POWER SUPPLY FOR MAGNETRON IN MICROWAVE OVEN OR THE LIKE

Inventor: Egbert M. Tingley, Kankakee, Ill.
Assignee: Roper Corporation, Kankakee, Ill.
Filed: Sept. 3, 1970


Field of Search 315/102, 104, 175, 176, 207, 315/220, 331/86, 87, 185, 186; 328/230, 258, 262, 267, 270, 131; 219/10.55, 321/16, 317/139, 141 R, 141 S; 323/41, 60, 61; 307/141, 141.8, 293

References Cited

United States Patents
3,324,273 6/1967 Ogburn ................................ 219/10.55

Abstract
A power supply for a permanent magnet type magnetron tube in which a high impedance transformer furnishes power to two half-wave, oppositely poled voltage doubler circuits in which a time delay is provided, responsive to the load current of the magnetron, to delay the turning on of one of the half-wave voltage doubler circuits to insure operation in the desired oscillating mode. Switching of the second half-wave voltage doubler into the circuit is accomplished by normally open contacts on a main relay, preferably shunted by high value resistor. In the preferred modification additional time delay is achieved by employing an auxiliary time delay relay to inhibit operation of the main relay, thereby to establish successive low power and high power modes. The filament of the magnetron is preferably fed by a separate filament transformer turned on at the same time as the high impedance transformer, but which includes means for lowering the filament voltage incident to switching to the high power mode.

12 Claims, 6 Drawing Figures
In the operation of a magnetron tube in a high power microwave oven it is desirable to use full wave rectification so that the peak magnetron current does not exceed the rating of the tube. However, magnetrons exhibit an unfortunate tendency not to "turn-on" or oscillate when initially connected to a full wave high voltage supply, particularly where the high voltage is applied simultaneously with application of filament current, a so-called "cold start." Failure to oscillate in the desired mode may be highly destructive.

Accordingly it is an object of the present invention to provide a power supply for a magnetron tube in a microwave oven or the like in which operation from a cold start is assured and which protects the expensive tube, transformer and other components from damage, insuring a long and useful life. It is a more specific object of the present invention to provide a power supply for a magnetron tube in which half-wave voltage pulses are first applied incident to turning on the filament to insure oscillation followed, shortly thereafter, by half-wave pulses of complimentary phase for subsequent operation of the tube in a high power mode.

It is another object of the present invention to provide a power supply for a magnetron tube having provision for an accurate and well defined time delay following application of voltage thereby to insure stable oscillation before the tube is switched to its high power mode.

It is another object of the present invention to provide a power supply for a magnetron tube in which the surge of input current to the transformer is minimized on turn-on. It is a related object to provide a power supply having first and second half-wave voltage doubler circuits containing capacitors and in which means are provided for minimizing the capacitor surge when energizing the second doubler circuit.

It is an object of the invention to provide a power supply and procedure which insures prompt oscillation in the desired mode but which is highly economical, permitting various circuit protection components, formerly thought necessary as a practical matter, to be dispensed with.

Other objects and advantages of the invention will become apparent upon reading the attached description and upon reference to the drawings in which:

FIG. 1 is a schematic diagram of a preferred form of power supply embodying the present invention and intended for supplying current to a magnetron tube.

FIG. 2 is a diagram showing the type of transformer employed in the circuit of FIG. 1.

FIGS. 3 and 4 show the half-wave pulses of current respectively produced by the half-wave doubler circuits of FIG. 1.

FIG. 5 shows the form of current wave produced when the circuit is operating in its high power mode, being the summation of the waves in FIGS. 3 and 4.

FIG. 6 shows the circuit of FIG. 1 redrawn to illustrate operation in the low power mode.

While the invention has been described in connection with a preferred circuit it will be understood that I do not intend to be limited to the particular circuits shown but intend, on the contrary, to cover the various alternative and equivalent arrangements which are included within the spirit and scope of the appended claims.

The circuit, supplied by lines 10, 11, connected to the usual 240 volts or similar a-c. source by a switch SW, feeds a magnetron tube 12 having an anode 13 and a filament 14. The filament is supplied from a transformer 15 having a primary 16 and a secondary 17. The filament lines 18 have interposed r.f. choke coils 19. The magnetron tube may, for example, be of the type L-5,001 manufactured by Litton Industries.

For producing the high voltages required for the magnetron tube a transformer 20 is used having a primary winding 21 and a secondary winding 22 wound about a core 23. The transformer is preferably of the high impedance type including a magnetic bridge (FIG. 2) interposed between the primary and secondary windings. Use of a high impedance transformer is necessary in magnetron power supplies.

In accordance with the present invention two half-wave voltage doubler circuits each including a diode and capacitor are connected across the secondary winding of the transformer with the diodes being oppositely polarized and with the capacitors having a common connection to the secondary winding. Output terminals between the diodes and their associated capacitors are connected to the magnetron, a set of normally open contacts being connected in series with the second capacitor with means for delaying closure so that the voltage initially applied consists of separated half-waves thereby to insure that the magnetron, starting from a cold start, will go immediately into its desired oscillating mode, with oscillation being continued in a high power after the contacts close.

Thus, turning to the drawing, a first half-wave voltage doubler circuit 30 is provided including a diode 31 and a capacitor 32 which are connected, as shown, across the terminals of the secondary winding 22 of the transformer. The effect, acting alone, is to produce a series of separated, half-waves of current to the magnetron, such pulses being indicated at 35 in FIG. 3.

Also connected across the transformer winding is a second half-wave voltage doubler circuit 40 including a diode 41 and a capacitor 42 having a first terminal 43 and a second terminal which is connected to the terminal 34 of the capacitor 32. Assuming that the terminal 43 of the capacitor and the lower terminal, indicated at 44, of the diode 41, are connected together, and assuming that the diodes 31, 41, 42 are connected as shown, half-waves of current are fed to the magnetron by the circuit 40 as indicated at 45 in FIG. 4. Since both of the half-wave doubler circuits 30, 40 are connected to the same transformer winding, and because of the opposite polarizing, the two sets of voltage half-waves will be of complimentary, or interfitting, phasing as shown by comparing FIGS. 3 and 4. While the invention is not limited thereto, it is preferred to employ a diode of the "avalanche" type for the diode 31. This assists in preventing the voltage from rising to an excessive peak value at the moment that the oscillations start in the magnetron which might result in arcing and possible damage to the tube.

With both doubler circuits active, the currents are additive as shown at 46 in FIG. 5.

A low value series resistor 48, connected to output terminal 47, is interposed in line 49 which leads to the anode of the magnetron. A voltmeter calibrated in units of current provides convenient measurement of the current waves shown in FIGS. 3-5.

For the purpose of delaying operation of the second half-wave voltage doubler, a relay is provided which has a set of normally open contacts which are connected in series with the second capacitor. Thus, referring to FIG. 1, the relay has a winding 50, a main set of normally open contacts 51, an auxiliary set of normally closed contacts 52 and an auxiliary set of normally open contacts 53. The normally open contacts 51 are included in series with the terminal 43 of the capacitor 42, tending to isolate the capacitor 42 from the anode output line 49. It is one of the features of the invention, however, that the capacitor 42 is not completely isolated from the magnetron but continues to be coupled to it via a high value resistor 55 which is connected in shunt with the main relay contacts 51 during operation in the low power mode.

The winding 50 of the relay is connected to the circuit so as to be subjected to the load current. It is preferred to connect the winding 50 from the terminal 44 of the diode 41 to the output terminal 47 which leads to the anode of the magnetron, although, if desired, the relay winding may be interposed in the line 49 without departing from the present invention.

It will be seen that when the main relay contacts 51 are in the open condition, substantially all of the current supplied to the magnetron is in the form of separated half-waves 35 (FIG. 3) derived from the first half-wave voltage doubler circuit 30. The spaced, repetitive, pulses tend to shock the magnetron into the desired oscillating state. For more readily understanding the function of the circuit in the half-wave or low power
mode, with the contacts 51 open, the circuit has been redrawn in FIG. 6, the secondary of the transformer winding being inverted by the polarity of 51.

During the one half of the cycle when the transformer terminal 34 is positive and the remaining terminal is negative, the diode 31 is polarized for conduction and current flows through the capacitor 32 and diode 31 to charge the capacitor with the polarity indicated. During the succeeding half cycle, when the terminal 34 is negative and the magnetron is polarized to conduct, current flows from the transformer through the diode 41, relay 50, resistor 48 and line 49, thence through the mag- netron and through the capacitor 32 to the opposite terminal of the transformer to complete a loop circuit. Because the capacitor retains a charge from the preceding half cycle, the voltages from the capacitor and transformer winding are additive so that an augmented voltage, referred to as a half wave "- doubled" voltage is applied across the terminals of the magnetron tube.

As stated, during such "half-wave" operation the capacitor 42 is not completely isolated from the magnetron since some current continues to be supplied through the resistor 55. In short, the resistor 55, where used, causes the circuit, during the time that the main relay contacts 51 are open, to act as a circuit between a half-wave doubler circuit and a full-wave doubler circuit, with the spaced half cycles of load current predominating to provide a type of pulsing which has been found to establish the desired oscillating mode of the magnetron promptly when starting from cold filament conditions.

For the purpose of causing the main relay contacts 51 to be open, for operation in the half-wave or low power mode when the device is initially turned on but closed after a well-defined full wave operation in the high power mode, a time delay relay is provided having a coil or winding 60 and a set of normally closed contacts 61, the time delay relay and the contacts being connected in series with one another as a shunt around the coil 50 of the main relay. Moreover, the winding 60 of the time delay relay preferably has a resistance which is substantially lower than the resistance of the winding 50 of the main relay so as to prevent the main relay from picking up as long as the time delay relay is in shunting condition. The relay 60 is preferably of the known thermal type including a bimetal or the like so that the normally closed contacts 61 do not open until current has been applied to the winding for a second or two. Alternatively, however, the relay winding 60 may be of the magnetic type, including any desired means to delay opening of the contacts 61.

In any event, the main relay contacts 51 are open at the time that power is applied by closing the switch SW in the a-c line. Closure of the switch energizes the transformer 15 to begin heating of the filament. Closing the switch also applies a high direct voltage across the magnetron. Pulses of current flow through the diode 41 once the magnetron starts to oscillate, through the winding 60 of the time delay relay and thence through normally closed contacts 61, and contacts 52, of the main relay which are in series therewith, to the line 49 which leads to the anode of the magnetron. Prior to operation of the time delay relay, and during the time that the contacts 51 are open, sufficient current flows through the resistor 55 so as to charge up the capacitor 42 to the polarity shown. Assuming the time delay relay 60 to be of the thermal type, sufficient heating occurs so that the normally closed contacts 61 open after a second or two thereby removing the shunt which exists about the winding 50 of the main relay. Current is therefore free to flow through the winding 50 of the relay causing it to pick up (armature moves in downward direction) so as to close the contacts 51. Closure of the contacts 51 to the capacitor 42 is not accompanied by any appreciable current irruption to the capacitor since the capacitor has been previously charged by current flowing through the resistor 55. Thus the effect of closing the contacts 51 is to connect the capacitor 42 directly to the lower 42 terminal 44 of the diode 41 to complete the second of the two half-wave circuits so that they work together to provide full wave doubling action. In short, the pulsating direct current indicated at 46 in FIG. 5 is applied to the terminals of the magnetron tube to produce operation of the latter in the high power mode. Oscillation of the magnetron, which was reliably initiated by supplying the separated half-waves of current, continues without any risk of going into an unwanted mode, for example, the destructive mode referred to as the "n/2-1" mode.

After the relay 50 picks up, contacts 52 thereon remain open to prevent the time delay 60 from recycling.

In order to prevent the winding 50 of the main relay from overheating during sustained operation of the magnetron tube, a shunting resistor 65 is connected in series with the auxiliary normally open contacts 53, the value of the resistor 65 being such as to bypass much of the current while nevertheless permitting sufficient continued flow of current through the winding 50 to insure that the latter remains reliably sealed in.

It is preferred, in practicing the present invention, to employ a separate filament transformer 15 to produce prompt heating of the filament of the magnetron tube at a relatively high voltage under conditions of start-up while reducing the applied filament voltage during steady state running conditions. For example, the filament voltage may be at a level of 4.6 volts during start-up and at a level of 3.9 volts during normal full power operation. This is accomplished by providing a tapped primary winding on the filament transformer and by switching the taps by a single pole, double throw switch which is connected to the armature of the main relay. Thus the primary 16 of the transformer has a pair of alterable engageable taps, with switching by a single pole, double throw switch 70 having a first contact 71 to provide a high filament voltage during start up and a second contact 72 which is engaged to produce a lower voltage, after the relay 50 has operated.

It will be understood, however, that the time delay aspects of the invention may be used without necessity for employing a separate filament transformer, and the secondary winding 17 may, if desired, be in the form of a limited number of turns coupled to the primary winding 21 of the transformer 20. The term "transformer means" used herein is intended to be generic to both integral or separate filament supply.

It is one of the features of the present circuit that sustained operation in the low power mode is available by effectively disabling the contacts 51 which are connected to the capacitor 42. This may be conveniently done by providing a switch 75 which is in shunt with the winding 50 of the main relay. When the blade of the switch is swung upwardly to open the circuit, corresponding to the "high" condition, the circuit operates in the normal way as described above, switching after a time delay into the high power mode. When the switch is thrown to its closed or "low" position, both of the windings 50, 60 of the relays are shunted out of the circuit so that the contacts 51 remain open for continued half-wave or low power operation.

In the preferred embodiment of the present invention, two relays are employed, a main relay and a time delay relay which inhibits operation of the main relay for a short time interval. It will be apparent to one skilled in the art, however, that the invention may be practiced in a simpler form by simply omitting the time delay relay 60 and by incorporating delay into the construction of the main relay 50. Indeed, it has been found that sufficient time delay may be obtained, as a practical matter, using a relay of relatively slow response providing at least a fraction of a second between energization and actual closure of the contacts.

The term "relay" as used herein is intended to be a general and generic term to include any device in which application of current or voltage to the device causes closing of an output circuit, regardless of whether the device is of the thermal, magnetic, or solid state type.

The term "high reactance" as applied to the transformer is not limited to any particular degree of magnetic shunting and selection of a transformer for use in the present environment is a matter well within the skill of the art. Similarly it will be apparent that the circuit parameters may be varied over a relatively wide range without departing from the invention. How-
ever for the guidance of one employing the present invention the following suggested values are set forth.

<table>
<thead>
<tr>
<th>Transformer 20</th>
<th>1,700 volts r.m.s. open circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diode 31</td>
<td>6 amp; oscillograph, 6-7 kv.</td>
</tr>
<tr>
<td>Capacitor 32</td>
<td>1.5 ma.</td>
</tr>
<tr>
<td>Resistor 36</td>
<td>1 megohm</td>
</tr>
<tr>
<td>Diode 41</td>
<td>0.8 amp, 8 kv. peak inverse voltage</td>
</tr>
<tr>
<td>Capacitor 42</td>
<td>0.9 ma.</td>
</tr>
<tr>
<td>Resistor 46</td>
<td>1 megohm</td>
</tr>
<tr>
<td>Resistor 47</td>
<td>10 ohms</td>
</tr>
<tr>
<td>Relay Winding 50</td>
<td>24 v. AC</td>
</tr>
<tr>
<td>Resistor 55</td>
<td>100K ohms</td>
</tr>
<tr>
<td>Relay Winding 60</td>
<td>63V, 2 w.</td>
</tr>
<tr>
<td>Resistor 65</td>
<td>20 ohms</td>
</tr>
</tbody>
</table>

While the winding 50 of the main relay is preferably connected in series with the magnetron, as discussed, it is not essential that the relay winding be located at this point in order to practice the invention in certain of its aspects and, indeed, the portion of the circuit included between the terminals 44 and 47 may be included, if desired, in series with the primary winding of a high voltage transformer. The effect would still be to maintain the normally open contacts 51 open until a second or after the main switch SW is closed. If this change were made it would, of course, be necessary to employ low resistance current coil relays as contrasted with conventional relays with voltage coils. Thus the term "load current" is intended to refer to any current in the circuit which varies in accordance with the anode-cathode current of the magnetron.

The term "high value resistor" has been used in describing the resistor 55 which is connected across the main relay contacts 51, a 100 K ohm resistor being employed. The term "high value" as used herein is intended to cover a resistor which has a resistance sufficiently high as to cause appreciable unbalance between the successive half-wave pulses of current so that the tube proceeds reliably, upon cold starting, into the oscillating state. If desired, the value of this resistor may be reduced to a point safely above that which will produce this desired result. Moreover the capacitance of capacitors 32 and 42 may be equal or unequal. Finally, while the term "voltage doubler" has been used throughout, it will be understood that the term is not limited to a precise doubling of the voltage but that the term refers to means for producing a rectified voltage having a peak value which is increased substantially beyond the r.m.s. value of the incoming wave.

I claim as my invention:

1. In a power supply for a magnetron tube in a microwave oven or the like, the combination comprising a transformer of the high reactance type having a primary winding and a secondary winding, transformer means for supplying the filament of the magnetron, a first half-wave voltage doubler circuit including a first diode and a first capacitor connected in series across the secondary winding, a second half-wave voltage doubler circuit including a second diode and a second capacitor connected in series across the secondary winding when the second diode being oppositely poled, means for applying the output of the voltage doubler circuits across the terminals of the magnetron tube, a set of switch contacts interposed in series with the second half-wave doubler circuit so that when the transformer means is energized with the contacts open the voltage applied to the magnetron is derived substantially from the first half-wave voltage doubler circuit for positively initiating oscillation and for operation of the magnetron in a low power mode, and means for closing the switch contacts following a brief time delay to activate the second half-wave doubler circuit for continued oscillation of the magnetron thereafter in a full wave high power mode.

2. In a power supply for a magnetron tube in a microwave oven or the like, the combination comprising transformer means for supplying filament current, a first source of half-wave voltage pulses, a second source of half-wave voltage pulses of complimentary phase, means for connecting the sources to the magnetron, means for simultaneously energizing the transformer means and connecting the magnetron to the first source of pulses to initiate oscillation, and means including a time delay device for connecting the magnetron additionally to the second source of pulses after a brief time delay.

3. In a power supply for a magnetron tube in a microwave oven or the like, the combination comprising a transformer of the high reactance type having a primary winding and a secondary winding, transformer means for supplying the filament of the magnetron, a first half-wave voltage doubler circuit including a first diode and a first capacitor connected in series across the secondary winding, a second half-wave voltage doubler circuit including a second diode and a second capacitor connected in series across the secondary winding with the second diode being oppositely poled, the capacitors being connected to a common terminal so that the two capacitors are connected in series across the terminals of the magnetron tube, a relay having a winding and a set of normally open contacts for the purpose of providing time delay, the winding being connected in series with the magnetron so as to conduct load current flowing therein and the normally open contacts being interposed in series with the second capacitor so that when the transformer is energized the voltage applied to the magnetron is derived substantially from the first half-wave voltage doubler circuit for initiating oscillation and for operation of the magnetron in a low power mode until such time as the contacts close to connect the second half-wave doubler circuit for continued oscillation of the magnetron thereafter in a high power mode.

4. The combination as claimed in claim 3 in which the transformer means for supplying the filament of the magnetron includes means for reducing the filament voltage and in which the relay includes auxiliary contacts for operating the voltage reducing means such that the filament voltage on the magnetron is reduced during operation in its high power mode.

5. The combination as claimed in claim 4 including a switch connected to the relay for effectively disabling the same to maintain the contacts open for sustained operation of the magnetron in the lower power mode.

6. The combination as claimed in claim 4 including a switch connected to the relay for effectively disabling the same to maintain the contacts open for sustained operation of the magnetron in the lower power mode.

7. The combination as claimed in claim 6 in which the disabling means is in the form of a switch connected in shunt with the relay winding for preventing response of the winding when the switch is in closed condition so that the output circuit is supplied substantially by the first half-wave doubler circuit for continued operation of the magnetron in the lower power mode.

8. In a power supply for a magnetron tube in a microwave oven or the like, the combination comprising a transformer of the high reactance type having a primary winding and a secondary winding, transformer means for supplying the filament of the magnetron, a first half-wave voltage doubler circuit including a first diode and a first capacitor connected in series across the secondary winding, a second half-wave voltage doub-
bler circuit including a second diode and a second capacitor connected in series across the secondary winding with the second diode being oppositely poled, an output circuit including the two capacitors connected in series across the magnetron tube, a first relay having a winding and a set of normally open contacts, the winding being coupled to the output circuit so as to conduct magnetron load current and the normally open contacts being interposed in series with the second capacitor so that when the transformer is initially energized the voltage applied to the magnetron is derived substantially from the first half-wave voltage doubler circuit for initiating oscillation and for operation of the magnetron in a low power mode, and an auxiliary time delay relay coupled to the first relay for inhibiting the response of the latter to achieve a time delay before closure of the normally open contacts for subsequent operation of the magnetron in a high power mode.

9. The combination as claimed in claim 8 in which the auxiliary relay is in the form of a time delay relay having a winding and set of normally closed contacts connected in series across the winding of the first relay and in which the time delay relay has a relatively low resistance so as to inhibit operation of the first relay until the normally closed contacts on the time delay relay have opened.

10. The combination as covered in claim 8 in which the first relay has a set of normally closed contacts which are interposed in series with the normally closed contacts of the time delay relay for the purpose of disabling subsequent operation of the time delay relay as long as the first relay is closed.

11. In a power supply for a magnetron tube in a microwave oven or the like, the combination comprising transformer means of the high reactance type having a primary winding and a secondary winding as well as a winding for supplying the filament of the magnetron, a first half-wave voltage doubler circuit including a first diode and a first capacitor connected in series across the secondary winding, a second half-wave voltage doubler circuit including a second diode and a second capacitor connected in series across the secondary winding with the second diode being oppositely poled, the capacitors having a common connection, terminals at the junction of last diode and its associated capacitor to define an output circuit connected to the magnetron, relay means having a winding and a set of normally open contacts, the winding being connected into the circuit so as to be subject to magnetron load current and the normally open contacts being interposed in series with the second capacitor so that when the transformer means is turned on the voltage applied to the magnetron substantially in the form of spaced half-waves supplied from the first half-wave voltage doubler circuit for initiating oscillation and for operation of the magnetron in a low power mode until such time as the contacts close to activate the second half-wave doubler circuit for operation of the magnetron thereafter in a high power mode, the relay means being so constructed and arranged as to delay closing of the contacts until a brief time after the transformer is energized.

12. In a power supply for a magnetron tube in a microwave oven or the like, the combination comprising a transformer of the high reactance type having a primary winding and a secondary winding, transformer means for supplying the filament of the magnetron, a first half-wave voltage doubler circuit including a first diode and a first capacitor connected in series across the secondary winding, a second half-wave voltage doubler circuit including a second diode and a second capacitor connected in series across the secondary winding with the second diode being oppositely poled, the capacitors having a common connection and the magnetron having its terminals connected to the doubler circuits between the diodes and their associated capacitors, and a set of contacts interposed in series with the second capacitor, means for delaying closure of the contacts so that when the transformer is energized the voltage applied to the magnetron is derived substantially from the first half-wave voltage doubler circuit for operation of the magnetron in a low power mode, and a high value resistor connected in parallel with the contacts for furnishing charging current to the second capacitor during operation in the low power mode thereby to reduce the inrush to the second capacitor when the contacts are subsequently closed for operation in a high power mode.

* * * * *