Feb. 28, 1939. A. W. VANCE 2,149,077

DEFLECTING CIRCUITS

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FIG. 1.

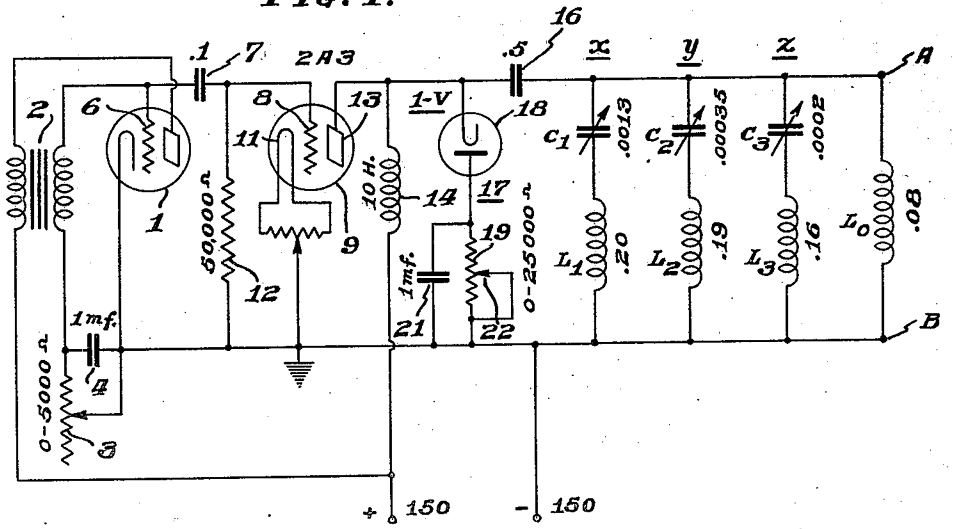
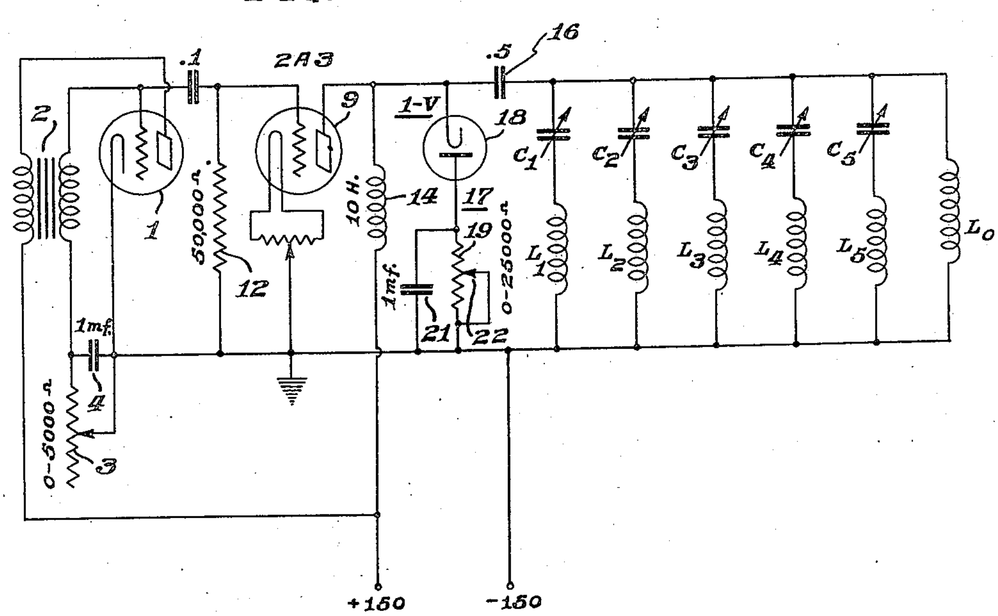


FIG. 2.



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DEFLECTING CIRCUITS

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FIG. 3.

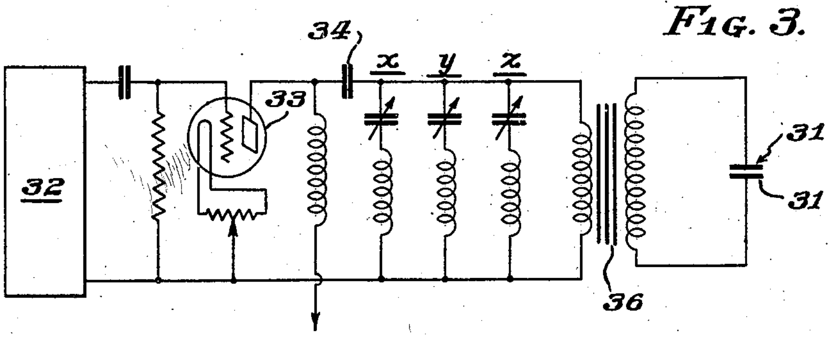


FIG. 4.

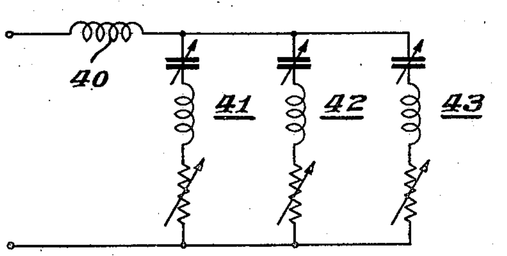


FIG. 5.

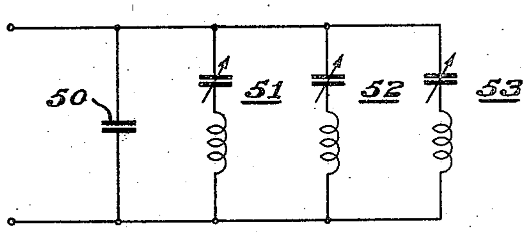
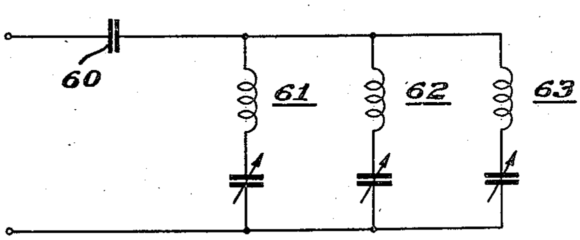


FIG. 6.



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Patented Feb. 28, 1939

2,149,077

UNITED STATES PATENT OFFICE

2,149,077

DEFLECTING CIRCUITS

Arthur W. Vance, Haddonfield, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application September 26, 1936, Serial No. 102,670

10 Claims. (Cl. 250—27)

My invention relates to electrical circuits in which non-sinusoidal currents or voltages are produced, and particularly to deflecting circuits for cathode ray tubes or the like.

In cathode ray tube deflecting circuits employing deflecting coils, it is the usual practice to impress across the deflecting coils a voltage which builds up a flow of current therethrough, this current being supplied through an output tube, and then to swing the output tube to cut-off. When the tube is swung to cut-off, the energy stored in the deflecting coils is dissipated either in the output tube or in a resistor shunting the coils if such a resistor is provided.

If the energy in the coils could be made to flow into some storage device and then flow back again, the only power that would have to be supplied would be that required to supply the losses of the deflecting coils and the storage device. A tuned sine wave deflecting circuit has these characteristics and, as is well known, is very efficient.

The problem of obtaining increased efficiency in deflecting coils may be considered from another viewpoint. The impedance of the deflecting coils is much lower at the fundamental frequency and lower harmonics of the saw-tooth current than at the higher harmonics. By effectively increasing the impedance of the deflecting coils at the lower frequency components of the saw-tooth current, whereby the voltage across the coils is maintained at a high value, an increase in efficiency may be obtained if, at the same time, the inductance of the coils is not increased.

In deflecting circuits employing deflecting plates instead of deflecting coils, it is usually desirable to employ a step-up transformer for obtaining the required high voltage across the deflecting plates. If the transformer secondary is wound with a large number of turns to make its impedance high, it has considerable distributed capacity thereacross, with the result that the impedance of the deflecting circuit is lowered and the deflecting efficiency is reduced.

In practicing one embodiment of my invention, I provide a plurality of resonant circuits associated with the deflecting coils (or with the step-up transformer in the case of deflecting plates), these resonant circuits being so adjusted that the circuit as a whole is resonant at a plurality of preselected frequency components. Preferably, the deflecting coils or transformer and the associated resonant circuits are resonant at the fundamental of the saw-tooth wave and at the lower frequency harmonics such as the second and third harmonics. In the case of deflecting plates, the transformer is wound with a sufficiently small number of turns to keep the distributed capacity at a low value, and then the impedance of the transformer is increased at the lower frequencies by resonating a plurality of resonant circuits, as previously mentioned.

It is, accordingly, an object of my invention to provide an improved method of and means for deflecting a cathode ray.

A further object of my invention is to provide an improved method of and means for passing a non-sinusoidal current of desired wave shape through a reactive load such as an inductance coil.

A further object of my invention is to provide an improved circuit for passing a saw-tooth current through a deflecting coil.

A still further object of my invention is to provide an improved method of and means for producing a non-sinusoidal voltage across a reactive load.

A still further object of my invention is to provide an improved method of and means for impressing a voltage of non-sinusoidal wave form across a pair of deflecting plates.

Other objects, features and advantages of my invention will appear from the following description, taken in connection with the accompanying drawings, in which

Figure 1 is a circuit diagram of one embodiment of my invention, and

Figures 2 to 6 are circuit diagrams of other embodiments of my invention.

Referring to Fig. 1, my invention is shown applied to a deflecting circuit for a cathode ray tube (not shown). The circuit comprises suitable means for producing voltage impulses periodically, this means in the particular circuit illustrated including an electric discharge tube 1 having its plate circuit coupled to its grid circuit through a transformer 2. The grid circuit of the tube 1 includes one winding of the transformer 2, a variable grid resistor 3, and a grid condenser 4.

The coupling of the plate and grid circuits through the transformer 2 is in such direction that the grid 6 of the tube 1 is made more positive as the flow of plate current increases. It will be noted that the plate and grid circuits are untuned. This type of oscillator is described and claimed in my co-pending application Serial No. 718,353, filed March 31, 1934, and assigned to the Radio Corporation of America. As explained in the above identified application, such an oscillator produces voltage impulses periodically, the voltage impulse on the grid 6 being of negative polarity.

The inductance coil through which it is desired to produce a flow of saw-tooth current is indicated at L_0. In the circuit illustrated, this is a cathode ray tube deflecting coil.

It is well known that to produce a flow of saw-tooth current through a purely inductive coil a rectangular voltage impulse should be impressed across the coil. This may be done by impressing a voltage impulse across the inductance coil through a low impedance output tube, providing the impedance of the deflecting coil is high compared with the tube impedance. Otherwise the saw-tooth current flowing through the tube and coil causes a substantial voltage drop in the tube, this voltage being saw-tooth in shape and necessitating a like voltage being impressed upon the tube grid.

Both a saw-tooth wave and an impulse or rectangular wave contain a large number of harmonics, the greater part of the energy being contained in a few of the lower frequency harmonics. Obviously, an inductance coil may have the required high impedance with respect to the tube impedance for the high frequency components of a saw-tooth wave, but not for the low frequency components. Therefore, if the impedance of a deflecting coil is effectively increased for the low frequency components of the current to be forced therethrough, the necessity for adding a saw-tooth voltage component to the voltage impulse applied to the grid of the output may be avoided. From one aspect of my invention, this is what I accomplish by the circuit shown in Fig. 1.

Referring again to Fig. 1, the negative voltage impulses from the oscillator tube 1 are impressed through a coupling condenser 7 upon the grid 8 of a low impedance tube 9 which may be of the 2A3 type. The grid 8 may be connected to the cathode 11 of the tube 9 through a grid resistor 12 for operation at zero bias, if desired. Preferably, the negative voltage impulses supplied from tube 1 are of sufficient amplitude to drive the tube 9 to cut-off or beyond, whereby what may be referred to as Class C operation is obtained.

The plate 13 of the tube 9 may be supplied with a positive voltage through a choke coil 14, while the deflecting coil L_0 is coupled to the output circuit of the tube through a coupling condenser 16. If there is no objection to having a flow of direct current through the coil L_0, the choke coil 14 and coupling condenser 16 may be omitted and the voltage applied to the plate 13 through the deflecting coil L_0.

In accordance with my invention, a plurality of series resonant circuits x, y and z are connected across the deflecting coil L_0. The circuit x includes the condenser C_1 and the inductance coil L_1, the circuit y includes the condenser C_2 and the inductance coil L_2, and the circuit z includes the condenser C_3 and the inductance coil L_3.

It is desired that between the points A and B the circuit exhibit parallel resonance at the fundamental frequency of the saw-tooth wave to be passed through coil L_0 and at the second and third harmonics of this wave. This result may be obtained by making circuit x resonate at a frequency lying between the fundamental and the second harmonic, by making circuit y resonate at a frequency between the second and third harmonics, and by making circuit z resonate at a frequency between the third and fourth harmonics. Then by proper adjustment of L_0, L_1, L_2 and L_3, the circuit will have the desired characteristic.

The mathematical solution for the ratio of the inductance and capacity values in my deflecting circuit is simple, but may become somewhat tedious when extended to a large number of harmonics. For three harmonics, as in Fig. 1, it involves the solution of six simultaneous equations, three of which are the arbitrarily chosen series resonant conditions for the branches x, y and z. The other three equations are obtained by setting the admittance of the whole circuit to zero for W_0, $2W_0$ and $3W_0$, where W_0 is $2\pi f$, f being the fundamental frequency of the saw-tooth wave. Below are listed the ratios between the inductance values and the condenser values for the particular solution where the circuit resonates at the fundamental frequency and two harmonics:

Parallel resonance at W_0, $2W_0$ and $3W_0$.

Series resonance at $3/2\ W_0$, $5/2\ W_0$ and $7/2\ W_0$.

$$L_1=1.27\ L_0 \qquad C_2=.474\ C_1$$
$$L_2=.76\ L_1 \qquad C_3=.455\ C_1$$
$$L_3=.403\ L_1 \qquad 3/2\ W_0=\frac{1}{\sqrt{L_1C_1}}$$

At frequencies below 3/2 fundamental branches x, y and z are capacitive, since the reactances of the condensers are greater than those of the coils. At fundamental frequency the inductive reactance of the deflecting coil L_0 exactly equals the capacitive reactances of branches x, y and z in parallel, and the circuit resonates at fundamental frequency. Above 3/2 and less than 5/2 fundamental frequency, branch x is inductive and branches y and z capacitive. At second harmonic frequency the inductive reactance of L_0 and branch x in parallel exactly equals the capacitive reactance of branches y and z in parallel, and the circuit becomes resonant at second harmonic frequency. Above 5/2 fundamental frequency and below 7/2 fundamental frequency, branches x and y are inductive and branch z capacitive. At third harmonic frequency the inductive reactance of branches x and y and L_0 in parallel exactly equals the capacity reactance of branch z, and the circuit becomes resonant at third harmonic frequency. Above 7/2 fundamental frequency, all branches become inductive and the whole circuit presents inductive reactance. The series resonant frequencies of the branches may fall anywhere in between their respective harmonics, and by proper adjustment of the ratios between the inductances, the circuit may be made to resonate at the fundamental frequency and the harmonics.

It will be understood that if the deflecting coil L_0 and its associated resonant circuits were made to resonate at harmonics containing substantially all of the saw-tooth current energy, and if these harmonics were then combined in the proper phase relation and with the proper relative amplitude, a good saw-tooth current wave would flow through the deflecting coil. As a practical matter, it is almost impossible to produce a good saw-tooth wave by relying upon such a circuit adjustment.

In the circuit shown in Fig. 1, the gradually sloping or useful deflecting portion of the saw-tooth current wave flowing through the coil L_0 is made a substantially straight line by connecting a damping circuit 17 in shunt to the coil L_0. While this damping circuit may be a resistor of proper resistance value, I prefer to employ a circuit consisting of a rectifier tube 18 such as an RCA 1—V in series with a resistor 19, the two elements 18 and 19 in series being connected across the deflecting circuit. The resistor 19 is shunted by a condenser 21 having a large enough capacity to cause the damping circuit to be effective for at least the major portion of the duration of a saw-tooth wave. The amount of damping in the circuit may be controlled by moving a variable tap 22 and thereby shunting out a portion of the resistor 19.

The particular damping circuit illustrated provides damping in the deflecting circuit only for the duration of the useful deflecting portion of the saw-tooth wave, there being no damping or loading on the circuit during the return line portion of the saw-tooth, whereby, when the grid 8 of the output tube 9 is driven negative, an exceedingly high voltage is built up across the coil L_0 to give the desired fast return line. The reason that the damping circuit provides damping only during the useful deflecting or charging portion of the saw-tooth is that during this period the coil L_0 is being energized by a flow of current from the point B in the circuit through the coil L_0 and through the output tube 9. Therefore, at this time the plate of the rectifier tube 18 is positive and the rectifier tube is conducting. During the return line period, however, the polarity of the voltage across the rectifier tube 18 is reversed and the tube is non-conducting.

The damping circuit illustrated in Fig. 1 is described and claimed in application Serial No. 61,499, filed January 30, 1936, in the name of Robert Andrien, and assigned to the Radio Corporation of America. In the aforesaid application, the damping circuit is shown connected across a deflecting coil which does not have any resonant circuits corresponding to the circuits x, y and z associated with it. As described in the Andrien application, the action of the damping circuit is to straighten the saw-tooth by damping out resonant effects which cause distortion of the saw-tooth. The operation of the damping circuit when employed with my deflecting circuit shown in Fig. 1 may be explained in the same way.

When the circuit shown in Fig. 1 is first set up, the adjustment is as follows: The damping circuit is temporarily disconnected from the deflecting circuit and the oscillator is adjusted to operate at the correct frequency. The variable condensers C_1, C_2 and C_3 are then adjusted until the nearest approximation to a saw-tooth wave is obtained. It will be understood that the capacity values for the condensers C_1, C_2 and C_3 have been calculated as previously described, and that the adjustments just referred to are for the purpose of making minor corrections or for obtaining a more desirable phase relation between the fundamental frequency and the harmonics. Next the damping circuit is connected across the deflecting circuit and the variable tap on the resistor is adjusted until the deflecting portion or charge line portion of the saw-tooth is substantially a straight line.

By employing a large amount of damping in the circuit, as is done in the circuit illustrated in Fig. 1, the production of a good saw-tooth wave is dependent to only a comparatively small extent on the phase relation between the several harmonics, the circuits x, y and z acting to hold up the impedance of the circuit at the lower frequency harmonics, whereby the desired impulse voltage can be forced across the coil L_0.

The choice of the series resonant point depends on several factors. For instance, for a given L/R ratio for the coils in the circuits x, y and z, as the series resonant points are placed closer to the next lowest parallel resonant point (that is, as the series resonant point of L_1 and C_1 nears the fundamental and that of L_2 and C_2 nears the second harmonic, etc.), the tendency is for the resonant impedance at the harmonics to become higher than the fundamental. As the series resonant point is shifted the other way, the fundamental tends to reach a higher resonant impedance than the harmonics. If the L/R ratio is about .001 and the fundamental frequency 10 kc., for nearly equal impedance at all harmonics, the series resonant point of L_1 and C_1 should be set about .34 of the way up from the preceding parallel resonant point; that is, if the fundamental is 10 kc., the series resonant point of L_1 and C_1 should be 13,400 cycles; L_2 and C_2, 23,400 cycles; L_3 and C_3, 33,400 cycles, etc. However, it is not always desirable to have the resonant impedance at each frequency the same, but to have the maximum impedance possible at each frequency, since the circuit is to be highly damped anyway.

It is to be noted that this type of circuit becomes inductive at all frequencies above the series resonant point of the last branch. Thus, it is possible to drive higher harmonics across the circuit, although it is only resonant to a few of the lower ones. In case this is done, it is best to set the series resonant points quite close (within 10%) to the next lowest harmonic frequency. This insures the highest possible effective inductance above the frequency of the last series resonant branch.

The method of driving the deflecting coil and associated resonant circuits consists in simply forcing an impulse wave across the network, which insures a saw-tooth current through the deflecting coil. Since the deflection of the cathode ray is proportional to the voltage across the deflecting coil divided by the square root of the inductance of the deflecting coil, as will be shown below, the advantage in employing tuned circuits lies in the use of a deflecting coil having less inductance than could be used without tuning. Another advantage is that, as previously mentioned, no saw-tooth component need be supplied to the grid of the output tube, and consequently the tube may be operated saturated and more output obtained therefrom.

Considering now the reason for the increase in deflection efficiency caused by increasing the impedance of the circuit, the deflection is proportional to the deflecting coil flux, the flux in turn being proportional to IN where I is the current flowing through the deflecting coil and N is the number of turns in the coil. Also $L=KN^2$ where L is the inductance of the deflecting coil and K is a constant. Then,

$$N=K'\sqrt{L}$$

Substituting for N, the deflection is proportional to

$$I(K'\sqrt{L})$$

Also $E=I2\pi fL$ where E is the voltage across the deflecting coil and f is the frequency of the sine wave or saw-tooth wave harmonic being considered. Then

$$I=\frac{E}{2\pi fL}$$

Substituting for I, the deflection is proportional to

$$\left(\frac{E}{2\pi fL}\right)(K'\sqrt{L})=K'\frac{E}{2\pi f\sqrt{L}}$$

By resonating the deflecting coil with associated resonant circuits, the quantity L can be made small while the voltage E is prevented from dropping to a low value, whereby the amplitude of deflection is increased.

In Fig. 2, I have shown another embodiment of my invention, in which the deflecting circuit is caused to resonate at the fundamental frequency of the saw-tooth wave and at its second, third, fourth and fifth harmonics. Like parts in Figs. 1 and 2 are indicated by the same reference characters. Except for the circuit adjustments, it will be noted that the only difference between the two circuits is that in Fig. 2 two additional series resonance circuits have been added to the deflecting circuit.

Below are listed the ratios between the inductance values and the condenser values for the circuit shown in Fig. 2, where W_0 equals $2\pi f$, f being the fundamental frequency of the saw-tooth wave:

Parallel resonance at W_0, $2W_0$, $3W_0$, $4W_0$, $5W_0$

$$\left.\begin{aligned} L_1C_1&=\frac{.56}{W_0^2}\\ L_2C_2&=\frac{.18}{W_0^2}\\ L_3C_3&=\frac{.09}{W_0^2}\\ L_4C_4&=\frac{.053}{W_0^2}\\ L_5C_5&=\frac{.035}{W_0^2}\end{aligned}\right\}\text{These relations determine the series resonant frequencies.}$$

$$\begin{aligned} L_1&=1.6207\,L_0 & C_1&=3.2260\,C_2\\ L_2&=1.7428\,L_0 & C_3&=.47538\,C_2\\ L_3&=1.8380\,L_0 & C_4&=.3023\,C_2\\ L_4&=1.6975\,L_0 & C_5&=.2788\,C_2\\ L_5&=1.2146\,L_0 & & \end{aligned}$$

In Fig. 3, my invention is shown applied to a deflecting circuit employing electrostatic deflecting plates indicated at **31**. Suitable means, indicated at **32**, is provided for producing a saw-tooth voltage wave which is impressed upon the input circuit of a non-distorting or Class A amplifying tube **33** which, in the circuit illustrated, is of the low impedance type.

The output circuit of the tube **33** is coupled through a blocking condenser **34** and a step-up transformer **36** to the deflecting plates **21**. The step-up transformer **36** is desirable in order to obtain sufficient voltage across the deflecting plates for satisfactory deflection. In order to obtain efficient action of the step-up transformer, the impedance of its windings should be high. However, if enough turns are put on the secondary winding to permit the use of a high impedance primary winding, there will be a large amount of distributed capacity across the secondary winding, with a resulting decrease in the efficiency of deflection.

In accordance with my invention, I wind the transformer **36** with the desired step-up ratio and with a sufficiently small number of turns in the secondary winding to keep the distributed capacity to a comparatively low value. The impedance of such a transformer will be high enough at the higher harmonics of a saw-tooth wave, but not at the fundamental frequency and the lower frequency harmonics. Accordingly, I shunt three resonant circuits, x, y and z, corresponding to the circuits x, y and z in Fig. 1, across the primary winding of the transformer. The three branch circuits x, y and z and the primary winding of the transformer **36** are adjusted in the manner described in connection with Fig. 1, to make the circuit resonant at the fundamental frequency of the saw-tooth wave and at its second and third harmonics. It will be noted that in this circuit the transformer primary corresponds to the coil L_0 in Fig. 1

In Fig. 4 I have shown my invention applied to a circuit for passing a non-sinusoidal current through an inductance coil **40**. Three series resonant circuits, **41**, **42** and **43**, are connected in parallel with each other and in series with the coil **40**. The circuit is preferably so designed that the coil **40** and the circuits **41**, **42** and **43** are series resonant at the fundamental frequency and at the second and third harmonics of the current passed through coil **40**. To make the circuit operate in this way, the series resonant circuit **41** is made resonant between the fundamental frequency and the second harmonic, the circuit **42** is made resonant between the second and third harmonics, and the circuit **43** is made resonant between the third and fourth harmonics. The correct condenser and inductance values are obtained by means of six simultaneous equations, as in the case of the circuit shown in Fig. 1.

If it is desired to pass saw-tooth current through the inductance coil **40**, the circuits **41**, **42** and **43** may be supplied with current from a low impedance output tube, operated Class A, which has a saw-tooth voltage wave applied to its grid, as in the circuit shown in Fig. 3. It will be understood that, in order to obtain a current through the coil **40** having a reasonably good saw-tooth wave form, it is necessary to so adjust the resonant circuits that the harmonics are of the proper relative amplitude and are in the proper phase. The proper amplitude and phase of the harmonics may be obtained by adjusting the values of the condensers and resistors in the series resonant circuits.

In some cases it may be desired to produce a flow of current through the coil **40** having strong second and third harmonics without regard to the wave form. Such a flow of current may be produced by applying to the grid of the low impedance output tube supplying the coil **40** and its associated resonant circuits, an impulse voltage such as that supplied to the grid of the output tube shown in Fig. 1.

Referring to Fig. 5, I have shown my invention applied to a circuit for producing a non-sinusoidal voltage across a capacitive load such as a condenser **50**. Since the reactance of such a load decreases with increasing frequency, it may be desirable to cause the condenser **50** to exhibit parallel resonance at a plurality of the higher harmonic frequencies. Tis result may be obtained by connecting the series resonant circuits **51**, **52** and **53** in parallel with the condenser **50** and in parallel with each other.

Assuming that the circuit is to exhibit parallel resonance at the fourth, fifth and sixth harmonics of a saw-tooth wave to be impressed across the condenser **50**, the circuit **51** may be made series resonant below the fourth harmonic, the circuit **52** may be made series resonant between the fourth and fifth harmonics, and the circuit **53** may be made series resonant between the fifth and sixth harmonics. To produce the desired saw-tooth voltage across the condenser **50**, a saw-tooth voltage may be impressed upon the grid of a low impedance output tube supplying the circuit **50**, **51**, **52** and **53**.

Referring to Fig. 6, a capacitive load, such as a condenser 60, may be made to series resonate at the fundamental frequency and at a plurality of harmonic frequencies of a non-sinusoidal current to be passed through the capacitive load. This may be accomplished by connecting the series resonant circuits 61, 62 and 63 in parallel with each other and in series with the condenser 60. The circuit 61 may be made series resonant below the fundamental frequency, the circuit 62 series resonant between the fundamental frequency and the second harmonic, and the circuit 63 series resonant between the second and third harmonics.

If the current through the condenser 60 is to have a saw-tooth wave form, it may be supplied from a low impedance output tube which has a saw-tooth voltage applied to its grid. As in Figs. 4 and 5, where no damping is provided the resonant circuits must be so adjusted that the harmonics have the correct relative amplitude and phase relations if a good saw-tooth wave is to be produced. As previously mentioned, however, in some cases the wave shape of the current or voltage is immaterial, it being required only that strong harmonics be present.

In the circuits shown in Figs. 4, 5 and 6, if it is desired to produce a saw-tooth current or saw-tooth voltage, the output tube is operated as a non-distorting or Class A amplifier and, as previously stated, a saw-tooth voltage is applied to its grid. If it is desired merely to obtain a current or voltage containing strong harmonics, the output tube may be operated Class C, with an impulse voltage applied to the grid.

From the foregoing description, it will be apparent that various other modifications may be made in my invention without departing from the spirit and scope thereof, and I desire, therefore, that only such limitations shall be imposed thereon as are necessitated by the prior art as set forth in the appended claims.

I claim as my invention:

1. A cathode ray tube deflecting circuit comprising an electric discharge tube having an input circuit and an output circuit, a deflecting coil through which it is desired to pass a saw-tooth current, said coil being coupled to said output circuit, means for making said deflecting coil exhibit parallel resonance at the fundamental frequency of said saw-tooth current and at at least one harmonic thereof, and means for impressing upon said input circuit a voltage recurring at said fundamental frequency and having the correct wave shape to produce said saw-tooth current.

2. The invention according to claim 1 characterized in that a damping circuit is connected in shunt to said deflecting coil.

3. In combination, an inductance coil through which it is desired to pass a current of non-sinusoidal wave form, means for impressing a voltage recurring at a certain frequency across said inductance coil, and a plurality of series resonant circuits connected in shunt to said coil, said series resonant circuits being so tuned with respect to said coil that they and said coil exhibit parallel resonance at said certain frequency and at at least one harmonic thereof.

4. The invention according to claim 3 characterized in that a damping circuit is connected in shunt to said deflecting coil.

5. A cathode ray tube deflecting circuit comprising an output tube having input and output circuits, a deflecting coil coupled to said output circuit, a plurality of series resonant circuits connected in shunt to said deflecting coil, and means for impressing voltage impulses periodically upon said input circuit to produce a flow of saw-tooth current through said deflecting coil, said series resonant circuits being so tuned that the circuit comprising said deflecting coil and said series resonant circuits is parallel resonant at a plurality of harmonics of said saw-tooth current.

6. In combination, a low impedance electric discharge tube having an input circuit and an output circuit, means for impressing voltage impulses periodically upon said input circuit, a deflecting coil through which it is desired to pass saw-tooth current, means for coupling said deflecting coil to said output circuit, and a plurality of series resonant circuits connected in shunt to said deflecting coils, one of said shunt circuits being tuned to a frequency lying between the fundamental frequency of said saw-tooth wave and the second harmonic of said wave, and another of said shunt circuits being tuned to a frequency lying between said second harmonic and the third harmonic of said wave, said shunt circuits also being so tuned with respect to said deflecting coil that the shunt circuits and the deflecting coil exhibit parallel resonance at said fundamental frequency and at said second harmonic.

7. The method of producing a flow of saw-tooth current through a deflecting coil which comprises impressing voltage impulses across said coil periodically and parallel resonating said coil at the fundamental frequency of said impulses and at at least one of their harmonics.

8. The method of producing a flow of saw-tooth current through a deflecting coil having an associated resonant circuit which comprises impressing voltage impulses across said coil periodically, parallel resonating said coil at a plurality of frequencies having a harmonic relation to the fundamental frequency of said impulses, and damping said coil and associated resonant circuit.

9. A cathode ray tube deflecting circuit comprising a low impedance electric discharge tube having an input circuit and an output circuit, a deflecting coil through which it is desired to pass a saw-tooth current, said coil being coupled to said output circuit, means for making said coil exhibit parallel resonance at the fundamental frequency of said saw-tooth current and at a plurality of harmonics thereof, and means for driving said tube from a condition of plate current saturation to plate current cut-off at regularly recurring intervals, said intervals recurring at the rate of said fundamental frequency.

10. In combination, a reactive load, means for impressing upon said load a voltage recurring at a certain fundamental frequency, and a plurality of series resonant circuits connected in parallel with each other, one of said resonant circuits being series resonant at a frequency between said fundamental frequency and the first harmonic thereof and another of said resonant circuits being series resonant at a frequency between said first harmonic and the second harmonic of said fundamental frequency, said series resonant circuits being so coupled to said reactive load and being so tuned that said load and said series resonant circuits resonate as a whole at said fundamental frequency and at said first and second harmonics thereof.

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