

April 25, 1939.

L. M. CRAFT

2,155,404

AMPLIFIER CIRCUIT

Filed Dec. 26, 1935

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FIG. 1.

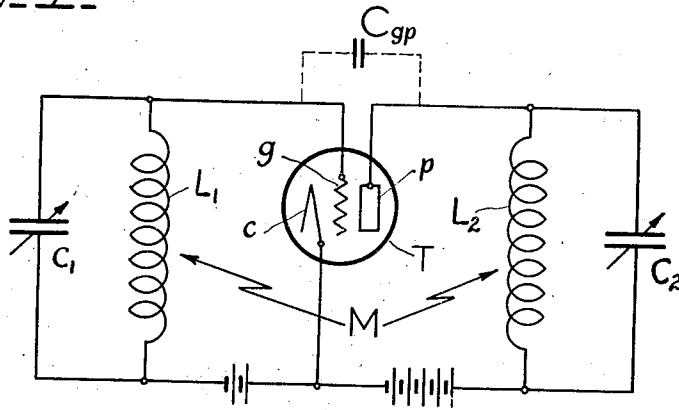


FIG. 2.

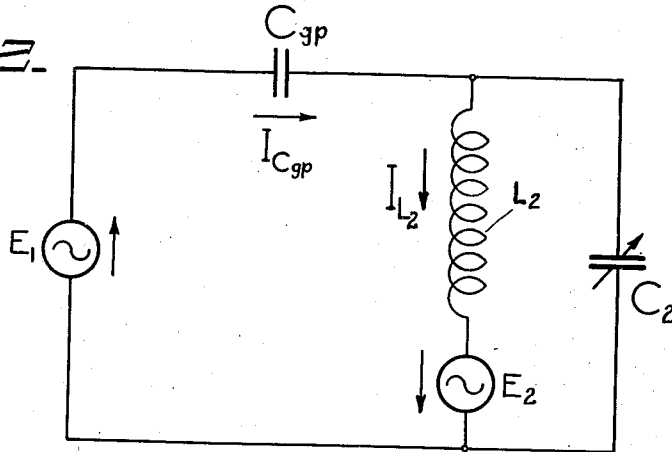
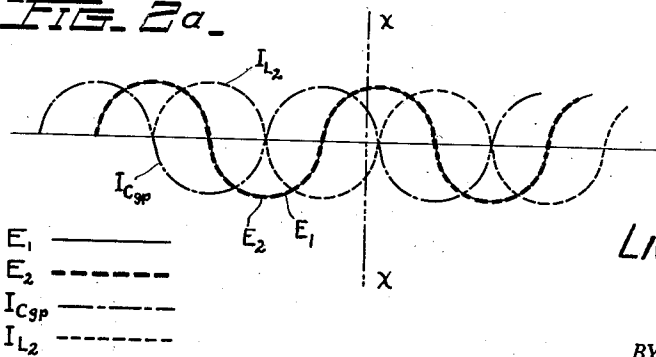


FIG. 2a.



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FIG. 3.

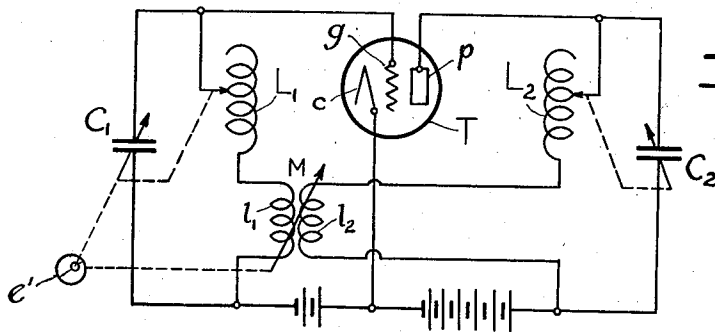
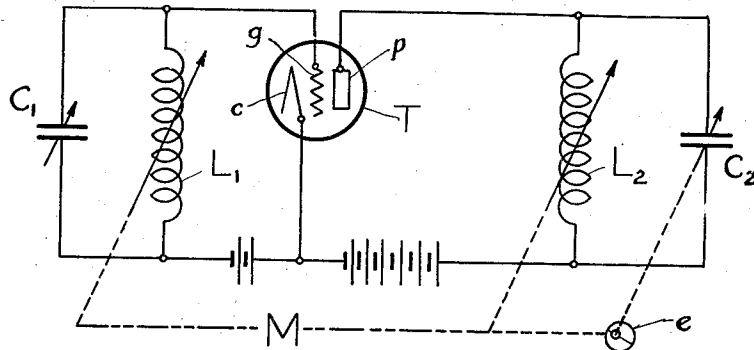
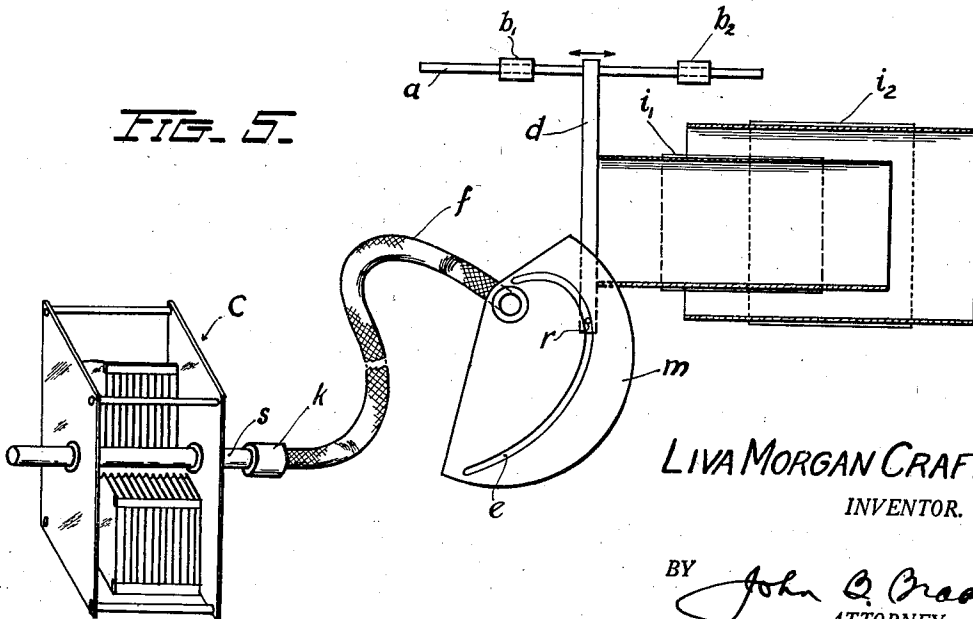


FIG. 4.

FIG. 5.



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2,155,404

AMPLIFIER CIRCUIT

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Application December 26, 1935, Serial No. 56,266

1 Claim. (Cl. 179—171)

My invention relates broadly to electrical amplifier circuits and more particularly to an arrangement of amplifier circuit for eliminating or reducing retroactive currents due to capacity coupling between electrodes of the electron tubes.

One of the objects of my invention is to provide means for overcoming or neutralizing the effect of capacity coupling between electron tube electrodes to the end that a greater amplification of input power may be obtained without resulting instability of operation.

It is a well known fact that in the three element vacuum tube, such coupling cannot be avoided due to the mutual capacity of the elements of the structure. According to my invention, I induce a voltage in the output circuit of the tube due to mutual induction between the input and output circuits in such a manner as to compensate for the current which flows between the grid and plate due to this mutual capacity.

Another object of my invention, therefore, is to provide means for inducing a voltage in the plate circuit of a three-electrode amplifier tube to produce a current in opposition to the current passed by the inter-electrode grid-plate capacity in the amplifier tube, whereby the effect of the grid-plate capacity coupling is neutralized.

A further object of my invention is to provide means for inducing a voltage in the plate circuit of an amplifier tube from a current in the grid circuit by mutual induction, the resulting current in the plate circuit being effective to neutralize the current due to the grid-plate capacity coupling in the amplifier tube.

Still another object of my invention is to provide inductances in the grid and plate circuits of a three electrode amplifier tube coupled in such a manner that voltage induced in the plate inductance is connected with the plate electrode in the same polarity as the signal voltage impressed upon the grid electrode, that is, in a counter-regenerative sense; the current resulting from the induced voltage being effective to neutralize the current due to the grid-plate capacity coupling in the amplifier tube.

A still further object of my invention is to provide means for varying the mutual inductance of inductances connected in the plate and grid circuits of an electron tube as set forth in the preceding paragraph, the mutual inductance being varied simultaneously with the tuning of the plate or the grid circuit, whereby the neutralization is complete at all frequencies received.

My invention will be more fully understood

from the specification hereinafter following by reference to the accompanying drawings, in which:

Figure 1 is a schematic circuit diagram of a three element vacuum tube connected as an amplifier with mutual inductance between input and output circuits in accordance with my invention; Fig. 2 is a simplified diagram of the impedance elements of the alternating current network illustrated in Fig. 1; Fig. 2a is a theoretical graph employed in connection with Fig. 2 to illustrate the theory of operation of the system of my invention; Fig. 3 is a circuit diagram of a modified form of my invention; Fig. 4 is a circuit diagram of a further modified form of my invention; and Fig. 5 illustrates one form of mechanism which may be employed in connection with the system shown in Fig. 3 or Fig. 4, for varying the inductive relation of a pair of inductance coils.

The circuit arrangement of my invention may be applied to amplifiers having various types of input circuits, as, for example, an untuned transformer secondary, or condenser feed to grid with means for supplying proper bias. I may use a tuned circuit C_1-L_1 connected to the input of the amplifier as shown in Fig. 1 with advantage. Inductance L_2 and condenser C_2 form the output circuit, with mutual inductance M between input and output, with a coefficient of coupling substantially less than unity and in a positive sense. By coupling in a positive sense, I mean that species of coupling between the two coils which, if acting alone, would cause the plate p and grid g to be at the same polarities with respect to the cathode c of the amplifier electron tube T . The grid-plate inter-electrode capacity is represented at C_{gp} in Figs. 1 and 2.

If a current I_1 is assumed flowing in L_1 , then referring to Fig. 2, E_1 is equal to $I_1\omega L_1$ and

$$E_2 = -I_1\omega M,$$

where E_1 and E_2 are the voltages acting around the circuit in a clockwise direction. Assuming temporarily that C_2 is replaced by a short circuit, the current through the short circuit due to the voltage E_1 will be

$$I_{C_{gp}} = E_1\omega C_{gp} = I_1\omega^2 L_1 C_{gp}$$

which leads E_1 90° in phase. Also, the current through the short circuit due to the voltage E_2 will be

$$I_{L_2} = \frac{E_2}{\omega L_2} = \frac{I_1 M}{L_2}$$

which lags E_2 90° in phase. The voltages E_1 and E_2 are 180° out of phase due to the fact that E_2

is generated by mutual induction from E_1 . According to my invention, however, the terminals of the inductance L_2 are so connected in circuit, in relation to the voltage E_1 , that, as set forth above, the same polarity is applied to the grid and plate electrodes. Referring to the assumed short circuit across C_2 , the polarities of the applied voltages E_1 and E_2 , are, therefore, alike; but because of the fact that the current $I_{C_{gp}}$ leads E_1 by 90° and the current I_{L_2} lags E_2 by 90° , the currents produced by the two voltages are in opposition.

The current in the short circuit, then, is $I_{C_{gp}} - I_{L_2}$, and will be zero when $I_{C_{gp}} = I_{L_2}$, or $M = \omega^2 C_{gp} L_1 L_2$.

$\omega = 2\pi$ times the frequency of I_1 .

The above description can perhaps be better understood by reference to Fig. 2a which indicates theoretically the phase relations of the voltages and currents considered with respect to the assumed short circuit, the curve representing each being clearly designated on the drawings, in connection with Fig. 2a. Line $x-x$ gives, at its intersection with the several curves, theoretical instantaneous values of the various currents and voltages, and indicates that the currents $I_{C_{gp}}$ and I_{L_2} , as represented, are equal and flowing in opposite directions. The resultant current, or that which would flow in the short circuit assumed, is, therefore, zero.

As there will be no current in the short circuit, it may be replaced by any value of C_2 and no voltage will appear across it and no circulating current flow in L_2-C_2 . This neutralization is complete at only one frequency but gives a workable amplifier over a two to one frequency range.

In order to increase the effectiveness of the neutralizing system of my invention over a wider frequency range, an arrangement such as that shown in Fig. 3 may be employed. The circuit illustrated diagrammatically in Fig. 3 is substantially identical with that shown in Fig. 1 and comprises an input circuit including inductance L_1 and condenser C_1 connected with the grid g , and an output circuit including inductance L_2 and condenser C_2 connected with the plate p , of the amplifier electron tube T which also includes the cathode c . The inductances L_1 and L_2 are coupled, as in the circuit shown in Fig. 1, with a mutual inductance of M , which, however, in the system illustrated in Fig. 3, is variable and controlled simultaneously with the tuning of the output circuit through the action of a cam element e . From the equation $M = \omega^2 C_{gp} L_1 L_2$, where $\omega = 2\pi f$, it is clear that if the mutual inductance M is varied in proper proportions as the frequency f is varied, neutralization is effected over the entire frequency range covered. Also, according to my invention, the mutual inductance may be varied simultaneously with the tuning of the input instead of the output circuit.

In Fig. 4, I indicate a further modification of the system of my invention wherein portions only of the inductance in the input and output circuits are coupled. Inductances l_1 and l_2 are coupled, with mutual inductance M , and the inductance relation thereof is variable in connection with the variation of the tuning of the input circuit (or the output circuit) through the cam element e' . The tuning in the modified circuit of Fig. 4, is effected by varying both the inductance and the capacitance of the circuit: L_1 and

C_1 in the input circuit; and L_2 and C_2 in the output circuit.

Fig. 5 illustrates a mechanism adaptable to the systems shown in Figs. 3 and 4 for varying the inductive relation of a pair of coils in connection with a tuning element such as a variable condenser. The mechanism shown in Fig. 5 comprises a pair of inductance coils i_1 and i_2 arranged in variable inductive relation, the coil i_1 being movable with respect to the coil i_2 . The coil i_1 is mounted on a support d , connected with a bar a which is slidably mounted in supporting guides b_1 and b_2 . At the lower end of the support d is a pin or roller r engaging the eccentric slot e in the rotatable element m . A variable tuning condenser C has its shaft s connected through a coupling k and a flexible drive shaft f to the rotatable element m , so that as the tuning condenser is varied the inductive relation of the coils i_1 and i_2 is varied in accordance with the contour of the eccentric slot or cam slot e . It is noted from the equation $M = \omega^2 C_{gp} L_1 L_2$ that M must vary in proportion to the square of the frequency; and the contour of the eccentric slot e is devised to provide for such relative variation of the mutual inductance. The slot e shown in Fig. 5 is merely illustrative of the position and function of the slot in the mechanism, and is not an accurate trace of the particular form of slot adaptable to the system of my invention.

The circuit arrangement of my invention has numerous advantages among which are the inexpensive assembly possible by use of the circuit and the simplicity of the circuit. As it is ordinarily necessary to shield the input and output circuits, this is eliminated by using this coupling in a predetermined manner. The circuit of my invention also has the advantage that there is no tapping of the coils required, nor are neutralizing condensers necessary. Also, there is less loss in the circuits due to lack of shielding and due to the fact that coils having opposite ends at high radio frequency potentials from cathode and ground have larger dielectric losses than single ended coils.

My invention extends to all arrangements in which there is mutual inductance between the input circuit and the output circuit in such a manner as to secure the advantages already stated and explained. The invention is not limited to the specific circuit details illustrated in the accompanying drawings, as mutual induction may occur only between portions of L_1 and L_2 , as suggested in Fig. 4.

The circuit arrangement of my invention is particularly adapted for eliminating or substantially reducing electrode capacity effects in transmitting amplifiers without the employment of auxiliary neutralizing circuits which add cost and complication to the equipment.

While I have described my invention in one of its preferred embodiments, I desire that it be understood that modifications can be made and that no limitations upon my invention are intended except as may be imposed by the scope of the appended claim.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

An electron tube amplifier circuit comprising an electron tube having anode, control grid, and cathode electrodes with inherent capacity (C_{gp}) between said grid and plate electrodes, a tunable input circuit connected with said control grid and cathode electrodes, a tunable output circuit connected with said anode and cathode elec-

trodes, variable capacitive elements in said input and output circuits for tuning said circuits inductive elements (L_1 and L_2) in said input and output circuits providing substantially the entire inductance in said circuits and being arranged with mutual inductance therebetween, and means operative in conjunction with one of said tunable circuits for varying said mutual inductance, said

means being adapted to cause the coefficient of said mutual inductance (M) to vary as the square of the frequency (f) to which said tunable circuit is tuned, in accordance with the relation $M = (2\pi f)^2 C_{gp} L_1 L_2$, said coefficient of mutual inductance being substantially less than unity and effective in a positive, non-regenerative sense.

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