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OPERATING CIRCUIT FOR A DISCHARGE TYPE OF TRANSDUCER

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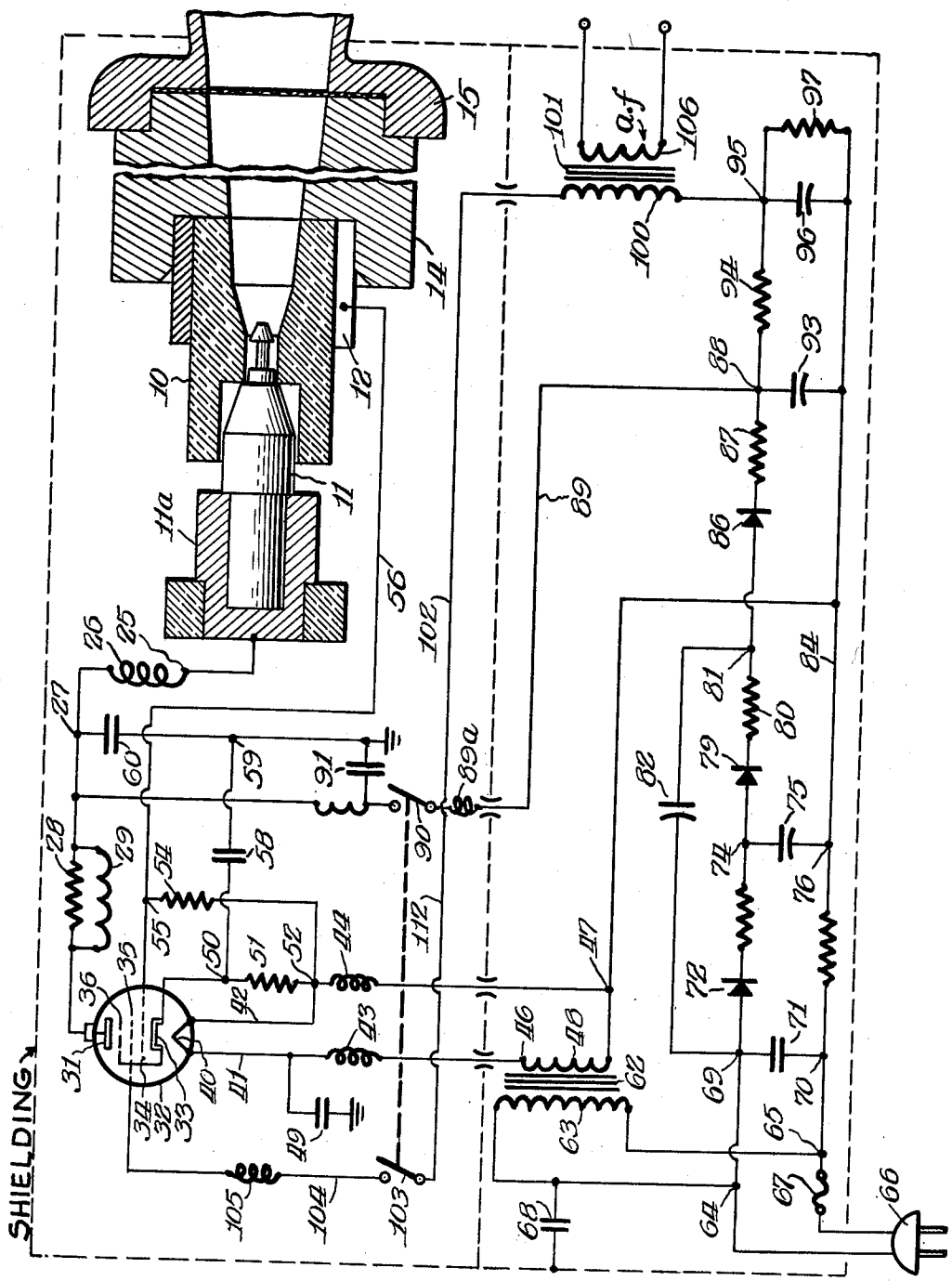

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OPERATING CIRCUIT FOR A DISCHARGE TYPE OF TRANSDUCER

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This invention relates to an operating circuit for a discharge type of transducer and more particularly for the transducer disclosed and claimed in United States Patent No. 2,768,246, issued on October 23, 1956, to Siegfried Klein. The operating circuit forming the subject matter of the present invention is useful for the transducer disclosed and claimed in said patent, and is particularly useful for the transducer disclosed and claimed in the copending application of William Torn, Serial No. 92,069, filed February 27, 1961, now Patent No. 3,105,124, and assigned to the same assignee as the present application. The transducer disclosed in said application identified above is illustrated here in connection with the operating circuit. It is understood however, that the operating circuit has general application to this type of a transducer, and the illustration of the details of this transducer are by way of example and not by way of limitation.

It is believed that the transducer disclosed in said issued patent and in the copending application operates with an arc discharge within an insulating chamber. The discharge is initiated and maintained by high frequency currents, the frequency being in the radio frequency range. The actual value of the frequency is not important insofar as general transducer operation is concerned, although specific values of frequency may be desirable for certain special applications. As a transducer, the radio frequency currents responsible for the initiation and maintenance of the arc discharge may be modulated by currents of a lower frequency, such as for example, audio frequencies, in a manner well known in the art of carrier current communications.

The arc type of transducer referred to above has certain peculiar characteristics which differentiate it from other transducers. Thus when a discharge is first initiated, a higher than normal operating potential is required. After the discharge has become stabilized, the potential necessary to maintain the discharge is lower than the starting potential.

It is important that the operating circuit for this type of a transducer be compact and make an economical and efficient package permitting the transducer system as a whole to be readily coupled to any source of modulating currents such as audio frequency currents. In particular, the transducer and operating circuit forming the subject matter of this invention is particularly useful for use with such devices as radios, electric phonographs and other devices wherein audio frequency currents are to be converted to sound waves over an extended frequency range.

The gaseous discharge or arc discharge transducer may be used for handling any desired frequency range. In practice, it may be used with a conventional speaker as a dynamic speaker for convenience and to avoid the necessity of providing an extremely bulky and large horn for the arc discharge transducer. Thus in practical transducers of this type, a comparatively small horn having a length of about six or eight inches may be used over a frequency range of about 3,500 cycles per second and up, leaving frequencies below about 3,500 cycles per second to be handled by a conventional speaker. However, it is to be understood that the operating system and circuit for the arc discharge transducer disclosed herein is independent of any cooperation between this type of a transducer and a conventional speaker. Insofar as the present invention is concerned, the arc discharge transducer functions as a separate unit.

The present invention takes advantage of peculiarities of the transducer characteristics which for conventional circuitry would present very serious problems. The transducer, prior to discharge, presents a substantially pure capacitive reactance. After discharge, however, the impedance appears to be capacitive plus resistive. The change in the character of the impedance from substantially pure capacitive reactance to an impedance consisting of capacitive reactance and resistance results in a substantial variation of impedance and a great change in phase shift across the load. The phase shift is difficult to measure, but would be substantially 90° prior to discharge and could drop to less than 45° with discharge. Since the discharge is being modulated by signal currents, the resistance of the arc varies substantially and would thus have an effect on the total phase shift due to the transducer.

A conventional oscillator and tank circuit with the transducer load would require elaborate circuitry and switching to maintain the oscillator in operation. In accordance with the present invention, a network is provided wherein the transducer load is the terminating capacitor of the network. Prior to arc discharge, the network is practically unterminated, the cell capacity being the only element across the network. This causes the potential at the network end to be high to initiate an arc. After the arc has been initiated, the network has an effective resistance terminating it. The cell capacity in conjunction with the input capacitor provides proper voltage division. The potential across the terminating resistance is fed back to the control electrode of the amplifier to maintain the same in oscillation. The peculiarity of this circuitry appears to provide the desired amount of feedback to the amplifier in desired phase relationship with minimum components and expense. The network input portion consisting of a capacitor and inductor exercises considerable control over the oscillator frequency to maintain the oscillator frequency reasonably constant within a desired range. Manufacturing tolerances of the transducer, resulting in tolerances of capacitance and operating resistance, have a negligible effect on the oscillator as a whole as far as frequency is concerned. Furthermore, the new circuitry makes it possible to impress a direct biasing potential on the transducer without any extra connections.

The net result of the new circuitry is to provide efficient, stable operation with long life of transducer and with unusual economy of circuit components and connections.

A further important feature of the present invention resides in the power supply for the oscillator and transducer. This power supply has a predetermined drooping voltage characteristic for providing a relatively high starting potential at the transducer terminals and for drooping the potential to a desirable operating value. This voltage regulation is in addition to the desirable voltage regulation present across the transducer terminals by the action of the oscillator circuit itself. While many power supplies have a drooping voltage regulation, this is usually obtained by means of current drops through resistors. In the present invention, however, the drooping voltage regulation is obtained by a reduction in the value of the filter capacitor forming part of an R-C network for filtering rectified current. In fact, the power supply in the operating system has the desirable characteristic of having means for tripling the applied potential from an alternating current supply line such as might be present in a home. As a result, no large transformers are required, making the entire transducer system light and reducing cost as well as weight.

For a more complete disclosure of the invention, reference will now be made to the drawings showing in dia-

grammatic form a transducer of the arc discharge type. The single figure shows a complete system.

The transducer unit consists of cell 10 of refractory insulating material such as quartz. Inner or center electrode 11 and outer electrode 12 are disposed as shown. The transducer unit has coupling member 14 of insulating material for coupling the transducer to horn 15 shown in part. As pointed out in the Klein patent referred to, this horn may taper to provide acoustic coupling to atmosphere or any shape may be used to provide a path to atmosphere of the radiant energy generated by the discharge.

Inner electrode 11 preferably has the shape illustrated and is disposed within cell 10. Cell 10 has the interior thereof cut out to provide a pair of coaxial chambers as shown in the drawing. Outer electrode 12 is disposed around the outside of cell 10 and as will be noted, rear edge 18 of the outer electrode overlaps edge 19 of the conical shaped head of inner electrode 11. Outer electrode 12 is slotted and consists of a metal sleeve hugging the cell.

Inner electrode 11 has metal cap 11*a* connected by wire to terminal 25 of inductor 26. Inductor 26 is an air core inductor having a desired number of turns depending upon the frequency desired to be generated. Inductor 26 has terminal 27 connected through resistor 28 shunted by inductor 29 to anode 31 of vacuum tube oscillator 32. Resistor 28 and inductor 29 are provided for the purpose of suppressing parasitic oscillations. As an example, the frequency to be generated can be 27 megacycles. This value is desirable principally because of government regulations in the United States. Other values may be readily used. The parasitic suppressor, consisting of resistor 28 and inductor 29, will therefore be designed to suppress spurious oscillations.

Vacuum tube 32 is a pentode having cathode 33, control grid 34, screen grid 35 and suppressor grid 36. Suppressor grid 36 is connected to cathode 33 in the usual fashion. Tube 32 has cathode heater 40 connected through wires 41 and 42 to radio frequency chokes 43 and 44, then to terminals 46 and 47 of transformer secondary 48. Cathode heater 40 is grounded for RF by capacitor 49.

Cathode 33 is connected to junction 50. Resistor 51 is connected between junctions 50 and 52. From junction 52, resistor 54 is connected to junction 55 connected to control grid 34. Junction 55 is also connected by wire 56 to outer electrode 12 of the transducer for feedback to the amplifier. This connection functions to complete the load circuit and at the same time provide the feedback potential to maintain amplifier 32 oscillating.

Junction 50 is connected to one terminal of bypass capacitor 58, the other terminal of which is connected to ground at 59. Capacitor 60 is connected between grounded junction 59 and terminal 27. Capacitor 60 and inductor 26 determine, for the most part, the frequency of oscillation. Capacitor 60, inductor 26 and the transducer form a network. The network is connected to ground at input capacitor 60 and to control grid 34 at the output capacitor and load.

Transformer winding 48 is the secondary of transformer 62 having primary winding 63 connected to junctions 64 and 65. Junctions 64 and 65 may be connected to conventional plug 66 for insertion into a receptacle providing 60 cycle or any other frequency at a suitable potential, usually about 115 volts. One side of the power line is provided with fuse 67. The power line is also grounded for RF by capacitor 68. Junctions 64 and 65 are connected to junctions 69 and 70 of a power supply. Across junctions 69 and 70 is connected line surge capacitor 71. Junction 69 is connected to one pole of rectifier 72, the other pole of which is connected to resistor 73 and hence to junction 74. Junction 74 is connected to one terminal of filter capacitor 75 and the other terminal

of this capacitor is connected to junction 76. Between junctions 70 and 76, resistor 77 is connected. Junction 74 is connected to rectifier 79 and this rectifier in turn is connected to resistor 80 and hence to junction 81. Between junctions 69 and 81, capacitor 82 is connected. Junction 76 is connected to wire 84. Terminal 47 of transformer secondary 48 is connected to wire 84.

Terminal 81 is connected to one terminal of a third rectifier 86, the other terminal of which is connected through filter resistor 87 to junction 88. Junction 88 is connected by wire 89 through RF choke 89*a* to one pole of switch 90, the other pole of the switch being connected through choke 91 to junction 27. Junction 88 is connected to one terminal of filter capacitor 93, the other terminal of which is connected to wire 84. Junction 88 is also connected through screen drop resistor 94 to junction 95. Junction 95 is connected to wire 84 through filter capacitor 96 and resistor 97 in shunt thereto. Junction 95 is also connected to one terminal of secondary 100 of modulating transformer 101. Secondary 100 has its other terminal connected to wire 102 going to switch 103 (ganged to switch 90) and thence by wire 104 through RF choke 105 to screen grid 35 of vacuum tube 32. Transformer 101 has primary 106 for connection to a suitable source of voice currents. The audio frequency source may be a public address system, a microphone or radio, or any other device having voice currents to be reproduced. The modulating potentials may be fed into the anode, control grid or cathode circuits in accordance with conventional modulation practice.

It will be noted that there is a metallic or direct current connection between anode 31 and electrode 11 of the transducer. Thus the inner electrode of the transducer will have impressed thereon a direct potential upon which is superimposed the alternating potential resulting from the generation of oscillations by oscillator 32. As previously pointed out, resistor 28 and inductor 29 function as a filter to suppress parasitic oscillations.

Capacitor 60, in addition to forming one of the frequency determining components, also determines the amount of RF impressed on the transducer load. If the capacitance of 60 is increased, more RF would be bypassed to ground. In designing the network, the value of capacitor 60 will be larger than that of the load but should be kept as low as possible. For example, a ratio of about 20 or 25 to 1 will work nicely. After the arc begins, the ratio drops to about 10 or 12 to 1. Too low a ratio after discharge will result in distortion of voice potentials.

If for some reason it is desired to use a coupling capacitor between inductor 26 and the load, then a much larger capacitor than any used in the network would be desirable. Thus in the system described, in an actual installation where the oscillation was at 27 megacycles, capacitor 60 had a value of 12 mmfd. In such case, a coupling capacitor might have a value 100 or 200 times as great.

The remainder of the oscillator system works in conventional fashion. When switches 90 and 103 are closed, oscillations will be generated and modulating potentials from transformer secondary 100 will be fed to screen grid 35. Thus tube 32 functions as a modulated oscillator.

Referring now to the power supply, rectifiers 72, 79 and 86 are in separate sections in series which function to triple the potential available at junctions 69 and 70. By having the value of line surge capacitor 71 small in comparison to any filter capacitors for a power supply, it is only necessary to rely upon capacitors 75, 82, 93 and 96 for filtering action. These capacitors have values in the microfarad range. Thus for 60 cycles per second, capacitors 75 and 93 may each have a value of the order of about 40 microfarads. Capacitor 96 may have about the same value or may have a somewhat smaller value. It was found that if capacitor 82 has one-half the value of capacitors 75 and 93 that a very desirable action results. Thus in the example given above, capacitor 82 would

have a value of 20 microfarads if capacitor 75 has a value of 40 mfd.

When the system is first turned on, an unusually high potential is available across the terminals of the transducer which aids greatly in the initiation of a discharge. Once the transducer starts to draw current, then conditions stabilize and the power supply functions in a normal manner to provide suitable output.

In a typical system, tube 32 was type 6DQ6. Inductor 26 had a value of 11 microhenries. The rectifiers were of the silicon type. Resistors 73 and 80 were each 10 ohms. Resistor 77 was 5 ohms. Resistor 87 was 100 ohms while resistor 94 was 33,000 ohms. Resistor 97 was 220,000 ohms. Resistor 51 was 120 ohms, while resistor 54 was 33,000 ohms. Surge capacitor 71 is provided principally to protect the rectifiers against large line surges and noise potentials. Thus capacitor 71 can have a value of about .05 mf. Capacitor 58 is small, about .002 mf., while capactor 60 has a value of about 12 mmf.

The transducer when starting will have a capacitance of about .5 mmf. Hence with capacitor 60 at a value of about 12 mmf., the ratio is about 24 to 1. For the particular type of tube used here, a ratio of about 10 or 15 to 1 is satisfactory. The coil impedance drops after discharge so that the equivalent capacitance of the cell is about 1 mmf. Actually a good part of the cell impedance is resistive after discharge has been initiated. If distortion of voice currents is not considered, then the ratio of capacitances of 60 and the cell can be enough to insure arc initiation, after which the ratio automatically drops. For a different type of tube, linearity may be obtained with a ratio different from that provided here.

The entire system is preferably arranged to prevent radiation. Thus the various RF chokes may be each about 10 microhenries. It may be desirable to have the power supply shielded from the oscillator and mixer section as suggested by dotted lines. In such case, feedthrough means as indicated can be provided. Such feedthroughs are widely used in TV receivers. For example, the feedthroughs for coils 43, 44 and switch 90 may be used for filtering out RF and can have values of about 1000 mmf. each. The feedthrough to switch 103, however, should be about 10 mmf. A higher value would result in bypassing to ground the higher frequency components of the A.F. spectrum. Choke 105 is in this line.

The parasitic filter had a 47 ohm resistor while the inductor consisted of four turns of No. 18 wire disposed around the resistor body. The design of such a filter is simple, the objective being to suppress spurious oscillations.

The cell itself is mounted so that its capacitance to ground is low. The resistance to ground is very high. These factors are similar to corresponding factors in high frequency equipment and are usually taken into consideration in the assignment of values for various capacitors. The various bypass capacitors, such as 49 and the one for inductor 91, will be large enough to pass the desired frequency (27 megacycles in the assumed example). For this example, these capacitors may be each about .002 mfd.

While the frequency of oscillation of the system is largely determined by the values of inductor 26 and capacitor 60, the capacitance of the load does have some effect. It has been found that after discharge has been initiated, the frequency of oscillations drops a slight amount below the free running frequency prior to initiation of discharge. However, the change in frequency is negligible.

With regard to the power supply, the fact that capacitor 82 has less capacitance than capacitor 72 or 79 is significant principally with respect to providing poor voltage regulation. The fact that capacitor 96 is smaller than capacitors 75 and 93 is not too important and only affects the filtering action. In the system having the values previously specified, the potential available at point 88 with respect to ground prior to a discharge in the transducer was about 430 volts, this dropping to 310 volts after discharge. The corresponding values for point 95 to ground were 310 and 150 volts respectively.

Capacitor 58 has a value of a higher order than capacitor 60. In this example the ratio is about 167 to 1. It is clear that for oscillation frequencies, capacitor 60 is effectively connected across the anode and cathode of tube 32.

What is claimed is:

1. The combination of an operating circuit and a gaseous discharge type of transducer having one electrode as a point and the other electrode having a relatively larger surface, said transducer operating with a gaseous arc discharge about said one electrode maintained by radio frequency potentials between said electrodes, said transducer, in the absence of a discharge, presenting a capacitive load, said load, after discharge initiation, having so much of a resistive component that the normally 90° capacitive phase shift changes very substantially, said transducer also requiring a voltage for initiating an arc discharge which is greater than the voltage required to maintain the arc, said operating circuit including the following: a vacuum tube amplifier having a cathode, anode and control grid, a direct wire connection between said control grid and said other transducer electrode, means for impressing a uni-directional energizing potential on said cathode and anode, said anode being connected to the positive terminal of said energizing potential source, a first capacitor connected between the tube anode and tube cathode, an inductor connected between the tube anode and said one transducer electrode, said first capacitor having a value of the order of about 25 times the transducer capacitance with no discharge, said ratio dropping to the order of about 12 after discharge has been initiated in said transducer, said first capacitor and inductor having suitable values to determine generally a desired RF for transducer operation, the operating circuit and transducer cooperating to provide a network which is conducive to impressing a desired RF potential on said transducer for arc initiation and for maintaining a lower desired potential for arc maintenance, and means for modulating the RF impressed on said transducer for signalling purposes.

2. The combination according to claim 1 wherein said modulating means includes a source of signal potentials, a screen grid in said tube, and connections disposing said modulating means across the screen grid and cathode.

3. The combination according to claim 2 wherein said potential source includes an R-C filter system having poor voltage regulation so that when said transducer has an arc therein and draws normal load current, the potential available for said operating circuit is substantially lower than is available prior to arc initiation.

4. The combination according to claim 3 wherein the power supply has a first R-C filter section with a rectifier, a second R-C filter section with a rectifier, the capacitor of said second section being connected in shunt to the two rectifiers and resistors on one side of the line, said last named capacitor having about one-half the value of the first section capacitor and a third R-C rectifier section connected to the output of the second section.

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