voltage and D.C. bias voltage to said heater, said cathode and said grids, respectively, said conductors extending internally of said hollow conductor in insulated relation thereto and to each other and having the same electrical length as said hollow conductor.

6. A vacuum tube circuit operative at radio frequency, including a vacuum tube having an anode, a cathode and a control grid, means grounding said anode for direct current and radio frequency current, a cathode load comprising a parallel resonant tank circuit A.C. coupled between said cathode and ground, said parallel resonant tank circuit including in parallel a capacitor and a length of hollow conductive tubing representing an effective inductance at said radio frequency.

7. The combination according to claim 6 wherein is provided a B— lead for said cathode, said B— lead extending internally of said length of tubing in insulated relation thereto and having the same electrical length as said length of tubing and connected directly to said cathode at a point immediately adjacent the point of coupling of said length of tubing to said cathode.

8. The combination according to claim 6 wherein is provided a co-axial transmission line extending in insulated relation through said hollow tube, means A.C. coupling the inner and outer conductors of said co-axial transmission line at one end to said grid and cathode in driving relation thereto, means for supplying radio frequency driving signal to said inner and outer conductors of said co-axial transmission line at the other end thereof, said co-axial transmission line having the same electrical length as said hollow tube.

9. The combination according to claim 8 wherein is provided a source of D.C. grid bias connected to said outer conductor at said other end thereof, and means providing a D.C. connection from said one end of said outer conductor to said grid.

10. In combination, a vacuum tube having a cathode and a grid, a cathode load impedance comprising a length of hollow metallic tubing having a length at an operating frequency of said vacuum tube which provides an inductance as seen from said cathode, means capacitively coupling said cathode to an external point of said length of hollow metallic tubing adjacent one end thereof, means grounding the other end of said length of hollow metallic tubing, a drive circuit for said vacuum tube including a two conductor co-axial transmission line having substantially the same length as said length of hollow metallic

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tubing and extending internally of said hollow metallic tubing over its entire length and in insulated relation thereto, means for applying drive signal for said vacuum tube to one end of said co-axial line, and means coupling the other end of said coaxial line between said grid and said cathode in driving relation thereto.

11. The combination according to claim 10 wherein is provided a D.C. connection of one conductor of said co-axial transmission line to said grid and an A.C. connection of the other conductor of said co-axial transmission line to said cathode.

12. In combination, an amplifying device having an output electrode, a signal input electrode and a common electrode, a circuit parallel resonant at a predetermined frequency coupled between said control electrode and said output electrode, a drive circuit for said amplifying device comprising a co-axial transmission line having an inner and an outer conductor and having two ends, means coupling one end of said inner and said outer conductor to said common electrode and said signal input electrode, respectively, via said parallel resonant circuit, a load circuit coupled to said output electrode, said load circuit comprising an inductance at said predetermined frequency, said inductance being a length of hollow metallic tubing co-extensive with and insulated from said co-axial transmission line and external thereof, means coupling said output electrode to an exterior point of said tubing adjacent one end thereof, means coupling said tubing at a point adjacent the other end thereof to a point of reference potential for signal at said predetermined frequency, said co-axial transmission line and said tubing having substantially the same electrical lengths.

13. The combination according to claim 12 wherein said common electrode is an anode connected to said point of reference potential.

14. The combination according to claim 12 wherein said common electrode is connected to said point of reference potential, wherein is provided a source of D.C. voltage, means connecting said source of D.C. voltage to said output electrode, said last named means comprising a lead extending interiorly of said length of hollow metallic tubing and in insulated relation thereto and having an electrical length as seen from said output electrode substantially equal to the electrical length of said length of hollow metallic tubing.

15. The combination according to claim 14 wherein is provided a source of D.C. bias voltage for said signal input electrode and means connecting said source of D.C. bias voltage to the other end of said outer conductor of said co-axial transmission line.

16. In combination, an amplifying device including an output electrode, an input electrode and a common electrode, means grounding said common electrode, a co-axial transmission line having an inner conductor and an outer conductor and two ends, a D.C. connection from one end of said outer conductor to said input electrode, an A.C. connection from said one end of said inner conductor to said output electrode, and a source of D.C. bias voltage connected to the other end of said outer conductor, a source of signal coupled between said other end of said inner conductor and ground, said co-axial transmission line having a length exhibiting a high reactance as seen from said input electrode.

17. The combination according to claim 16 wherein is

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further provided a load impedance for said amplifying device, said load impedance comprising a parallel resonant circuit including a lumped capacitive branch, and a distributed inductive branch, said distributed conductive branch consisting of a hollow conductive tube, said co-axial transmission line being co-extensive with said hollow tube and extending therethrough in insulated relation therewith.

18. The combination according to claim 17 wherein is further provided a D.C. voltage terminal for supplying D.C. voltage to said output electrode, a lead extending within said hollow conductive tube from said D.C. voltage terminal to said output electrode, said lead being co-extensive with said hollow conductive tube.

19. The combination in accordance with claim 18 wherein is further provided a plurality of further D.C. voltage supply terminals for supplying electrodes of said amplifying device, a separate lead extending from each of the last mentioned terminals to the appropriate ones of said electrodes, each of said last mentioned leads extending within said hollow tube, being co-extensive therewith, and being insulated therefrom.

20. The combination according to claim 19 wherein said amplifying device is a vacuum tube, said common electrode is an anode and said output electrode is a cathode.

21. The combination according to claim 20 wherein is provided a parallel resonant circuit connected between said input electrode and said cathode, one end of said parallel resonant circuit being directly connected to said input electrode, the other end of said parallel resonant circuit being capacitively coupled to said cathode, said parallel resonant circuit including an inductive branch consisting of a winding having two end taps, and a mid tap, said mid tap being directly connected to the inner conductor of said co-axial transmission line, one of said end taps being directly connected to said input electrode, and the remaining end tap being connected directly to the outer conductor of said co-axial transmission line.

22. In combination, a tank circuit for a predetermined frequency comprising an elongated conductive hollow tube having reactance at said predetermined frequency, a condenser in shunt to said elongated inductive hollow tube and resonating with its reactance to provide a parallel resonant circuit at said predetermined frequency, an amplifying device, and means for conveying excitation voltage and D.C. voltages to said amplifying device comprising leads extending internally of said hollow tube, said leads being insulated from each other and from said hollow tube and being lengthwise co-extensive with said hollow tube, and means coupling said tank circuit to said amplifying device in driven relation with respect thereto.

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