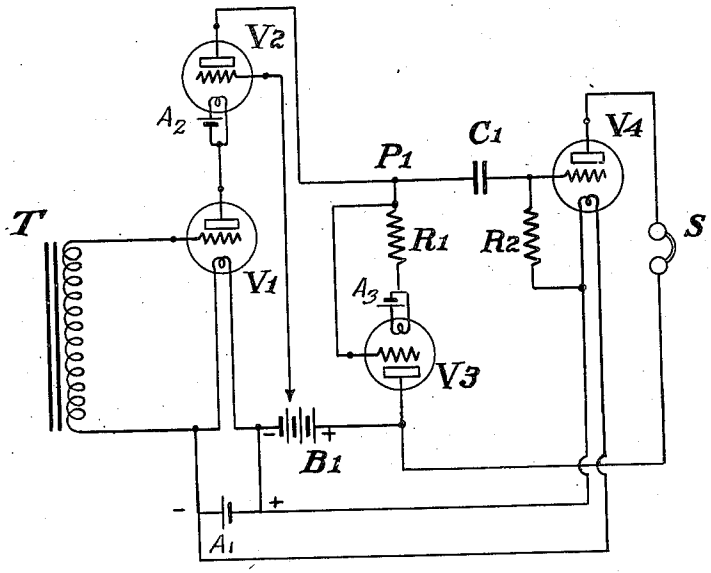
Nov. 8, 1932. O. T. FRANCIS 1,886,386

RADIO

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Inventor:
Oliver T. Francis,
by Spear, Middleton, Donaldson + Hall
Attys.

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OLIVER T. FRANCIS, OF QUANTICO, VIRGINIA

RADIO

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This invention relates to amplifier circuits, and more particularly to the means of coupling between the units thereof.

One object of this invention is to provide a new means of coupling, which I may designate as "direct coupling," and which shall allow for more gain in amplification per stage than is possible with present day means.

Another object is to provide in the output circuit of a vacuum tube amplifier a variable load which shall vary in accordance with some predetermined factor such as the current through the same or the grid voltage impressed on said vacuum tube amplifier or a combination of the two, which shall allow for greater utilization of the plate voltage impressed on said circuit and which shall by limiting the current flowing in said circuit allow for greater voltages to be impressed on the same than is possible by present day means. It is well known that with present day resistance coupled amplifiers that it is possible to utilize but fifteen percent of the B battery voltages applied to the circuit. With the circuit herein described practically the entire B battery voltage is utilized. Where the majority of amplifiers utilize about ten milliamperes of current per stage the circuit herein described utilizes but one milliampere. This results not only in a saving of B batteries but in the much more important factor of allowing greater voltages to be impressed on the plates of the tubes in the circuit without injury to the same, as less energy will be dissipated in them with one milliampere flowing in the circuit than if ten milliamperes is flowing through them.

Another object of this invention is to provide a circuit where the distortion shall be less than in present day circuits. It is well known that resistance coupled amplifiers are as free from distortion as any amplifiers in common use. The cause of distortion in them is the fact that small coupling condensers of the order of one-tenth of a microfarad or smaller must be utilized, and that large grid leaks of the order of a megohm must also be used for economy of the dynamic variations in potential. This causes distortion due to the impedance of the small coupling condensers to the lower frequencies, and also due to the fact that when strong signals are being received the grid of the tube to which this condenser is connected becomes negative because of the *IR* drop through the magohm resistance. By alleviation of the necessity for this economy of dynamic variations, capacities of much higher value can be used and impedances of lower value can be used as grid leaks.

Another object of this invention is to allow for economy in set construction. A casual observation of the circuit herein described will show that no expensive transformers or output tubes are necessary as sufficient amplification can be obtained without the aid of either.

With these and other objects in view the features of the device can best be understood by a reference to the following description in connection with the drawing which shows diagrammatically an embodiment of the invention.

The figure shows a multi-stage amplifier which illustrates one means of using a vacuum tube in the input and output circuit of a second vacuum tube.

Referring to the figure we find the vacuum tube V1 coupled to the previous stage of amplification through transformer T in accordance with the ordinary means of transformer coupling in common use today. A1 heats the filament of V1 and V4; A2 and A3 heat the filaments of V2, and V3 respectively. B1 furnishes plate current for both of the stages of amplification illustrated. V1 is connected in the input and the output circuit of V2. The input circuit of V2 may be traced as follows: Cathode of V2, anode of V1, cathode of V1, negative terminal of B1, point where arrow head makes contact with B1, grid of V2. The output circuit may be traced as follows: Anode of V2, point P1, resistance R1, cathode of V3, anode of V3, positive terminal of B1, negative terminal of B1, cathode of V1, anode of V1, cathode of V2. Since the anode and cathode of V1 are in the cathode to control electrode path of V2, a variation in voltage between the anode and cathode of V1 will cause the same variation in voltage between

the cathode and control electrode of V2. V3 is connected in the output circuits of V1 and V2, as a vacuum tube choke. This tube, V3, has a very high impedance to the effective value of the alternating component of the plate current of vacuum tubes V1 and V2. V4 is coupled to this stage thru condenser C1 by vacuum tube choke V3. In the output circuit of V4 is connected translating device S.

The principles involved in this circuit can best be brought out by an analytical procedure similar to that used by Morecroft "Principles of Radio Communication" page 944. $Eg1$, $Eg2$, $Eg3$, $Eg4$, equals the effective value of alternating voltage impressed upon the grids of V1, V2, V3, V4, respectively.

$Ep1$, $Ep2$, $Ep3$ equals the effective value of alternating voltage between the anode and cathode of V1, V2, V3, respectively.

Ip equals the effective value of alternating component of plate current of V1, and V2.

μ equals the amplification constant (that is the mu) of each and every tube used in the diagram.

$Rp1$, $Rp2$, $Rp3$, equals the a. c. plate filament resistance of V1, V2, V3, respectively.

$R1$ equals the value of $R1$ in ohms.

RL equals the a. c. resistance of the load which in the figure is $R1$ plus $Rp3$.

The following equations may then be written for the figure.

$$Ip = \frac{(\mu Eg1 + \mu Eg2)}{Rp1 + Rp2 + RL}$$

$Eg2$ equals $Ep1$ and since RL is very large, $Ep1$ approaches its maximum possible value of $Eg1$ and we may substitute $\mu^2 Eg1$ for $\mu Eg2$.

$$Eg4 = Ip\,RL = \frac{(\mu Eg1 + \mu^2 Eg1)\,RL}{Rp1 + Rp2 + RL}$$

Since RL is large $Rp1$ plus $Rp2$ can be neglected and

$$\frac{Eg4}{Eg1}$$

approaches its maximum of mu plus mu squared.

In the above calculations the resistance of the load RL has been assumed to be so large that resistances $Rp1$, $Rp2$ can be neglected. In order for this assumption to be justified the grids of vacuum tube generators V1, V2, must not be allowed to assume an excessive negative potential or Rp1, Rp2 will become so large that the efficiency of the circuit illustrated will be very greatly lowered as can be easily seen by reference to the above equations. The grid of V2 has therefore been connected to B1 at such a point as to tend to place a positive bias on the grid of V2 in order to nearly neutralize the negative bias impressed thereon by the direct current IR drop across V1, and thereby keep the alternating current resistance of vacuum tube generator, V2, low.

It will be understood that the filaments of V2 and V3 may be heated either by a separate source of "A" battery or by the use of tubes which have a separate heating element.

It is apparent that while vacuum tubes are shown as the coupling unit that any resistance which has the characteristic of increasing its value as a current through same increases, such as a tungsten lamp of sufficiently small filament, could be used as the variable impedance coupling unit.

It is further apparent that the general principles herein disclosed may be embodied in many other organizations widely different than those illustrated without departing from the spirit of the invention as defined in the following claims.

It will be understood that where vacuum tube amplifier is referred to in the claims it will include within its meaning thermionic tube amplifier or any equivalent tube amplifier.

I claim:

1. In an electric circuit, a vacuum tube having an input and an output circuit, a source of voltage for said output circuit, means for supplying impulses to said input circuit, said means comprising a second vacuum tube having an anode, a cathode and a control electrode, said anode and said cathode being connected in said input and said output circuit and means for varying the potential of said control electrode.

2. In a stage of vacuum tube amplification a plurality of vacuum tubes each having an anode, a cathode, a control electrode, and a common output circuit, a source of voltage and a load connected in said output circuit, the alternating current anode-cathode resistances of said tubes being connected in series, means for impressing a variable voltage between the cathode and control electrode of a first of said tubes, means for impressing the effective value of anode to cathode alternating current voltage of said first tube between the cathode and control electrode of a second of said tubes, and means for impressing the sum of said anode to cathode alternating current voltages on said load, said alternating current voltages being of the same phase.

In testimony whereof, I affix my signature.

OLIVER T. FRANCIS.