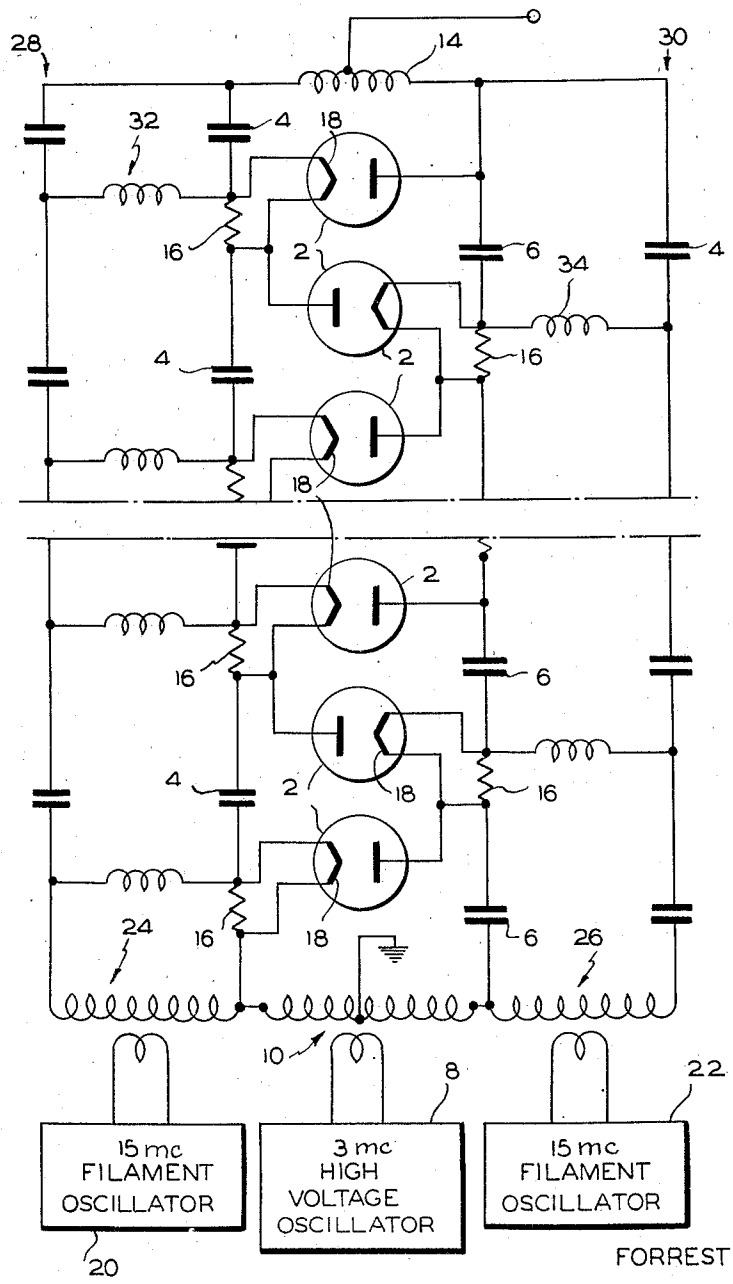
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RADIO FREQUENCY VARIABLE VOLTAGE MULTIPLIER

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RADIO FREQUENCY VARIABLE VOLTAGE MULTIPLIER

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This invention relates to a radio frequency voltage multiplier for producing direct high voltages of the order of several hundred thousand volts at currents of a few milliamperes, and more particularly to such a device capable of producing an output voltage level which can be varied over a wide range.

Cascade voltage multipliers are known in which a number of capacitors are charged from a low voltage source through a series of rectifiers and are discharged unidirectionally in series so that the voltages add, to provide essentially a series of cascade voltage doublers utilized to produce a desired high voltage. Limitations on the high voltage which can be so obtained are the voltage stress across the successive capacitors, which becomes greater as more output voltage is provided, limitation of possible load current which can be supplied due to the limitations on the peak current ratings of the rectifiers, and rapidly mounting cost as the voltage is increased due to the need for providing a separate filament transformer for each rectifier tube, and because each transformer must be insulated for high voltage. It will be apparent that this last limitation is very serious at voltages in the order of several hundred thousand.

It is a primary object of the invention in a high voltage multiplier of the above type, to provide a simple and inexpensive means for filament excitation.

When the initial voltage which is to be multiplied (i. e., the input voltage) is provided at radio-frequencies, e. g., in the megacycle range, the capacitors which are used provide a very low impedance at these frequencies; similarly, due to the interelectrode capacity of the rectifier diodes, these diodes also present a relatively low impedance. These low interelectrode and condenser impedances give rise to large circulating current in the system, which can be used to provide the necessary filament current. However, this current is tied to the output voltage, to which it is necessarily related, and the correct filament current can be provided only at one fixed output voltage, so that it is not possible to vary the output voltage in such a system. Many applications exist for high-voltage multipliers, e. g., in physics research work, etc., which require an output voltage which can be varied and accurately controlled over a fairly wide range. For such applications, the above described use of circulating currents as a filament supply source is unsatisfactory.

It is an object of the present invention to obviate the above difficulty and to provide high-frequency filament exitation in a radio frequency voltage multiplier, which permits the output to be varied over a wide range, with a correct filament supply throughout the entire range. A further object is to provide transformerless filament supply for a voltage multiplier of variable output.

Another object of the invention is to provide a simple variable high voltage multiplier of inexpensive construction using standard components, the high voltage output of which can be controlled and varied entirely at the low voltage input, without the need for controlling or manipulating high voltage circuitry.

According to the invention, at maximum output, the filaments are heated solely or mainly by the high frequency circulating currents which flow in the circuit at the normal maximum output voltage. For operation at lower voltages, an auxiliary high frequency circulating current is provided from one or more adjustable auxiliary sources coupled to the normal circulating system from which the filaments are supplied at the maximum output voltage.

The specific nature of the invention, as well as other objects and advantages thereof, will clearly appear from a description of a preferred embodiment as shown in the accompanying drawing. The single figure of the drawing is a schematic circuit diagram showing the principle of the invention.

Referring to the drawing, the high voltage multiplier proper consists of fifty rectifier tubes **2** and 100 condensers **4** and **6** arranged in the two columns shown. The drawing shows the top and bottom three diode stages of the circuit and the intervening stages are identical with the ones shown. 1B3 vacuum diodes are suitable for use as rectifiers. The multiplying condensers used in a practical embodiment were 500 $\mu\mu$f. at 20,000 volts.

Power for driving the multiplier column is obtained from a 1000-watt, 3 megacycle radio-frequency oscillator **8**, which is coupled to the column by transformer **10**. The secondary of transformer **10** is center tapped and the center tap is made the ground potential point of the system. Conventional means, involving variation of the radio-frequency oscillator plate supply voltage, are provided for varying the output of the oscillator **8**, to thereby vary the high voltage output.

At the 3 megacycle operating frequency the interelectrode capacitances of the diodes present a relatively low impedance (approximately 50,000 ohms per diode or 1000 ohms for the parallel combination of 50 tubes). The capacitance between condenser columns **4** and **6** is approximately equal to the total of that contributed by the diodes. These low interelectrode and intercolumn impedances give rise to large circulating currents in and between the two condenser columns. The center-tapped inductance **14** has been added to cancel the capacitive reactance and thereby eliminate the capacitive loading effect on the high voltage oscillator. The circulating currents of course still flow.

The center tap of inductance **14** is the high voltage connection to the circuit. For the present model the inductance **14** consists of 50 turns of number 20 copper wire wound on a coil form 6 inches long and 2¾ inches in diameter.

The filament excitation is achieved in the following manner. The fifty resistors **16** are connected in series with the two voltage multiplying condenser columns **4** and **6**. Connected in parallel with each of these resistors is a diode filament **18** which is thereby heated by the capacitive circulating currents. As it turns out in practice, the circulating currents are much higher at the extreme upper and lower ends of the condenser columns due to the inductive loadings of **14** and of transformer **10** at the two ends. Therefore the fifty shunt connected resistors **16** all do not have the same value. Much lower values will be required at the extreme ends than at the center. Although the resistance values to be used in a particular voltage multiplier must be chosen individually to obtain proper filament heating, it may be helpful to state that in a practical model the values range from 0.1 ohm to 22 ohms. The lower resistance values are obtained from short lengths of resistance wires while ordinary carbon resistors suffice for values in excess of one ohm. No other circuitry is required for fixed output voltage operation and the column is self-starting. That is, application of power from the high voltage oscillator

will give rise to circuating currents for heating the filaments and the output voltage will increase to full value.

If operation at decreased levels of output voltage is required, auxiliary filament power is required. This is necessary because lower output voltage is acquired by a reduction in power level of the high voltage oscillator which in turn reduces the circulating currents and hence the filament excitation. The auxiliary filament power is provided by the two 15-megacycle, 50-watt oscillators **20** and **22**. This power is coupled to the column via transformers **24** and **26** and is connected to the diodes whose filaments are in series with condensers **4** by way of condenser column **28** and to those whose filaments are in series with condensers **6** by way of condenser column **30**. The high voltage insulation required between successive stages is thus provided by the condensers themselves. Inductances **32** and **34** (24 on each side) are added between adjacent condenser columns to balance the inter-column capacitive reactants. Each inductance consists of 100 turns of No. 30 wire closely wound on a ⅝ inch diameter form.

With the complete circuit as shown, reduced output operation is achieved by a reduction of high voltage oscillation power level coupled with a corresponding increase of filament oscillator power level sufficient to maintain proper filament excitation.

The entire circuit of fifty stages can be mounted on a Plexiglas frame and the entire assembly of a model as actually constructed is 65 inches high by 9 inches by 9 inches.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of my invention as defined in the appended claims.

I claim:

1. In a voltage multiplier for producing high direct-voltage from a first radio-frequency alternating current source, a rectifier and multiplier circuit comprising at least two groups of high-tension condensers, a plurality of unidirectional discharge tubes connected between said groups, each of said tubes having an incandescible cathode, means for heating each cathode comprising individual impedance means associated with each tube for producing a voltage drop due to the normal radio-frequency circulating currents in said circuit, and means connecting each respective cathode with its associated impedance element for supplying each cathode with heating current, and at least one additional radio-frequency source, and means for coupling said additional source to said impedance elements to provide an additional supplementary voltage drop in said elements for supplying supplementary heating current to said cathodes.

2. The invention according to claim 1, said additional radio-frequency source being controllable for adjustment of the heating current to the optimum operating value.

3. The invention according to claim 1, there being two such additional sources, one for each of said groups of high-tension condensers.

4. In a high voltage direct current supply of the voltage multiplier type, a first high frequency source of power, a plurality of filament-type rectifier tubes and condensers connected to multiply and rectify the voltage of the power source, and individual circuits for heating the filaments of the rectifier tubes comprising an impedance device associated with each tube for producing a voltage drop due to the normal radio-frequency currents circulating through the interelectrode capacitances of the rectifier tubes and through said capacitors to provide the main filament excitation, a second high-frequency source of power, means

for coupling said second source of power to said impedance devices to furnish additional power for the filaments, said second source being adjustable to control the degree of filament excitation.

5. A high-voltage direct supply of the voltage multiplier type comprising a radio-frequency source of power, a plurality of rectifier tubes of the filament type and a condenser for each tube, connected to said radio-frequency source to multiply and rectify the voltage therefrom, said rectifier tubes being arranged in substantially parallel relationship with alternate tubes oppositely oriented and a condenser connected between the cathodes and anodes of at least alternate pairs of said tubes to form two groups of tubes, the tubes of each tube being similarly oriented, there being two groups of condensers, one group associated with the respective anode circuit of each group of tubes, a series of voltage devices respectively in series with the condensers of each group, there being one voltage device for each rectifier tube for producing a voltage drop due to the normal radio-frequency circulating currents in the circuit, and conductor means connecting the filament of each rectifier tube across one of said voltage means for supplying each cathode with heating current, and an inductance element connected across said two groups of condensers at the output end, and an output terminal connected to said inductance element intermediate its ends.

6. The invention according to claim 5, and an inductance element connected across said two groups of condensers at the output end, and an output terminal connected to said inductance element intermediate its ends.

7. The invention according to claim 5, an input transformer connected between said high voltage oscillator and said multiplier, said voltage devices being dropping resistors, the resistance values of said resistors being graded from a low value at the center of each group toward higher values toward the ends of the group to compensate for the inductive loading of said transformer and said inductance.

8. The invention according to claim 7, and at least one additional radio-frequency source of controllable amplitude, and means for coupling said additional source to said resistors to provide an additional supplementary voltage drop in said resistors for supplying supplementary heating current to said cathode.

9. The invention according to claim 8, there being two such additional radio-frequency sources, one for each of said groups of high-tension condensers.

10. The invention according to claim 9, said coupling means comprising a second set of two groups of capacitors, one corresponding to each of said first groups, with one capacitor of each of said second set connected with one capacitor of each of said first groups through inductive connecting means whereby a plurality of resonant circuits are formed, one for each capacitor and tube of the multiplier circuit, said resonant circuits being substantially tuned to the frequency of said second-frequency source.

11. The invention according to claim 10, the frequency of said second radio-frequency source being different from that of the first radio-frequency source.

12. The invention according to claim 11, said second radio-frequency source being coupled to the voltage multiplier circuit through transformer means.

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