Oct. 9, 1934. J. D. WALLACE 1,975,812

PROTECTIVE CIRCUIT FOR HIGH FREQUENCY OSCILLATOR TUBES

Filed March 13, 1931 2 Sheets-Sheet 1

FIG. 1

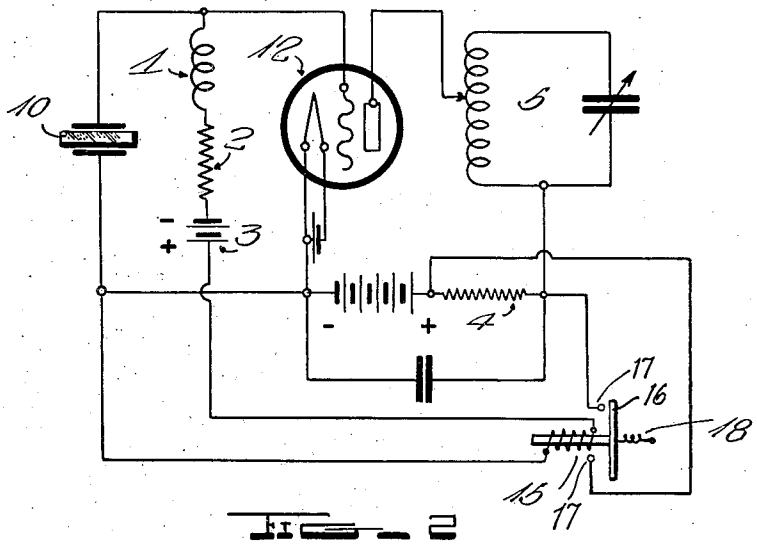
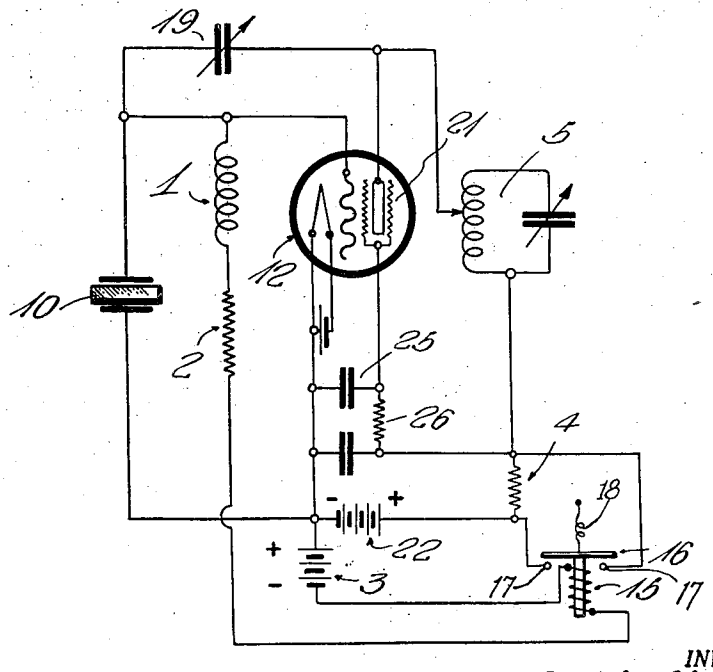


FIG. 2



INVENTOR.
James D. Wallace,
BY
Robert A. Somers
ATTORNEY.

Oct. 9, 1934. J. D. WALLACE 1,975,812

PROTECTIVE CIRCUIT FOR HIGH FREQUENCY OSCILLATOR TUBES

Filed March 13, 1931 2 Sheets-Sheet 2

FIG. 3

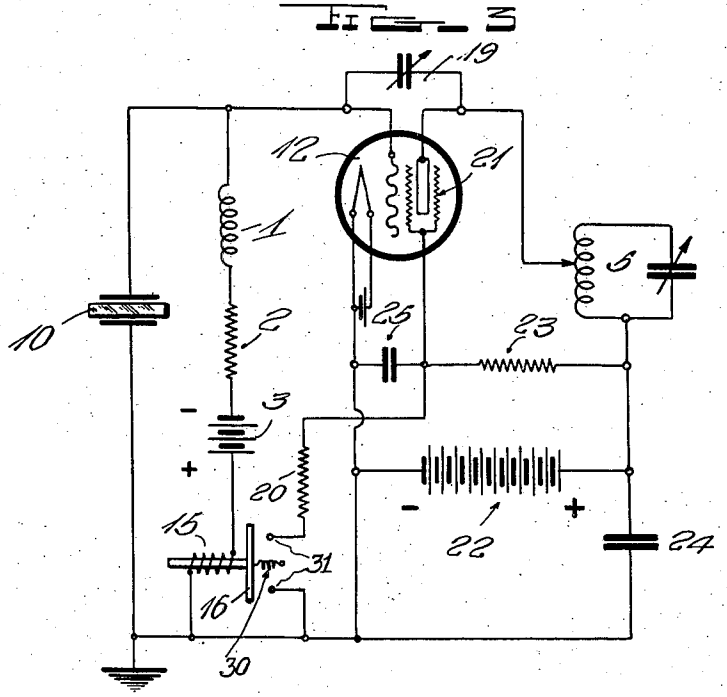
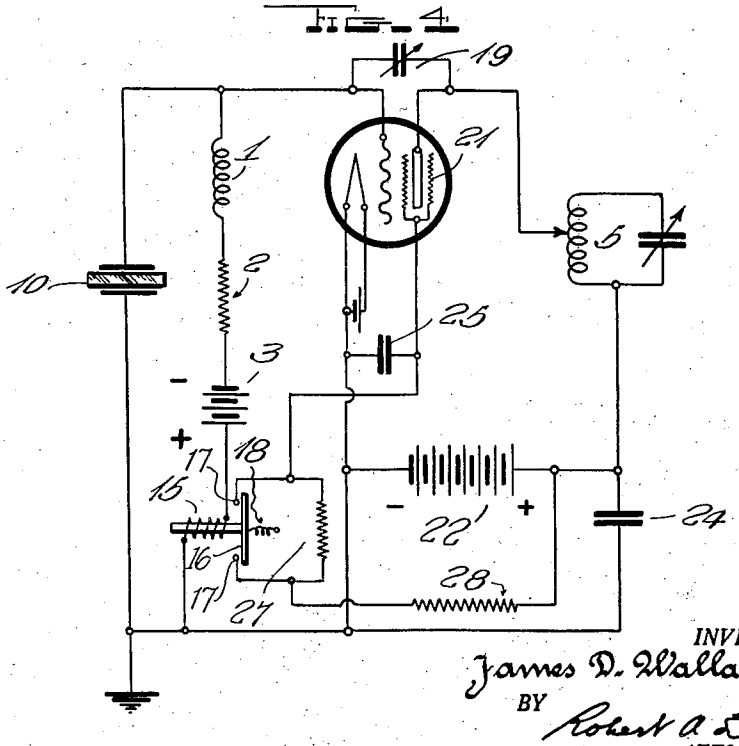


FIG. 4



INVENTOR.
James D. Wallace,
BY
Robert A. Lavender
ATTORNEY.

Patented Oct. 9, 1934

1,975,812

UNITED STATES PATENT OFFICE

1,975,812

PROTECTIVE CIRCUIT FOR HIGH FREQUENCY OSCILLATOR TUBES

James D. Wallace, Washington, D. C.

Application March 13, 1931, Serial No. 522,488

6 Claims. (Cl. 250—36)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

My invention relates broadly to high frequency transmitters and more particularly to a high frequency oscillator system for transmitters.

The object of my invention is to provide a circuit arrangement for piezo electric crystal controlled oscillators having means for protecting the electron tube from damage when the oscillator circuit is not properly adjusted.

Several embodiments of my invention are illustrated in the circuit arrangements shown in the accompanying drawings wherein:

Figure 1 shows a crystal oscillator circuit including the tube protective circuit of my invention; Fig. 2 illustrates the tube protective circuit of my invention applied to a shield grid oscillator tube in a transmission circuit; Fig. 3 shows a modified circuit arrangement for the tube protective device in a shield grid oscillator circuit according to my invention; and Fig. 4 shows another modification of the tube protective device circuit as applied to shield grid tubes.

My invention provides a method for protection of a crystal oscillator tube as used under certain conditions, when the circuit is improperly adjusted. In order to understand the necessity for such a device, it is necessary to study the operation and adjustment of a crystal oscillator circuit when the circuit is properly adjusted for oscillation.

Referring to Fig. 1, the parallel circuit 5 is adjusted to a slightly higher natural frequency than that of the crystal 10. The crystal 10 acts as a small alternator which obtains its driving power from the parallel circuit 5 through the capacity between the plate and grid of the three electrode tube 12. As the oscillation begins, the peak values of the crystal output voltages are greater than the voltage of grid bias battery 3, consequently during part of the positive half cycle rectified grid current flows. This rectified grid current flows through resistor 2 and the I. R. drop across the resistor is in series with the voltage of battery 3 and consequently, the negative bias is raised. However, this value or bias is never greater than the positive peaks of the alternating output voltage of the crystal. As a result, there is always a flow of rectified grid current from the grid to filament when the circuit is oscillating. Now, when the circuit is oscillating, the voltage and current wave forms of the plate to filament circuit contain pulsations. In other words, the plate voltage and current may be divided into two components—alternating and direct. The direct component expends a certain amount of power heating the plate of the tube. This power is equal to the product of the D. C. volts and D. C. amperes. Now, the parallel circuit 5 has a negligible resistance to the continuous component of power. However, this circuit has a high impedance to the alternating component of current, causing most of the impedance drop to be across the parallel circuit 5 when peak current is flowing. This necessitates a drop in the alternating component of voltage impressed across the plate and filament of the tube 12. Consequently, the alternating component of impressed plate voltage across the plate and filament, and the alternating component of electronic current between the filament and plate are 180° out of phase. To determine the power expended in heating the plate of the tube by the alternating component of plate current, find the product of the effective plate voltage and the effective plate current and the cosine of the phase angle (180°) which is —1. Now, the total power expended in heating the plate of the tube is equal to the sum of the continuous component of power and the alternating component of power, and the latter has been shown to be negative. Consequently, the total plate losses are less in magnitude than the direct current power input. In an efficiently designed crystal oscillator circuit it may be shown that the plate loss is about 35% of the total plate power input, the other part being expended in resistance losses in the parallel circuit 5.

If the parallel circuit 5 in Fig. 1 is detuned sufficiently for the crystal to stop oscillation, or if for any other reason oscillations stop, the alternating components of plate power disappear and the entire continuous component of input power is dissipated heating the plate of the tube. Heretofore, this dissipation of all power on the plate of the crystal oscillator has not been a serious matter since the particular tubes used could withstand it without damage because they were usually operated at from 30% to 40% of their rated plate voltage. However, when the particular tube used is operated at its rated plate voltage or above that value, if the crystal stops oscillating, the tube may be damaged from excessive heating of the plate. It is also clear that when oscillations cease, no rectified grid current flows.

The master oscillator tube of low power crystal controlled transmitters is often a receiving tube. These tubes very often have low plate impedances and are nearly always operated at above their rated plate voltage. A circuit such as shown in Fig. 1 would be very necessary with such a tube, since protection is given the tube

in case no oscillations are being produced. The rectified grid circuit of Fig. 1 contains a choke 1, a resistor 2, and a bias battery 3. It is to be understood that either the choke 1 or the resistance 2 may be used alone; the choke 1 may be used with resistor 2 eliminating the battery 3, or it may be used with the battery 3 eliminating the resistor 2; also the resistor 2 and battery 3 may be used eliminating the choke 1. The protective device to be described will be very useful with circuits which eliminate the battery 3. The circuit in Fig. 1 operates in this manner. When power is first applied to the plate circuit, the resistance 4 prevents the flow of enough plate power to damage the tube 12. Next, the operator adjusts the variable condenser of the parallel circuit 5 until oscillations begin. Initially the oscillations are weak, since the impressed plate potential is decreased by the resistor 4, but as soon as the oscillations start, rectified grid current flows from the grid to the filament of tube 12. Since it must pass through the coil 15 of the relay, the magnetic circuit of this relay is energized and the contactor 16 connects the contacts 17, and thereby the resistance 4 is short-circuited. This increases the plate voltage of the crystal oscillator, thereby increasing the radio frequency power output. It is also obvious that if for any reason the oscillations cease, the flow of rectified grid current ceases and the relay contacts open and insert the protective resistor 4 into the plate circuit, and this prevents flow of excessive power into the plate circuit of the tube. It is to be understood that the spring 18 causes the contactor 16 to be kept away from the contacts 17 when the coil 15 of the relay is not energized. It is obvious that the operation of this protective system is automatic, making it unnecessary for an operator to give careful attention to the crystal circuit. It is to be understood that a four element space charge grid tube may be substituted for the one shown in Fig. 1, provided that arrangements be made for furnishing space charge grid potential. It is also to be understood that a five element tube may be substituted for the one shown in Fig. 1, provided that arrangements be made for furnishing space charge and shield grid potentials, and provided feedback is furnished to facilitate the production of oscillations.

A 50 watt three element tube is frequently used as the crystal oscillator of high power radio transmitters. To protect the crystal, these tubes have usually been operated at a plate voltage of about 360 volts. Although this voltage might be obtained from a separate generator or a rectifier, it is usually obtained from a potentiometer across the 1000 volt midtap from a 2000 volt generator. The use of a potentiometer is somewhat undesirable due to its bad regulation when using different crystals which cause the tube to draw different plate currents. To eliminate the need of a separate generator, a rectifier, a potentiometer, or a midtap or a generator to supply 360 volts, it is desirable to use a tube as a crystal oscillator which will operate properly at a plate voltage of 2000 volts, since this voltage is used on the plates of certain power amplifier tubes now widely used. In order to use a plate potential of 2000 volts without damaging the crystal, the tube used is generally a shield grid tube, and feedback is obtained when using such a tube as an oscillator by connecting a small capacity from the plate to the control grid. The circuit has one big disadvantage—the tube is immediately ruined if for any reason the oscillations stop while the plate voltage is on unless the method provided by my invention is employed. And if my method of protection is not employed, in order to safely start the crystal circuit, it is necessary to reduce the plate voltage, unless the circuit is exactly tuned, and after the circuit is adjusted and the oscillations begin, the plate voltage can be raised to its proper value.

The circuit shown in Fig. 2 will operate safely at high plate voltages, protection being automatically provided if the oscillations cease. A shield grid tube 12 is shown as the oscillator. The grid circuit contains a choke 1, a grid leak 2, and a bias battery 3. It is not essential to use all of these. Either the choke may be used alone or the resistor alone, or the choke and resistor only, or the choke and battery only, or the resistor and battery only. When plate power is applied to the circuit in Fig. 2, and the variable condenser of the plate circuit 5 is properly adjusted, oscillations begin. Initially they are weak, since the resistance 4 decreases the plate and shield grid potential of the tube below their normal value. But after the oscillations start, rectified grid current flows, the coil 15 of the relay is energized, the contactor 16 connects the contacts 17, the resistor 4 is short-circuited, the potentials of the shield grid and plate are increased to their normal value, and the radio frequency power output of the circuit is thereby increased. The spring 18 of the relay pulls the contactor 16 from the contacts 17 when no current is passing through coil 15. If for any reason oscillations cease, no rectified grid current passes through coil 15, and the spring opens the relay contacts, the resistance 4 is then inserted in the plate and shield grid circuit, and thereby not sufficient power can flow in the plate circuit to damage the tube. Condenser 19 is provided for facilitating the production of oscillations in the tube system. If desirable, a five element tube could be used provided the necessary parts be included for supplying space charge grid potential.

Fig. 3 illustrates another arrangement of the circuit of my invention used in connection with a shield grid tube. The protection is afforded when no oscillations are being produced by means of decreasing the shield grid potential. The grid circuit may be modified as discussed in connection with Figs. 1 and 2 if desirable. The spring 30 of the relay holds the contactor 16 against the contacts 31 when no current is flowing in coil 15. The plate input power of a shield grid tube may be decreased by decreasing the shield grid potential of the tube with respect to the filament. The protective action of the circuit in Fig. 3 is accomplished in this manner. When plate power is initially applied to the tube, the shield potential is below normal. The current through resistor 23 divides into two circuits—one circuit is composed of the electronic path from the filament to shield of the tube 12, and the other path is resistance 20. The voltage drop across resistance 23 is determined by the product of its resistance and the current through it. The voltage from shield grid to filament is determined by the difference between the potential of the battery 22 and that of the voltage drop across resistance 23 and if the total current through resistance 23 is decreased, then the voltage across it decreases, and the voltage across the shield grid and filament circuit rises. If the coil 15 of the relay is energized, the circuit through resistance 20 is broken, and the current through resistance 23 decreases, and the voltage drop across it decreases,

and the voltage from the shield grid to filament of the tube increases, thereby increasing the plate power input to the tube. The coil 15 of the relay is energized only when the circuit is oscillating because rectified grid current flows only under that condition. If the oscillations cease, no rectified grid current flows, the spring 30 draws the contactor 16 into connection with the contacts 31, the circuit through resistor 20 is completed causing the current through resistance 23 to increase, which causes the voltage drop across resistance 23 to increase, which causes the shield grid to filament potential to decrease, thereby decreasing the plate input power to the tube. In this manner the tube is protected against excessive plate power input when no oscillations are being produced. A five element tube may be substituted for that one in Fig. 3 if desired, however, it is necessary to provide additional parts to supply space charge grid potential. Condenser 19 is provided for facilitating the production of oscillations in the tube system.

Fig. 4 illustrates another arrangement of the circuit of my invention used in connection with a shield grid tube. The protection is afforded when no oscillations are being produced by another means of decreasing the shield grid potential. The grid circuit may be modified as discussed in connection with Figs. 1, 2 and 3 if desirable. It is to be understood that the spring 18 holds contactor 16 away from the contacts 17 when the coil 15 is not energized. When the circuit is started, and the tuning circuit 5 is properly adjusted, the oscillations begin. Initially they are weak, because the plate circuit input power is decreased by an abnormally low shield grid potential with respect to the filament. The shield 21 obtains its power through resistors 27 and 28. The resistance 28 is of proper value to allow the shield to obtain its normal potential under normal operating conditions but the resistance 27 is of large enough value that when in series with the resistance 28, the shield grid to filament potential is diminished in such a manner that insufficient plate power will flow to damage the tube when no oscillations are being produced. Now, when oscillations are started, rectified grid current flows through the coil 15 of the relay, the contactor 16 is drawn into connection with the contacts 17. By this action the resistor 27 is short-circuited and the shield grid to filament potential is increased. By this means the plate circuit power input is increased to normal, and thereby the radio frequency output of the circuit is increased. If the oscillations cease, the spring 18 pulls the contactor 16 from the contacts 17, and the shield grid to filament potential is decreased, and thereby the tube is protected from excessive plate power input. A five element tube may be used in the circuit shown in Fig. 4, if means of supplying space charge grid potential is provided. Condenser 19 is for facilitating the production of oscillations.

The methods of protection discussed in connection with Figs. 2, 3 and 4, may be applied to the space charge grid of a vacuum tube provided that type of tube be used as a crystal oscillator.

The methods of protection discussed in connection with Figs. 2, 3 and 4 may be applied to both shield and space charge grids, provided a five element tube be used as a crystal oscillator.

The protective relays used are of a sensitive type because they must operate on small currents, and for that reason it may be difficult to obtain a sensitive relay with a contact system suitably designed to break the potentials encountered in the systems of protection described herein. This difficulty may be overcome by using the relay operated by grid current to control a relay with suitable contacts for breaking these high potentials.

All protective systems discussed have been in connection with crystal oscillator circuits. It is to be understood that protective systems as outlined herein can also be applied to self-oscillating vacuum tube circuits. This system of protection is necessary for the safe operation of self-oscillating tubes having critical adjustments of their circuits for starting oscillations.

While I have described my invention in certain of its preferred embodiments, I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

The invention herein described, may be manufactured and used by and for the Government of the United States of America, for governmental purposes, without the payment of any royalties thereon.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A protective system for oscillation circuits including in combination an electron tube containing cathode, grid, plate, and shield grid electrodes, an input circuit including said grid and cathode electrodes, an output circuit including said plate and cathode electrodes, a variable capacitor connected between the grid and plate of said tube, a piezo electric crystal element connected in said input circuit, a resonant circuit and a source of potential connected in said output circuit, a connection between said source of potential and said shield grid electrode, said connection including a series connected impedance element having a contact at each end thereof, a relay having an armature, a contactor carried by said armature and tensioned to normally open said contacts, a biasing circuit for said grid, the winding of said relay being connected in series in said biasing circuit and adapted to automatically move said armature to a position closing said contacts for changing the effective potential on said shield grid electrode upon the generation of oscillations in said circuits for protecting said tube against destructive effects of excess current through the electron discharge path thereof.

2. A protective system for oscillation circuits including in combination an electron tube containing cathode, grid, plate, and shield grid electrodes, an input circuit including said grid and cathode electrodes, an output circuit including said plate and cathode electrodes, a piezo electric crystal element connected in said input circuit, a resonant circuit and a source of potential connected in said output circuit, a connection between said source of potential and said shield grid electrode, said connection including a series connected impedance element having a contact at each end thereof, a relay having an armature, a contactor carried by said armature and tensioned to normally open said contacts, a biasing circuit for said grid, the winding of said relay being connected in series in said biasing circuit and operating only upon the generation of oscillations in said circuit to move said armature to a position whereby said contactor closes said contacts for increasing the potential on said shield grid electrode.

3. A protective system for oscillation circuits including in combination an electron tube containing cathode, grid, plate, and shield grid electrodes, an input circuit including said grid and cathode electrodes, an output circuit including said plate and cathode electrodes, a piezo electric crystal element connected in said input circuit, a variable capacitor connected between the grid and plate of said tube, a resonant circuit and a source of potential connected in said output circuit, a connection between said source of potential and said shield grid electrode, said connection including a series connected impedance element disposed in circuit with said plate electrode and having a contact adjacent each end thereof, a relay having an armature, a contactor carried by said armature and tensioned to normally open said contacts, a biasing circuit for said grid, the winding of said relay being connected in series in said biasing circuit operating only upon the generation of oscillations in said circuits to automatically move said armature to a position whereby said contactor closes said contacts for increasing the potential on said plate and upon said shield grid.

4. In an electron tube oscillator system, an electron tube including a cathode, control grid, shield grid, and plate electrodes, circuits interconnecting said electrodes, an electromechanical oscillator for sustaining oscillations in said circuits, means for supplying potential to said circuits and to said electrodes for the normal generation of oscillations therein and means automatically controlled by the cessation of oscillations in said circuits for modifying the potential of said shield grid for preventing the rise of current in the electron discharge path through said tube.

5. In an electron tube oscillator system, an electron tube including a cathode, control grid, shield grid, and plate electrodes, circuits interconnecting said electrodes, an electromechanical oscillator for sustaining oscillations in said circuits, means for supplying potential to said circuits and to said electrodes for the normal generation of oscillations therein and means automatically controlled by the cessation of oscillations in said circuits for reducing the potential of said shield grid for preventing the rise of current in the electron discharge path through said tube.

6. In an electron tube oscillator system, an electron tube including cathode, control grid, shield grid, and plate electrodes, circuits interconnecting said electrodes, an electromechanical oscillator for sustaining oscillations in said circuits, means for supplying potential to said circuits and to said electrodes for the normal generation of oscillations therein and means automatically controlled by the cessation of oscillations in said circuits for reducing the potential of said shield grid and said plate for preventing the rise of current in the electron discharge path through said tube.

JAMES D. WALLACE.