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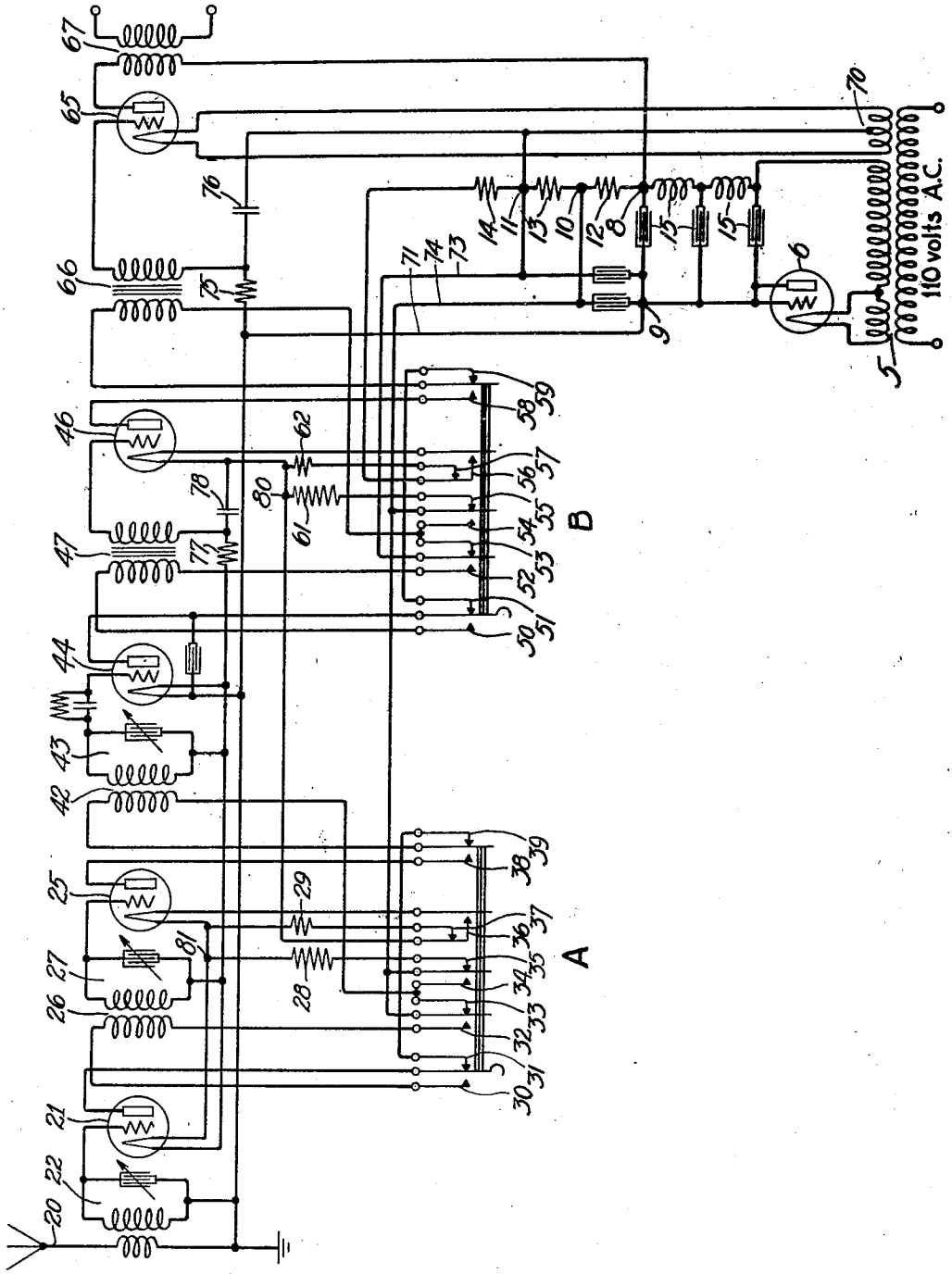

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VACUUM TUBE CIRCUITS

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This invention relates to vacuum tube circuits and more particularly to multi-stage amplifier circuits in which vacuum tubes are employed in the various stages.

One of the objects of this invention is to provide means for regulating the degree of amplification of a multi-stage amplifier set for signals impressed thereon.

It is well-known in the art that weak currents or signals may be amplified to any desired degree by impressing them on a plurality of vacuum tube amplifiers arranged to work into each other by suitable circuit connections. In employing such a multi-stage amplifier set for amplifying weak currents, it is frequently found undesirable to use the total amplification of the set before impressing the amplified currents on the outgoing line or the receiving instrument, since the degree of amplification desired for each particular case will depend largely on the strength of the incoming currents and on the electrical conditions in the output circuit into which the amplifier works. It is also frequently desirable to cut down the degree of amplification to prevent overloading the last stages of the set and to prevent excessive distortion resulting therefrom.

It is customary in multi-stage tube circuits to utilize common circuits to supply the various operating voltages to the various tubes. In such circuits, if a tube burns out or is purposely removed, the entire circuit is disabled or thrown out of adjustment, and if the circuit is to continue in operation without one or more of the tubes, rewiring is necessary.

It is a particular object of the invention to enable the insertion into or removal from such a circuit of one or more stages of amplification while maintaining the adjustments and supply voltages to the remaining part of the set undisturbed.

In accordance with this invention, unitary switching means are provided for cutting in or out, one or more of the stages of the set in order to vary by relatively large amounts the amplification produced. This switching means is arranged to substitute fixed resistance units for the filament and space resistances of the eliminated tube, which allows the switching to be done without substantially disturbing current and voltage conditions in the remainder of the circuit.

Another object is to decrease to a minimum the feed back capacity effect from the plate circuit of the cut-in tube to the grid circuit of the same tube. This is accomplished in accordance with the invention by the placing of the two necessary switches in the plate circuits of the tube to be removed and of the other tubes and by connecting the switches in such a manner that the capacity between the plates of the two tubes caused by the switches is a minimum. Each switch has only a small capacity between its contacts and as two of these capacities are in series between the plate circuits of the two tubes, the resulting capacity is decreased by one-half, thus minimizing deleterious feed back effects.

Where the vacuum tubes are energized from alternating current sources such as house lighting circuits, it is necessary to rectify the alternating current so as to obtain the direct current for the anode circuits of the tubes. It is frequently desirable to eliminate all batteries, in which case the grid biasing potential must be obtained in some manner such as by the use of a resistance in the space current circuit. This method has the advantage of tending toward stabilizing the space current when fluctuations occur in the value of the alternating potential supplied, maintaining thereby more nearly optimum operating conditions for the vacuum tubes.

Reference is made to the accompanying schematic drawing.

The invention has been shown in connection with a radio receiving circuit comprising two stages of radio frequency amplification, detector, and two stages of audio frequency amplification. All voltages necessary for the operation of this set are supplied through a transformer operating from a 110 volt alternating current source. The filaments of the rectifier and the last stage audio frequency tube are heated directly from the alternating current transformer while the filaments of the remaining tubes are heated by the rectified current of which the space or plate current of the above amplifier tube may form a part. Different values of direct current voltages are obtained for the individual amplifying tubes by a combination of resistances of varying values. This direct current potential is filtered through an inductance-condenser filter directly connected in the output of the rectifier circuit.

The power for this circuit is supplied through an alternating current transformer 5 and a rectifier tube 6 of the type commercially referred to as a "power tube". The output from the rectifier is passed through a condenser-inductance filter composed of elements 15 for smoothing out the uni-directional potential for the various tubes. From the point 8 in this filter the supply circuit divides, one branch going through the plate and filament of the last amplifier tube, and the other passing through resistance elements 12 and 13 which are so proportioned that the proper value of heating current is supplied to the filaments of the remaining tubes and the proper value of plate voltage is obtained for these tubes. The filament heating current for the last tube is supplied through a separate secondary winding 70 of the transformer 5.

As shown, potentials from the antenna 20 are impressed on the grid of a radio frequency amplifier tube 21 through tuned circuit 22, which comprises the first stage of radio frequency amplification. From the anode of tube 21, the signals may be impressed on the grid of tube 25 through a radio frequency transformer 26, and a tuned circuit 27. With the circuit in the condition illustrated, however, this second stage of radio frequency amplification is removed and signals from the first radio frequency stage are applied directly to the detector circuit.

Associated with this second stage of radio frequency amplification is a unitary switch or key A composed of contacts numbered from 30 to 39, inclusive, the operation of which is hereinafter described. A resistance 28 of approximately 50,000 ohms, or the direct current plate-circuit resistance of the tube 25, is shunted across the plate-circuit by contact 35, and a resistance 29 of approximately 50 ohms comparable to the resistance of the filament of tube 25 is shunted across the filament of this tube by the make-before-break contacts 36 and 37.

From the amplifier 25, when the latter is in circuit, the signals are fed through a radio frequency transformer 42 and a tuned circuit 43 into the detector tube 44 where they are rectified in the well-known manner. The audio frequency signals may then be impressed on the grid of tube 46 through an audio frequency transformer 47, although in the condition of the circuit shown transformer 47 and tube 46 are out of circuit. In either circuit condition the signals are next applied to audio frequency transformer 66 and tube 65 of the succeeding stage of audio frequency amplification, whence they pass into an output circuit through the transformer 67. To switch in or out this first stage of audio frequency amplification there is provided a unitary switch or key B, similar to switch A, composed of contacts numbered from 50 to 59, inclusive. Resistances 61 and 62 of approximately 65,000 and 50 ohms, respectively, are similar to the resistances 28 and 29 and are associated with the tube 46 in the same manner.

In the condition of the switches A and B indicated in the drawing, the second stage of radio frequency and the first stage of audio frequency amplification are eliminated from the circuit, as noted above. The filament current circuit, for all tubes except the last, may be traced from the filament of the rectifier tube 6, through the secondary winding of transformer 5, through the two filter coils 15 to point 8 where it divides into parallel paths, one path through the primary winding of transformer 67, to the plate of amplifier tube 65, to the filament of this tube, to the midpoint of the secondary winding 70, to point marked 11; while the other path is through the resistances 12 and 13 to point 11 from which point the combined currents pass through resistance element 14, contact 57, resistance 62, comparable to filament resistance of tube 46, contacts 36 and 37, resistance 29, comparable to the filament resistance of tube 25, filament of tube 21, filament of tube 44, conductor 71, to the plate and grid and thence to the filament of rectifier tube 6 from whence it started. Since this circuit supplies the filament current for the tubes 21, 25, 44 and 46 and the plate circuit of the last audio frequency amplifier tube, the direct current and, consequently, the direct current resistance in this circuit should be maintained substantially constant for both positions of switches A or B. This is accomplished by making the values of the replacing resistances 29 and 62 similar to the values of

the resistances of the filament of tubes 25 and 46, respectively. It will be noted that the contacts 36 and 37 of switch A and the contacts 56 and 57 of switch B are make-before-break arrangements adapted to prevent the breaking of this circuit during the switching operation with the attendant troubles which would be present due to the available high voltage from the rectifier which would become effective at the contacts if this circuit were broken.

The grid potential of tube 65 is supplied from point 9 in the rectifier circuit, the value of the bias being dependent upon the filament current and also upon the sum of the resistances of the first four tubes and the resistance element 14, which may be approximately 300 ohms, to obtain the proper amount of negative potential on the last tube. Resistance 14 further provides the correct amount of plate potential for the detector tube 44, the circuit, when tube 46 is eliminated, being from point 11 through conductor 73, contact 53, primary winding of the audio frequency transformer 66, contact 59, contact 51 to the plate. The circuit when tube 46 is operating is from point 11 through conductor 73, contact 52, primary winding of audio frequency transformer 47, contact 50 to the plate, comprising substantially the same values of resistance as when tube 46 is eliminated. It is to be noted that two contacts are included in the present circuit between the tubes 46 and 44 when tube 46 is in operation and as each set of contacts has a small capacity, the series arrangement decreases the total capacity minimizing feed back.

A resistance element 75 of approximately 50,000 ohms and a condenser 76 of approximately .5 microfarad are placed in the grid circuit of tube 65 to further smooth out the ripples of the rectifier voltage for producing quiet operation and preventing interaction between the plate and grid circuits of this tube. A resistance element 77 of approximately 100,000 ohms and a condenser 78 of approximately .5 microfarad capacity serves the same purpose in the grid circuit of tube 46. Such a condenser resistance filter has been disclosed in my copending application Serial No. 751,202, filed November 21, 1924.

Plate potential for the first stage audio frequency amplifier tube 46 and for the two radio frequency amplifier tubes 21 and 25, is obtained from point 10, the junction of resistances 12 and 13 which may be of the order of 9000 and 1500 ohms, respectively. For the plate of tube 46, when the tube is operating, the circuit follows conductor 74 through contact 54, primary winding of the audio frequency transformer 66, contact 58, the plate of tube 46, filament of this tube to a point 80. When the tube is eliminated, however, the circuit follows conductor 74 through contact 55, resistance element 61 to the point 80. The throwing of the switch B therefore, substitutes the resistance element 61 which has a resistance of approximately 65,000 ohms, comparable to the direct current impedance of the plate circuit of the tube 46 in operation, and circuit conditions are maintained uniform between the points 10 and 80 for both positions of the switch B.

Plate potential for tube 25 in the second stage of radio frequency amplification is supplied from point 10 as shown above. When this tube is employed, the circuit passes through conductor 74, contact 34, primary winding of radio frequency transformer 42, contact 38, plate of tube 25, the filament of this tube, to a point 81. When the tube is not employed, the circuit traces through conductor 74 to contact 35 through resistance 28, to the point 81. The resistances of these two circuits are approximately equal and the circuit conditions are therefore maintained substantially uniform in either position of the switch A.

Plate potential for the tube 21 is obtained from point 10 and when tube 25 is in operation, the circuit is through conductor 74, contact 32, primary winding of the radio frequency transformer 26, contact 30 to the plate of tube 21. When tube 25 has been eliminated, the circuit follows conductor 74, through contact 33, primary winding of radio frequency transformer 42, contact 39, contact 31, to the plate of tube 21. The series capacity arrangement of the contact switch springs operates in the same manner as described for the tube 46.

In accordance with another feature of the invention a circuit arrangement is provided which automatically maintains the tubes at approximately the proper operating conditions as regards plate and grid voltages under either of two conditions which are commonly encountered in practice. One of these two conditions is that of variations in the supply voltage, such as variations in the line voltage, in the case of circuits deriving their energy from a house lighting or other supply as specifically illustrated in the drawing. The other condition referred to is that of replacing a tube when it is burned out or for any other reason. The manner in which this automatic regulation is secured will now be briefly explained.

In the case of a variation in the supply voltage, the plate potential of the last tube 65 will change, tending to produce a corresponding change in the plate current and consequently in the current through resistances 12, 13 and 14 and the filaments of the first tubes. This change in the current through the resistances produces a change in the grid biasing potential for the tube 65 in such direction and by such an amount as

to tend to maintain the space current in tube 65 the same as it was before the variations in the line voltage took place. Since the plate potential and the filament current for the preceding tubes are derived from the circuit containing the resistances 12 and 13, if the current through these resistances varies at all, the filament current will also vary in response to variations in the line voltage and the plate potential will tend to vary correspondingly. However, the grid potentials of the amplifier tubes are derived from the filament heating circuit and are dependent on the potential drop in this circuit so that as the filament current varies, the grid biasing potential of the amplifier tubes is changed in such direction and by such an amount as to tend to compensate for the variations in the anode potential of these tubes.

When a tube is replaced by another tube having a different space current resistance, the substituted tube will tend to draw a greater or less amount of current from the space current supply circuit. However, the space current supply circuit includes resistances 12 and 13 through one or both of which the increased or decreased amount of current must flow, resulting in an increase or decrease in the potential drop through these resistances and a corresponding decrease or increase, respectively, in the plate potential applied to the tube. This reaction tends to cause stabilization of the plate current, which results in more uniform operation of the circuit when different tubes are employed than would usually result if the potential applied to the plate were maintained constant by the use of batteries or some other constant potential source. The stabilizing effect just described is most pronounced when the values of the resistances through which the potentials are applied to the plates of the tubes are large with respect to the values of the plate-to-filament resistances of the tubes themselves and when these resistances are independently associated with the individual tubes which they serve, although somewhat smaller resistances will give approximate or partial regulation.

This invention is disclosed in connection with a specific receiving amplifying radio set but is not to be considered as limited to this particular circuit but only by the scope of the following claims.

What is claimed is:

1. In a multi-stage tandem vacuum tube circuit comprising a plurality of vacuum tubes having a common source of voltage for energizing said tubes, switching means for eliminating certain of said intermediate tubes, said switching means substituting for said eliminated tubes resistances comparable to the space resistances of said tubes without affecting the grid circuit connections to any of said tubes.

2. In a multi-stage tandem vacuum tube circuit comprising a plurality of vacuum tubes having a common source of voltage for supplying space current and grid polarizing potential, a common source of filament current supplying said filaments in series, switching means for eliminating certain of said intermediate tubes, said switching means removing and simultaneously substituting for the filaments of said eliminated tubes, resistances comparable to the resistances of the filaments thereof, and removing and simultaneously substituting for the spaces of said eliminated tubes, resistances comparable to the space resistances thereof.

3. In a multi-stage vacuum tube circuit, a power stage and a plurality of preliminary stages feeding into said power stage, each stage comprising a discharge device having cathode, anode and grid elements, a common source of space current for all of said stages, means for removing one of said stages and substituting in circuit therefor resistances equivalent to the filament and anode circuit resistances, respectively, thereof, and means for maintaining the operating potentials of said stages substantially unaffected by said substitution, comprising resistance elements connected in the path of flow of the space current from said source to certain of said discharge devices, a connection for deriving grid biasing potential for certain of said stages from across one of said resistance elements, and connections for deriving anode potentials for said other stages from across certain of said latter resistance elements.

4. In combination with a plurality of vacuum tube stages interdependently supplied from a common energizing source, means for maintaining the respective energizing currents constant when one of said stages is removed, comprising means for inserting equivalent impedances in the connections occupied by the filament and the anode-filament path, respectively, of the vacuum tube of the stage removed.

5. A plurality of vacuum tube stages in which the respective operating voltages are mutually dependent on the current drawn from a common source of energy, means for deriving grid biasing potentials from the currents drawn by said stages and means for removing one of said stages and substituting equivalent resistances for the filament and the plate-filament path respectively, of the tube removed, whereby said grid biases are maintained constant.

6. A vacuum tube system comprising an incoming line, an outgoing line, a plurality of vacuum tubes in tandem relation and intermediate said lines adapted to amplify incoming signals, each of said tubes having an input and an output circuit and a connecting transformer, and means to remove at least one of the intermediate tubes of

said system without affecting the operation of the other of said stages to vary the degree of amplification in relatively large stages, said means comprising a unitary switch for deenergizing the filament, substituting equivalent elements for the anode circuits and said filaments of the tubes removed, and changing the connection from the output circuit of the tubes preceding the ones removed to the primaries of succeeding transformer, without altering the connections of said system to said lines.

In witness whereof, I hereunto subscribe my name this 25th day of January A. D., 1926.

DONALD F. WHITING.