Dec. 3, 1957 M. ROTHSTEIN 2,815,426

OSCILLATION CUT OFF

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FIG. 1

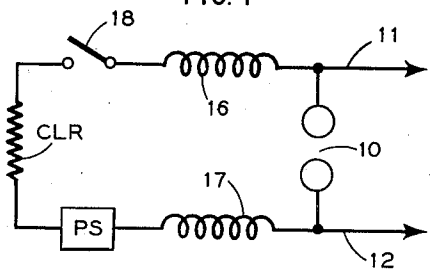


FIG. 2

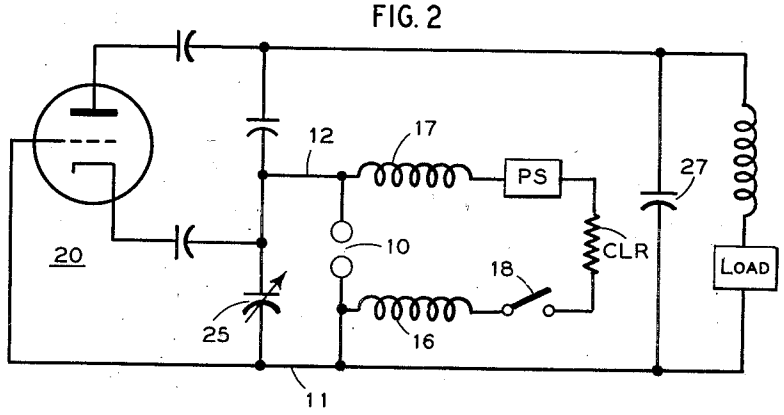
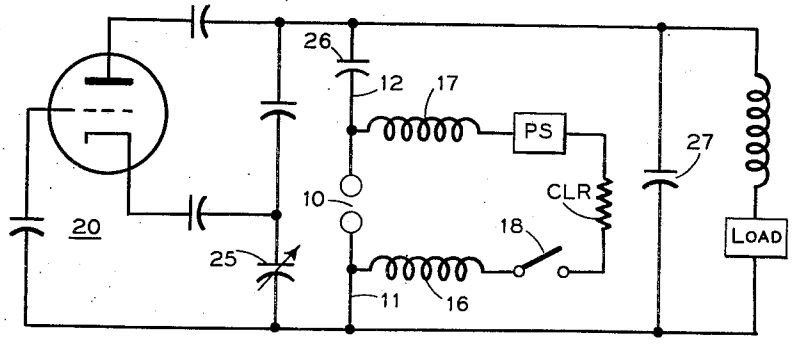


FIG. 3



INVENTOR.
Meta Rothstein
BY
Dan Mruz
ATTORNEY

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FIG. 4

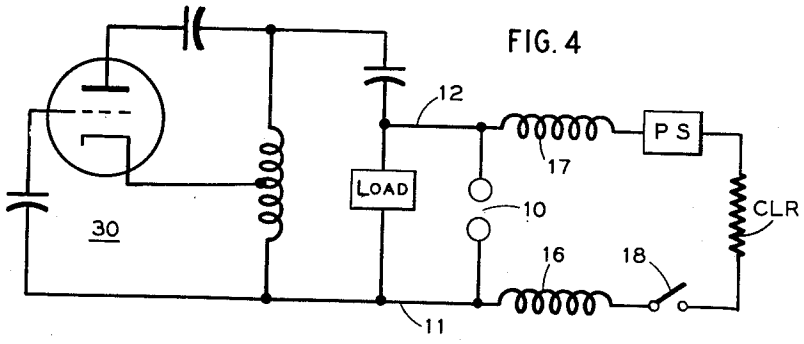


FIG. 5

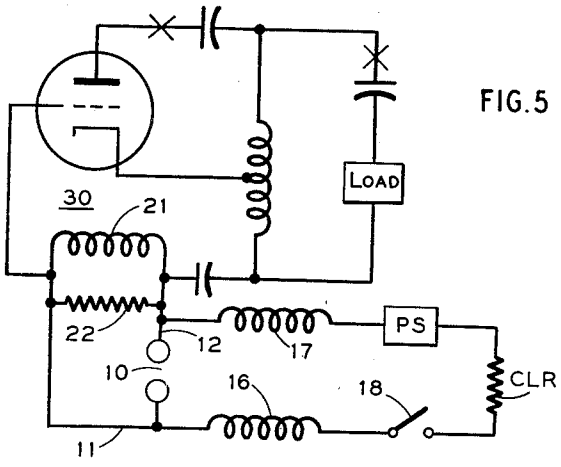
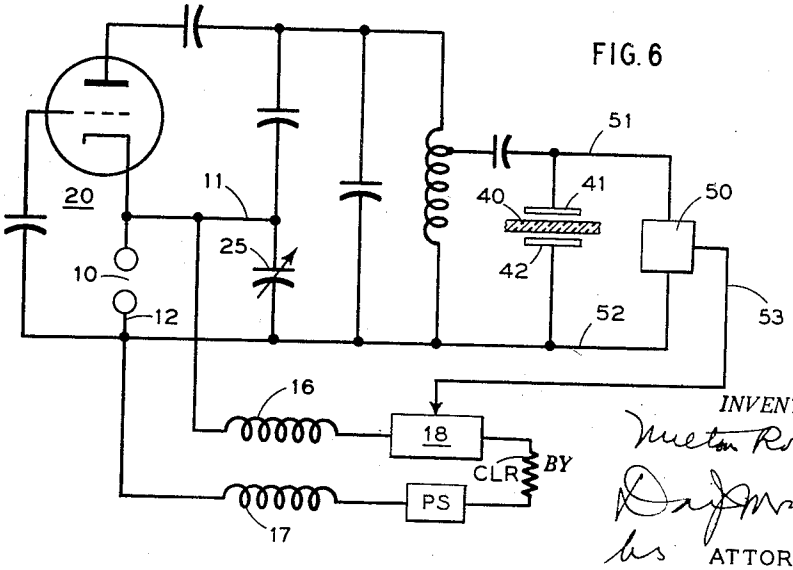


FIG. 6



INVENTOR.

Morton Rothstein

Daniel Mungo

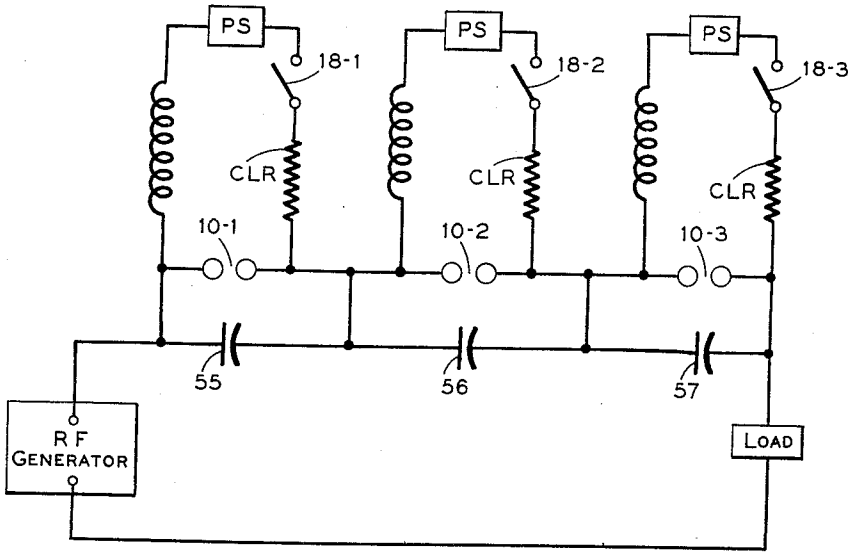
ATTORNEY

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FIG. 7



INVENTOR.
Milton Rothstein
BY
Dayton & Dayton
ATTORNEY

United States Patent Office

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OSCILLATION CUT OFF

Milton Rothstein, Flushing, N. Y., assignor to Radio Receptor Company, Inc., Brooklyn, N. Y., a corporation of New York

Application February 21, 1956, Serial No. 566,959

10 Claims. (Cl. 219—10.77)

This invention relates to protective arrangements for electronic apparatus and, more particularly, to a novel oscillation suppressor or oscillation frequency changer.

Many industrial applications of electronics involve the delivery of high frequency energy from a source, such as an oscillator or other type of generator, to a load circuit. A typical application is the high frequency electric field heating of dielectric materials, particularly thermoplastics. In this exemplary application, as well as in many others, it is necessary to rapidly interrupt the supply of high frequency energy either after a predetermined time interval or to prevent damage to the electrodes or the work from excessive current flow or arcing. In the case of high frequency electric field heating, as more particularly set forth in copending application Serial No. 357,836, filed May 27, 1953, for "Protective Arrangements for Heating Apparatus," now Patent #2,786,926, such excessive current flow or arcing may be due to any one or more of several factors, such as the presence of included conductive impurities in the material, variations in thickness of the material causing severe localized heating and/or flash-over, the application of excessive H. F. power or voltage, the application of H. F. power for excessive periods of time, or excessive compression of the material by the electrodes. Alternatively, it may be desirable to vary the power supply between different values at preselected intervals.

However, and particularly in the case of electronic oscillator supplied high frequency energy, the usual oscillation interrupting or suppressing arrangements, such as cutting off the plate voltage or applying a blocking bias to the grid, are not only costly but result in damaging transient voltages, or current in the power supply and/or in the high frequency components.

The present invention is directed to a novel, extremely rapid acting, and inexpensive oscillation suppressor or frequency changer arrangement characterized by the absence of damaging transient voltages when the oscillations are abruptly suppressed. More specifically, in accordance with the invention, a spark gap is connected at an appropriate point in the circuit in shunt or parallel relation with the load or with a control component of the generator. This spark gap functions as a normally open switch or very high capacitive reactance, when there is no arcing across the spark gap. However, when the spark gap is broken down, or "fired," and thus becomes conductive, its high frequency (R. F.) impedance is very low.

A direct current source is connected in series with the spark gap through a normally open switch and suitable choke means to isolate the A. C. and D. C. circuits from each other. To suppress the oscillations, the switch is closed to apply a D. C. potential to the spark gap to start sparking of the latter. The spark gap thus becomes a low R. F. impedance shunt effectively inhibiting transfer of the high frequency energy to the load.

The oscillation suppressing or frequency changing arrangement may be connected in a circuit in various ways.

For example, the spark gap may be connected across the variable capacitor adjusting the amount of feed back of an oscillator. In this case, when the spark gap is "fired" by the D. C. voltage, the feed back is reduced to zero so that oscillations will cease and the power to the load will drop to zero.

Alternatively, a condenser or inductance may be connected in series with the spark gap with this condenser-spark gap combination in shunt with the frequency determining elements so as to change the oscillation frequency when the spark gap is "fired." If the load is tuned reasonably sharply to the oscillation frequency obtained with the gap unfired, then firing of the gap will, in effect, detune the oscillator from the load and decrease greatly the power to the load.

Another alternative is to purposely design an oscillator to produce parasitic oscillations, under normal load conditions of a frequency widely removed from the design frequency. A parasitic oscillation suppressor is then built into the oscillator circuit with the spark gap connected in parallel therewith. With the spark gap inactive, the parasitic oscillations are suppressed, but when the spark gap is "fired" by the D. C. control voltage, the oscillator reverts to the parasitic oscillation frequency, greatly reducing the power delivery to the load.

The invention arrangement may also be used to effect stepped changes in the load power supply as by using a series of the D. C. fired spark gaps each in shunt with a condenser.

The D. C. voltage may be triggered or switched on in any desired manner. For example, in a high frequency dielectric heating system, the sensing arrangement of said copending application may be used to trigger the D. C. spark gap firing voltage. The normally open D. C. circuit switch may be a simple mechanical switch, an electronic switch, or a second spark gap "fired" by another circuit.

For an understanding of the invention principles, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings. In the drawings:

Fig. 1 is a schematic wiring diagram of the oscillation suppressor or frequency changer of the invention;

Figs. 2 through 5 are schematic wiring diagrams illustrating various ways in which the arrangement of Fig. 1 may be utilized in high frequency circuits;

Fig. 6 is a schematic wiring diagram of the invention arrangement as incorporated in a high frequency electric field heating system; and

Fig. 7 is a schematic wiring diagram of a power stepping arrangement incorporating the invention.

In the following description, the invention will be described as applied to circuits involving radio frequencies, or R. F. power. However, it should be understand that this is exemplatory only and the invention is equally applicable to audio frequencies (A. F.).

Referring to Fig. 1, the oscillation suppressor or frequency changing arrangement comprises a spark gap **10** arranged to be connected by conductors **11**, **12** into a high frequency circuit. A D. C. power source PS is connected in series with spark gap **10** through filter chokes **16**, **17** and a normally open switch **18** which, as stated, may be mechanical, electronic, or a second spark gap controlled by an auxiliary D. C. circuit. Normally, spark gap **10** acts as an open switch or a very low capacitance passing substantially no current. However, when switch **18** is closed, the D. C. current "fires" the spark gap and makes it conductive. With the spark gap **10** conductive, it constitutes a very low impedance path for R. F. energy. The filter chokes **16** and **17** isolate the R. F. and D. C. circuits from each other. The power supply is so designed, as by inclusion of a current limiting resistor CLR for ex-

ample, so that the current through the spark gap after breakdown of the latter is limited to a safe value to prevent destriction of the gap electrodes. The latter may be spherical elements, or the like, of conductive metal.

Figs. 2 and 3 illustrate the application of the oscillation suppressor to a typical oscillation circuit, such as a Colpitts oscillator. In Fig. 2, the spark gap **10** with its associated D. C. power supply **16, 17, 18** is connected by conductors **11** and **12** in parallel or shunt relation with a variable capacitor **25** provided to adjust the amount of feed back in oscillator **20** which feeds high frequency energy to a suitable load, as indicated. With spark gap **10** non-conductive, the oscillator **20** operates in a normal manner. However, when switch **18** is closed to apply a D. C. firing potential across spark gap **10**, the spark gap, becoming conductive, provides an effective shunt around capacitor **25** so that the feed back is reduced to zero. The oscillation of oscillator **20** ceases and the power of the load drops to zero.

In Fig. 3, the spark gap **10** is again connected in shunt with capacitor **25**. However, in this case a condenser **26** having a capacity widely different from that of capacitor **25**, is connected in series with the spark gap. Thus, when the spark gap is fired by closing switch **18**, condenser **26** is connected in parallel with condenser **25**. This causes a change of desired amount in the frequency of the output of oscillator **20**.

In Fig. 4, spark gap **10** with its D. C. firing circuit is connected in parallel with a load fed from a Hartley oscillator. In this case, when spark gap **10** is "fired" by closing switch **18**, and thus becomes conductive, the voltage across the load is reduced to substantially zero due to the shunting of the load by the conductive spark gap. Thus, delivery of power to the load is effectively reduced to a negligible value. In Fig. 5, a Hartley oscillator **30** is purposely designed so as to produce parasitic oscillations under normal load conditions and of a frequency widely removed from the design frequency. Such parasitic oscillations may be induced, for example, by introducing inductance at either or both of the points marked "X." A parasitic oscillation suppressor comprising a parallel connected combination of an inductance **21** and a resistance **22** is then connected in the oscillator circuit so that the parasitic oscillations will be suppressed. The spark gap **10** is connected in parallel with the parasitic oscillator suppressor. With the spark gap non-conductive, the parasitic oscillator suppressor is fully effective to suppress parasitic oscillations. However, when switch **18** is closed to fire spark gap **10**, the parasitic oscillation suppressor **21, 22** is effectively shunted so that oscillator **30** reverts to parasitic oscillation. The power delivered to the load will thus be greatly reduced compared to the power delivery in normal operation.

Fig. 6 shows the application of the invention to a high frequency electric field heating system for dielectric material. A Colpitts oscillator **20** of the type shown in Figs. 2 and 3 is arranged to deliver high frequency energy to electrodes **41** and **42** to apply a high frequency electric field across dielectric workpiece **40**. Such an arrangement of high frequency electric field heating system is described and illustrated in said copending application. Also, and as set forth in said copending application, a D. C. sensing circuit, generally indicated at **50, 51, 52**, is arranged to detect any change in the effective D. C. resistance of workpiece **40**, as might occur should a burn-through or undue softening of the workpiece be imminent. Sensing circuit **50** is illustrated as arranged, through a conductor **53**, to trigger switch **18**. Thereby, when a potential fault occurs in the dielectric field heating arrangement, switch **18** is triggered to apply the D. C. potential from power source PS to make the latter conductive. When the spark gap **10** becomes conductive, the feed back adjusting variable condenser **25** is shunted, reducing the feed back to zero and thus stopping the oscillations of oscillator **20** and reducing the power fed to electrodes **41** and **42** to zero.

While the invention arrangement has been described so far as used to interrupt R. F. power to a load, it may also be used either to reduce or to increase the R. F. power to the load in any desired increment or increments to values above or below an initial or preset value. More than one change in the R. F. power supply to the load may be obtained by designing several of the spark gap units to act in a sequence in the same circuit. This arrangement may be used advantageously, by way of example, in heat sealing thermoplastic material by the application of R. F. power. In this application, it is desirable to apply the power initially at a low level or value and then, after a short interval, to bring the power to full value in one or more steps.

Fig. 7 schematically illustrates an arrangement for effecting such an operation. Referring to this figure, the R. F. generator delivers power to the load through series connected capacitors **55, 56, 57**, which have values such as to reduce the initial value of the power to the desired low level. Spark gaps **10–1, 10–2**, and **10–3**, each in shunt with one of such condensers, are fired in sequence at desired intervals by their respective switches **18–1, 18–2**, and **18–3** connected to power supplies PS. As each capacitor **55, 56, 57** is shunted by its associated spark gap, the level of power supplied to the load will be correspondingly increased until the power level attains its full value.

The principal advantage of the present oscillator suppressor and frequency changer is its speed of operation, which is substantially instantaneous.

It is also inexpensive to construct and can be constructed with a very high current rating to thus handle large amounts of power while still being small enough to have low R. F. impedances. In effect, the invention arrangement constitutes a pure switch which does not introduce any spurious impedance into the control circuit and thus eliminates dangerous transient voltages.

Other devices for interrupting R. F. power supply to a load usually interrupt the D. C. current of the oscillator valve. If such interruption is rapid, high transient voltages are developed in the D. C. power supply components, causing breakdowns unless extraordinary protective measures are taken. With the invention arrangement, the design can be such that the D. C. currents do not change, or change only moderately, so that transient voltages are minimized.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the invention principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. In combination, a high frequency circuit including a high frequency generator, a load connected to said generator, and a control component controlling the output of said generator; a spark gap in circuit relation with said component and normally ineffective to conduct current thereacross during operation of said generator; a D. C. power source having one terminal connected to one side of said spark gap; and selectively operable normally open switching means connected between the other terminal of said source and the other side of said spark gap; whereby, when said switching means is operated to connect such other source terminal to such other side of said spark gap, a D. C. breakdown potential will be impressed across said spark gap to initiate conductive sparking thereacross to alter the control effect of said component on said generator to render said generator ineffective to deliver normal high frequency power to said load.

2. In combination, a high frequency circuit including a high frequency generator, a load connected to said generator, and a control component controlling the output of said generator; a spark gap in shunt circuit relation with said component and normally ineffective to conduct current thereacross during operation of said generator; a

D. C. power source having one terminal connected to one side of said spark gap; and normally open switching means connected between the other terminal of said source and the other side of said spark gap; whereby, when said switching means is operated to connect such other source terminal to such other side of said spark gap, a D. C. breakdown potential will be impressed across said spark gap to initiate conductive sparking thereacross to shunt out said control component to render said generator ineffective to deliver normal high frequency power to said load.

3. The combination claimed in claim 2 including means isolating said D. C. source from said high frequency circuit.

4. The combination claimed in claim 3 in which said isolating means comprises filter choke means connected between said source and said spark gap.

5. The combination claimed in claim 2 in which said generator is an electronic oscillator.

6. The combination claimed in claim 2 in which said generator is an electronic oscillator; and said control component is a variable capacitor.

7. The combination claimed in claim 6 including a second capacitor, differing substantially in capacity from said variable capacitor, connected in series with said spark gap and controlling the oscillator frequency when said spark gap is fired to shunt said variable capacitor.

8. In combination, a high frequency circuit including a high frequency electronic oscillator designed to produce parasitic oscillations at normal load differing substantially in frequency from the normal oscillations of said oscillator, a load connected to said generator, and a parasitic oscillation suppressor connected between said oscillator and said load and normally effective to suppress said parasitic oscillation; a spark gap in shunt circuit relation with said oscillation suppressor and normally ineffective to conduct current thereacross during operation of said oscillator; a D. C. power source having one terminal connected to one side of said spark gap; and normally open switching means connected between the other terminal of said source and the other side of said spark gap; whereby, when said switching means is operated to connect such other source terminal to such other side of said spark gap, a D. C. breakdown potential will be impressed across said spark gap to initiate conductive sparking thereacross to shunt out said oscillation suppressor to change the mode of oscillation to change the output frequency of said oscillator.

9. The combination claimed in claim 2 in which said load comprises electric field heating means for thermoplastic material; and sensing means operable to detect a change in condition of said material during high frequency heating thereof; said sensing means triggering said switching means to fire said spark gap upon occurrence of such change in condition.

10. An oscillation suppressor and frequency changing device for use with a high frequency circuit including a high frequency generator, a load connected to said generator, and a control component controlling the output of said generator; said device comprising, in combination, a spark gap constructed and arranged for connection in shunt circuit relation with said component and normally ineffective to conduct current thereacross during operation of said generator; a D. C. power source having one terminal connected to one side of said spark gap; and normally open switching means connected between the other terminal of said source and the other side of said spark gap; whereby, when said switching means is operated to connect such other source terminal to such other side of said spark gap, a D. C. breakdown potential will be impressed across said spark gap to initiate conductive sparking thereacross to shunt out said control component to render said generator ineffective to deliver normal high frequency power to said load.

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