Sept. 4, 1928. 1,683,083

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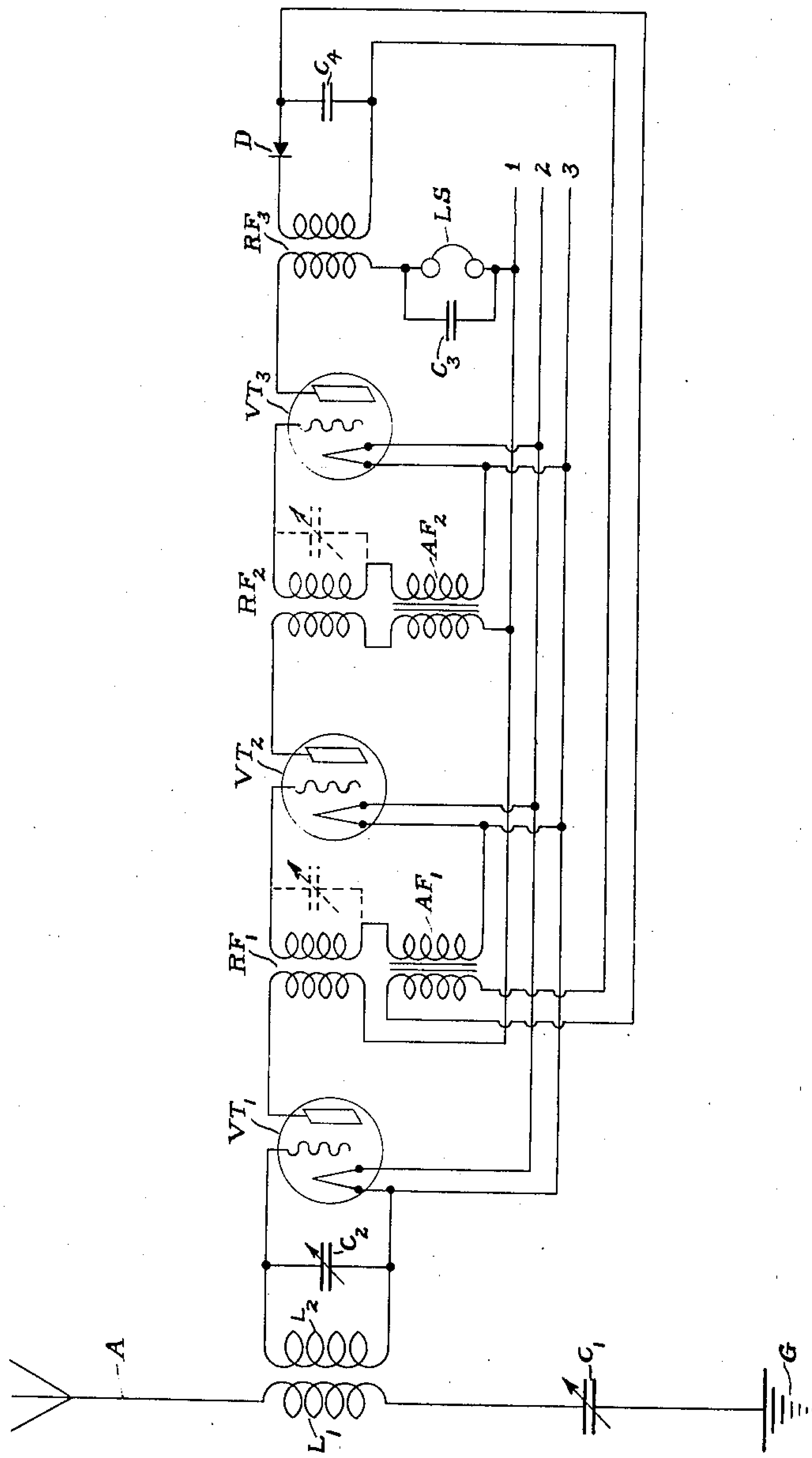
Filed June 22, 1923



E H Loftin Inventor

Patented Sept. 4, 1928. **1,683,083**

UNITED STATES PATENT OFFICE.

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AMPLIFIER OF ELECTRICAL CURRENTS.

Application filed June 22, 1923. Serial No. 647,027.

While my invention relates generally to amplifiers of electrical currents, a particular object is the simultaneous amplification of high frequency and low frequency electrical currents using the same amplifying devices and circuits in whole or in part for the double function.

Another object of my invention is to obtain a high order of amplification using a minimum of apparatus.

A further object is to obtain stable operation of multiple stage amplifiers, particularly in those types in which the same amplifying devices and circuits are used for radio and audio frequency amplification, through avoiding production of oscillations within the circuits or regenerative effects to the point of distortion, and to do so without the use of screened compartments for the several stages of amplification, and without the use of potentiometer stabilizers, neutralizers and like complications.

A further object is avoiding the use of radio frequency by-passes around audio frequency devices (such as transformers) hitherto considered essential, and taking advantage of a beneficial effect on amplifier circuits thereby secured.

Another object is to provide for the use of loud speaking devices as translating elements without additional amplifying devices for audio frequency amplification.

That part of my system which has to do with using the same amplifying devices and circuits for the double function of amplifying radio frequency and audio frequency currents is in general accomplished in a manner illustrated in U. S. Patent 1,087,892 of February 17, 1914, to Schloemilch, et al, Figure 4, but I do not employ by-pass condensers such as that illustrated at S in shunt with transformer winding O in the input circuit. I also refer to British Patent 131,092, of August 21, 1919, and point out that I do not use condensers such as 12 and 13 in shunt with transformer winding 9. Also to British Patent 132,668 of September 25, 1919, further pointing out that I do not use condensers such as 17 and 18 in shunt with transformer 13 and 20 and 21 in shunt with transformer 14.

My invention will be best understood by reference to the figure in the accompanying drawing in which I illustrate 3 three-electrode thermionic vacuum tubes having circuit connections for amplifying, the three tubes being employed in tandem as radio frequency amplifiers, indicated by reference designations VT_1, VT_2 and VT_3, and two of the tubes, namely VT_2 and VT_3, being further employed as amplifiers of audio frequency currents. The system is illustrated as employed to amplify radio signals collected on the antenna A having ground connection G, and tuning elements inductance L_1 and variable capacity C_1. The collected signals are transferred to the amplifier through the secondary circuit having inductance L_2 coupled to inductance L_1 and variable capacity C_2. A source of energy for the plate circuits of the vacuum tubes is impressed across the lines 1 and 2 so that line 1 is the positive side of the source. A source of energy for heating the filaments for the vacuum tubes is impressed across the lines 2 and 3, and by making the line 3 the negative side of this source a negative potential or bias is obtained on the grids of the several vacuum tubes, thereby causing them to function as amplifiers. A rheostat may be inserted in either of the lines 2 or 3 to control the amount of heating of the filaments of the vacuum tubes. RF_1, RF_2 and RF_3 are radio frequency transformers linking the several stages of the system together to transfer radio frequency currents from one to the other. AF_1 and AF_2 are audio frequency transformers to impress audio frequency currents on the system and pass them from one stage to another. D is any suitable form of rectifying device to aid in reducing modulated radio frequency currents to low frequency currents characteristic of the modulations, and may be a crystal rectifier, a vacuum tube rectifier, an electrolytic rectifier, or other well known forms. C_4 is a condenser in shunt with the circuit containing the detector D, not entirely essential to the system but which I have found to have a stabilizing effect on the action of a crystal detector. LS is a loud speaking or other translating device for translating the low frequency currents into corresponding characteristic audible sounds. C_3 is a condenser in shunt with the loud speaking or translating device LS to by-pass radio frequency currents around the usual high impedance encountered in such devices.

It will be noted that the secondary winding of audio frequency transformer AF_1 and the primary and secondary windings of the audio frequency transformer AF_2 are not shunted with condensers to provide low impedance paths for radio frequency currents around these devices, as is done in the art heretofore referred to; that is, these devices offer their natural impedances to the currents.

While I have illustrated the radio frequency and audio frequency transfer devices as transformers, it is not essential to the invention that they be of this form, as auto transformers or other suitable forms may be used; however, I prefer the transformer type as it simplifies the method of connection to prevent impressing the high potential of the plate circuits on the grids of succeeding tubes. The transformers I show are of the band type; that is, they are designed to amplify over a band of frequencies rather than being sharply resonant to a particular frequency, though in a special design or by adjustment where extreme selectivity is desired transfer elements sharply resonant to one frequency could be employed, as indicated by the variable condensers shown in dotted lines connected in a well known manner across the secondary winding of transformers RF_1 and RF_2. The operation of the system is as follows:

Radio frequency currents modulated at audio frequencies are collected on the antenna A and transferred to the amplifying system through the secondary circuit containing inductance L_2 and capacity C_2. The radio frequency currents are then amplified step by step by the vacuum tubes VT_1, VT_2 and VT_3, the currents being transferred from stage to stage by the radio frequency transformers RF_1 and RF_2. The currents having undergone three stages of amplification are passed into detector circuit containing the detector D through radio frequency transformer RF_3. In the audio frequency transformer AF_1 in the detector circuit the restified currents are converted into audio frequency currents characteristic of the modulations of the radio frequency current. These low frequency currents are then impressed upon vacuum tube VT_2 through audio frequency transformer AF_1, and thence to vacuum tube VT_3 through audio frequency transformer AF_2, and having undergone two stages of audio frequency amplification are translated in the loud speaking devices LS.

The radio frequency transformers do not offer any appreciable impedance to the flow of audio frequency electrical currents as the windings have few turns of wire, or wire of little length, compared to the windings of the audio frequency transformers, and in many cases do not have iron cores. In those radio frequency transformers having iron cores the iron employed has such magnetic characteristics and physical dimensions as not to appreciably influence the impedance to audio frequency currents. On the other hand the impedance of the audio frequency transformer windings to radio frequency currents is substantial, such windings consisting of a large number of turns of wire, or wire of great length, having iron cores. The distributed capacity of the windings permits passage of radio frequency currents, but this capacity not being large considerable capacitive impedance to such currents is had, and I have found this capacitive impedance of great value in restraining or holding down any tendency of the circuits to oscillate, or to distort through regeneration, which tendency comes about through reactive effects of the various circuits upon each other through the coupling between plate and grid circuits due to internal capacities of the vacuum tubes, and is also particularly strong in an arrangement of this kind where a feedback is introduced through the return connection for audio frequency currents. It has heretofore been considered necessary to provide by-pass condensers around the windings of the audio frequency transformers for the passage of radio frequency curents, thus rendering the effective capacitive impedance of these devices to radio frequency currents nonappreciable. But such provision destroys the utility of these windings as choking devices for oscillations and regeneration to a point of distortion.

While, by leaving out radio frequency bypasses, I render the impedance of the audio frequency devices to radio frequency currents large, yet I do not materially decrease the amplifying ability of the system. In the first place, while the radio frequency impedance is made relatively large as compared to a by-pass device, it still remains considerably less than the impedance of the radio frequency transformer to radio frequency currents, as the radio frequency transformer may be constructed or adjusted to be exactly in resonance with these currents, or nearly so in the band type of transformer, and a resonant or near resonant circuit offers an extremely high impedance to resonant currents, probably of the order of a hundred thousand ohms, while the audio frequency transformer may offer an impedance of the order of thousands of ohms. That is, by increasing the impedance of the audio frequency device from practically nothing to some thousands of ohms, I have not increased the overall impedance of the resonant input circuit more than probably ten per cent.

That the use of the unmodified capacitive impedance of the audio transformers prevents oscillation and limits regeneration is appreciated from analyzing the inherent actions and reactions that inevitably obtain in the system disclosed and taking into consideration well-known effects in such systems.

Considering tube VT_2, for instance, and its input and output circuits, if the transformers RF_1 and RF_2 are of the band type they do not have sharply defined resonance peaks, but nevertheless exhibit resonant characteristics, and therefore react inductively for current frequencies on one side of resonance and capacitively for current frequencies on the other side of resonance. Since an inductively reacting output circuit produces a feed back through the plate-to-grid capacity of a three-electrode vacuum tube that is favorable to regeneration or oscillation production, it is obvious that when the system is adjusted or used at frequencies on the inductively reacting side of the natural resonant frequency of transformers RF_1 and RF_2, as by adjusting tuning condenser C_2, there is a tendency for tube VT_2 to cooperate with its input and output circuits to produce oscillations. However, the reaction of audio frequency transformer AF_2 to radio frequency currents is always capacitive and, by not shunting the winding with condensers, the capacitive reaction is maintained substantial. The result is that though the system is used under conditions where an inductive output circuit reaction is produced which, acting unmodifiedly, would produce oscillation, there is always at hand a substantial capacitive reaction from the audio transformer to modify or neutralize the inductive reaction, and this reaction is therefore not effective to produce oscillations. If the capacitive reaction of the audio transformer is substantially reduced, as by shunting with a condenser, as has been the practice, the troublesome inductive reaction of the radio frequency transformer is not sufficiently overcome to prevent oscillation if the tubes are sufficiently energized to be useful amplifiers.

By not shunting the secondary winding of audio frequency transformer AF_1 with a condenser its capacitive reaction to radio frequency currents is maintained large also, and this capacitive reaction brings about a substantial change of phase of the input circuit currents, with the result that if all of the inductive reaction of the output circuit is not neutralized, permitting a residual reaction acting through the grid-to-plate capacity favorable to regeneration, the dephased input circuit currents assist in reducing the effectiveness of this feed back.

The effect of substituting tunable circuits for the band transformers is to make the resonant peaks movable throughout the whole range of tuning, so that the troublesome output circuit inductive reactions can be produced anywhere within the range of tuning provided, but since the reactions of the audio transformers are capacitive throughout any usual range of radio frequency operation, the capacitive reactions are always present to modify the effects of the inductive reactions, and thus prevent oscillations throughout a wide range in a variable tunable system.

I have constructed the identical combination illustrated in the figure without any precautions whatsoever as to shielding or screening one stage of amplification from another, without any precautions as to spacing of the transformer elements, wiring and other parts, and without any shield for the loud speaker leads, and have found the arrangement extremely efficient and effective and absolutely stable and uninfluenced by movement of hands about the various parts, or movement of the loud speaker and its leads in the immediate vicinity of amplification circuits. I have also found the reproduction of voice and music to be totally without distortion.

Having described my invention I claim:—

1. A stage of amplification in an amplifier system including a three-electrode vacuum tube, an input circuit having a portion tuned to currents above audibility, means for impressing currents above audibility on said tuned portion, means associated with said input circuit for simultaneously impressing substantially lower frequency currents on said input circuit, an output circuit, means for transferring said currents above audibility from said output circuit, and means for simultaneously transferring said lower frequency currents from said output circuit including a coil in said output circuit so connected as to unmodifiedly offer its natural impedance to the flow of said currents above audibility in said output circuit.

2. A stage of amplification in an amplifier system including a three-electrode vacuum tube, an input circuit having a portion tunable to high frequency electrical currents, an output circuit having an associated reactance system adapted to be tuned in consonance with the tunable portion in said input circuit, thereby producing high frequency reactions through the internal capacity of said tube in phase with currents in said input circuit, a coil in said plate circuit adapted through having high inductance and low distributed capacity to substantially alter the high frequency reaction of said output circuit, and a conductive impedance in said input circuit in series with said tunable portion.

3. A stage of amplification in an amplifier system including a three-electrode vacuum tube, an input circuit including a circuit tunable to high frequency currents, an output circuit having an associated circuit tunable in consonance with said tunable circuit in said input circuit, and means in both said input and output circuits having sufficient capacitative reactances to effectively alter the reactions in said circuits of said tunable circuits to said high frequency currents, whereby oscillation by reason of reaction through the internal capacity of said tube is prevented.

4. A stage of amplification in an amplifier system including a three-electrode vacuum

tube, an input circuit including a circuit tunable to high frequency currents, an output circuit having an associated circuit tunable in consonance with said tunable circuit in said input circuit, and audio frequency transformers associated with said input and output circuits so connected therein that their capacitative reactances to high frequency currents alter the reactions of said tunable circuits to sufficient degree to prevent oscillation by reason of reaction through the internal capacity of said tube.

5. A stage of amplification in an amplifier system including a three-electrode vacuum tube, an input circuit including a circuit tunable to high frequency currents, means for impressing high frequency currents on said tunable circuit, means for simultaneously impressing audio frequency currents on said input circuit, an output circuit having an associated circuit tunable to high frequency currents in consonance with the tunable circuit in said input circuit, and an audio frequency transformer connected in said output circuit to transfer amplified audio frequency currents therefrom, and so connected as to unmodifiedly offer the whole of its inherent capacitative impedance to amplified high frequency currents in said output circuit, whereby regenerative reaction through the internal capacity of said tube is limited to sufficient degree to prevent oscillation.

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