March 6, 1962 A. AZELICKIS ET AL 3,024,423

ELECTRICAL APPARATUS

Original Filed Aug. 9, 1957 3 Sheets-Sheet 1

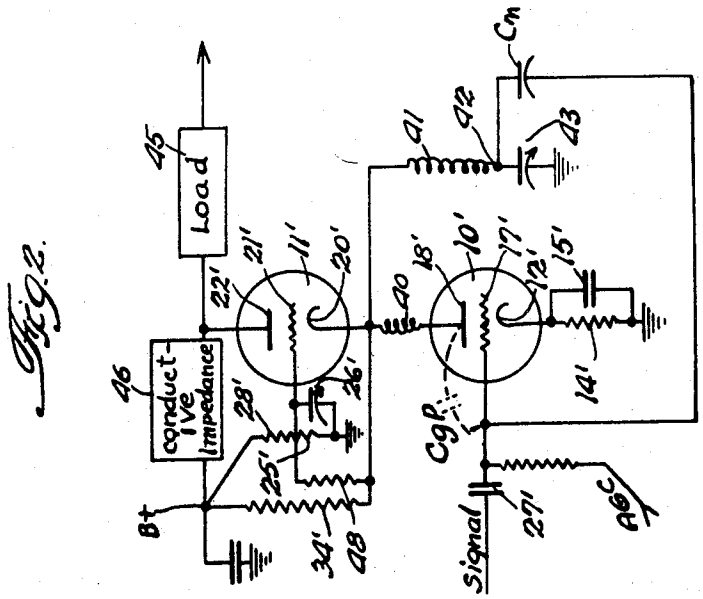


Fig. 2.

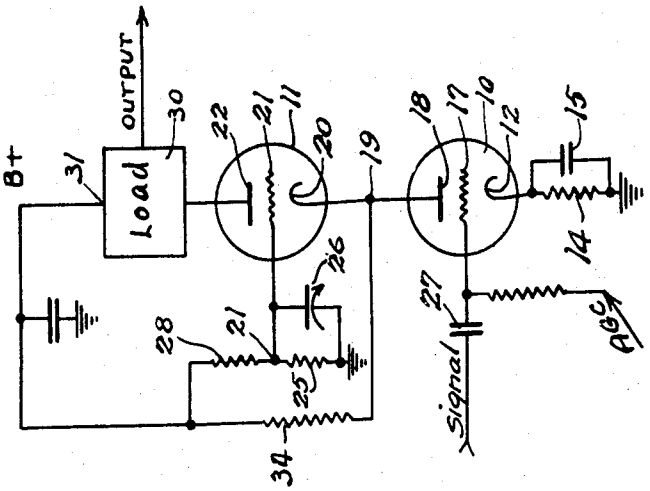


Fig. 1.

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ELECTRICAL APPARATUS

Original Filed Aug. 9, 1957 3 Sheets-Sheet 2

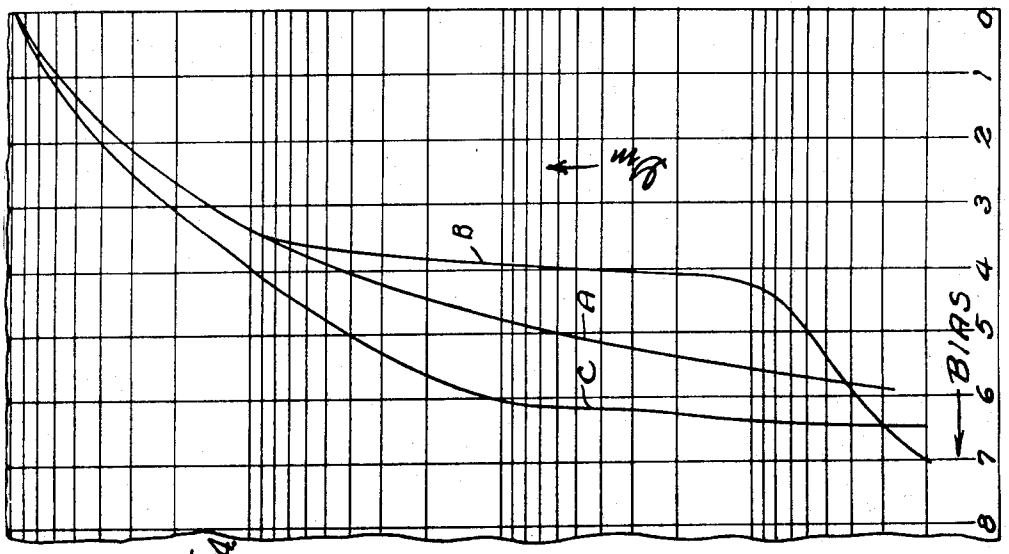


Fig. 4.

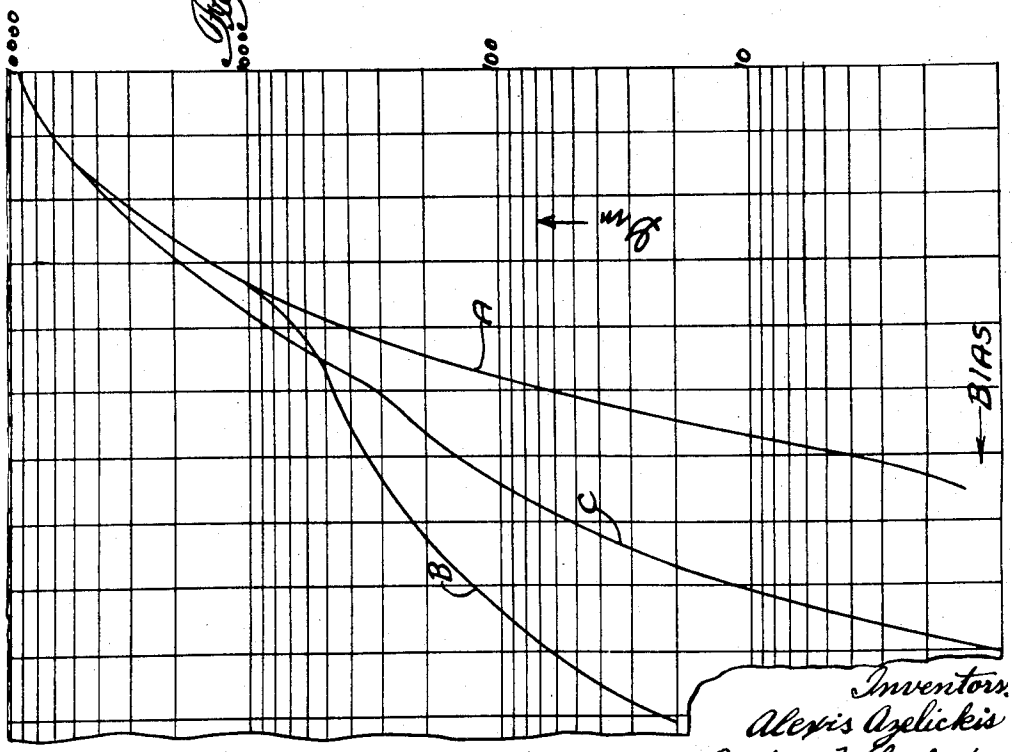


Fig. 3.

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Original Filed Aug. 9, 1957 3 Sheets-Sheet 3

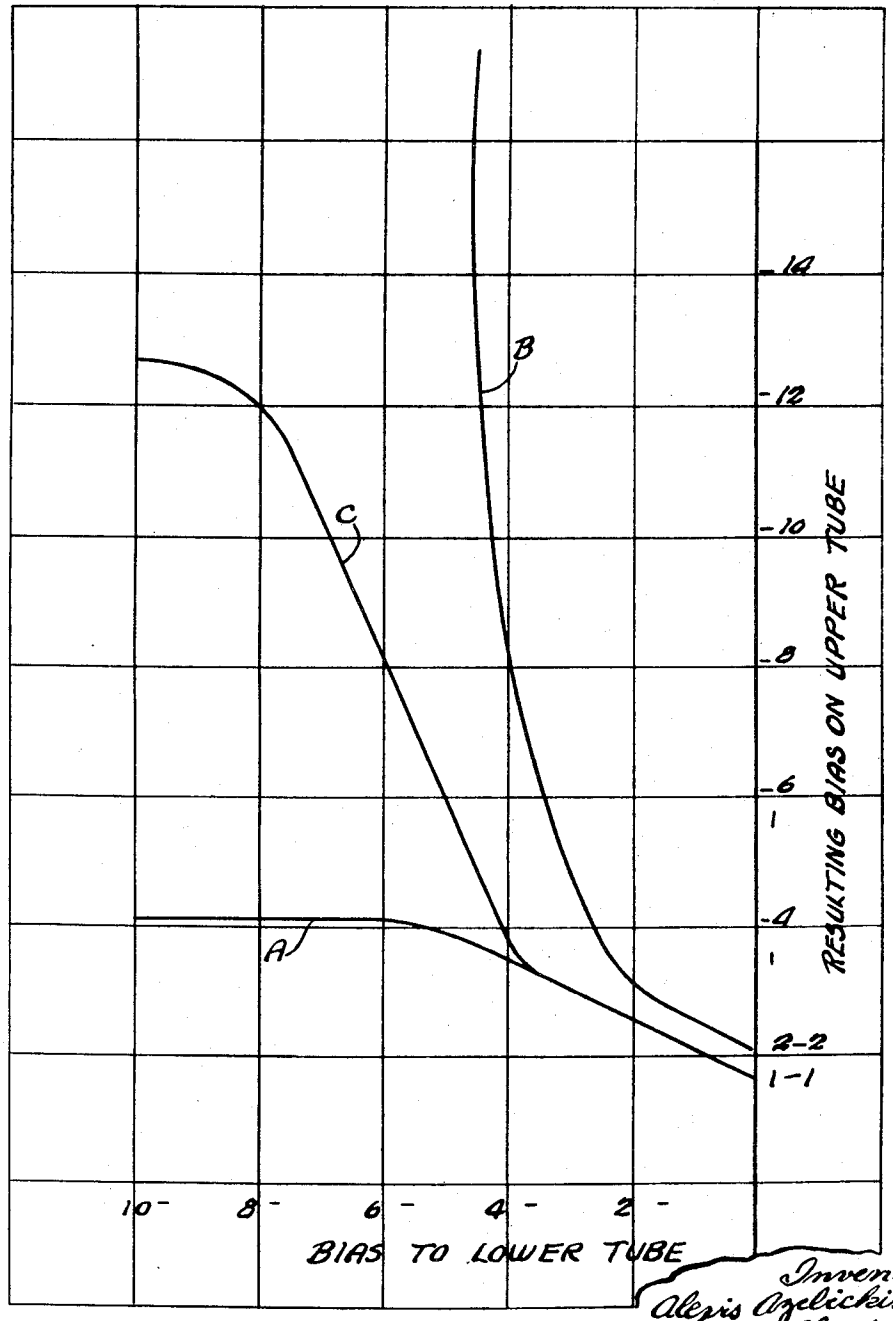


Fig. 5.

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ELECTRICAL APPARATUS

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Continuation of application Ser. No. 677,320, Aug. 9, 1957. This application July 1, 1960, Ser. No. 40,481

3 Claims. (Cl. 330—70)

This invention relates to electrical apparatus and more particularly to an amplifier utilizing two cascaded tubes in series.

It is possible to arrange two or more triodes or vacuum tubes having more than three electrodes in series relationship with the anode of the first tube conductively connected to the cathode of the second tube and so on to additional tubes so that the space discharge regions are in series.

A well known arrangement of such series connected tubes has been widely used in television and is generally known as a cascode arrangement. In such an arrangement, the input is between the cathode and grid of the first or lower tube while the output is between the anode and ground of the upper or second tube. The anode of the first tube is conductively connected to the cathode of the second tube.

Various modifications of this cascode arrangement are known, each such modification having its own peculiar requirements and advantages.

As a consequence of the present invention, a cascaded pair of vacuum tubes may be operated over greatly increased ranges with regard to signal voltages and frequencies without impairing the stability and operativeness of the amplifier as a whole.

As an example, a cascode stage may be provided in connection with TV operation. In the case of a TV receiver, such a stage may consist of two three element tubes. The lower tube has the signal input connected between the control grid and cathode. The upper tube provides the output between the anode and ground. Under normal conditions, if either tube is cutoff, the stage should not operate and there should be no output. However at high frequencies such as are used in TV, the inter-electrode and stray capacitances are significant. If the lower tube is cutoff, current at some frequencies may still get through to the cathode of the upper tube. This may also be true if the lower tube is neutralized.

While current at the neutralized frequencies will not get through, assuming the lower tube is at cutoff, current at frequencies above and below the neutralized frequency may get through. In such case, the cascode stage may operate with current at unneutralized frequencies within the desired signal frequency spectrum being passed through the upper tube. Such an effect is highly undesirable and impairs the objective aimed for in applying gain control voltage to the lower tube. This objective is to cut off the entire stage without amplitude distortion of the transmitted signal currents.

It is clear that in order to avoid the above objectionable effects and to meet the above objection it is necessary to insure that the top tube cuts off before the lower tube.

There may be other occasions when the cutoff characteristics of the lower tube of a cascode stage should be controlled differently from the cutoff of the entire cascode stage.

In order that the invention may be fully understood, reference will be made to the drawings wherein exemplary embodiments are illustrated. It is understood that variations may be made without departing from the

scope of the invention as defined by the appended claims.

In the drawings,

FIGURE 1 is a circuit diagram of a simple form of the invention.

FIGURE 2 is a circuit diagram of a modified form of the invention.

FIGURES 3, 4 and 5 show some characteristic curves of the operation of conventional cascode circuits and the operation of a circuit embodying the present invention.

Referring first to FIGURE 1, vacuum tubes **10** and **11** are illustrated as being connected in cascaded relation. The vacuum tubes are here shown as triodes but it is understood that either or both tubes may have additional electrodes if desired. Vacuum tube **10** has cathode **12** connected to ground through bias resistor **14** shunted by bypass capacitor **15**. Vacuum tube **10**, which may be considered as the first tube in this cascaded stage, has control grid **17** and anode **18**. Anode **18** is connected through junction point **19** to cathode **20** of vacuum tube **11**.

Vacuum tube **11** has control grid **21** and anode **22**. Control grid **21** is connected to junction point **24** which in turn is connected to ground through resistor **25** shunted by bypass capacitor **26**. Control grid **21** is also connected to B plus through resistor **28**. Anode **22** is connected to one terminal of a network **30** having connection **31** to B plus. Network **30** has an output for the amplified potentials. It is understood that a direct current path between B plus and anode **22** must be provided. Otherwise network **30** may be any kind, having any desired type of impedances.

The input of the stage so far described is between control grid **17** and ground while the output is between the output of network **30** and ground. Coupling capacitor **27** is in the input signal channel. The cascode stage so far described is conventional.

The bias of control grid **17** of the lower tube **10** will be maintained at a desired value by resistor **14** and bypass capacitor **15** and also by a potential impressed on control grid **17** from some A.G.C. (automatic gain control) source. It will be noted that tube **11** has its control grid **21** biased at predetermined value by what is in effect a voltage dividing network consisting of resistors **28** and **25**.

Assume that the A.G.C. control increases the negative bias on control grid **17**. The mutual conductance of tubes **10** and **11** are effectively decreased by the increase in negative bias of control grid **17** of tube **10**. In the circuit so far described, if the value of resistor **28** is substantially equal to the value of resistor **25** and tubes **10** and **11** are similar in type then the entire stage will have a generally sharp cutoff.

If the value of resistor **28** is less than the value of resistor **25** (the bias on control **21** is made more positive) then the cutoff for the entire stage is rendered more remote. By this is meant a gradual decrease in space current through the stage with increase in the negative bias of control grid **17** of tube **10** until gradually the space current disappears.

If the value of resistor **28** is greater than that of **25** (the bias of control grid **21** becomes more negative) then the cutoff characteristics of the cascode stage are sharpened even more and amplifier gain drops.

In accordance with the present invention, we have fundamentally altered the operation of the cascode stage and greatly enhanced the capabilities of the cascaded tubes by providing resistor **34** connected between anode **18** and the B plus supply. Resistor **34** must be high enough so that the current bypass path around upper tube **11** will not have too low a resistance compared to the plate to cathode resistance of upper tube **11**. Since the

tube resistance may vary over a wide range, some intermediate value for resistance 34 will have to be taken. In general, tube operating conditions and desired cutoff characteristics will determine a desirable value for resistor 34. The actual value is not critical within a substantial range which may readily be determined by one skilled in this art. Except for high negative bias potentials on the control grid of the upper tube when the cathode to plate resistance of the upper tube will become as high or higher than resistor 34, most of the current passing through lower tube 10 will also pass through upper tube 11 and be effective at the output of the cascode stage.

Considering the above circuit, there are situations where it is desirable to have remote cutoff on tube 10 and still maintain the sharp cutoff characteristics of the full cascode stage. This desirable result is achieved by the addition of resistor 34 which functions as a current supply resistor for vacuum tube 10 when second tube 11 is cut off.

We have found that the smaller the value of resistor 34 is, the more remote becomes the cutoff characteristic of tube 10 and the sharper the cutoff of second tube 11 as well as the entire cascode stage.

Referring now to FIGURE 2, there is illustrated a modification of FIGURE 1. Tube 10' has control grid 17' and anode 18' as in FIGURE 1. Between control grid 17' and anode 18' there is tube capacitance C_{gp}. This capacitance may be neutralized.

Anode 18' is connected to cathode 20' through inductor 40. Cathode 20' is also connected through inductor 41 to junction point 42. Inductors 40 and 41 may form part of one or more tuned circuits in a tuner. From junction point 42 tuning capacitor 43 is connected to ground. From junction point 42 neutralizing capacitor C_n is connected back to control grid 17'.

Tube 11' has its control grid 21' connected at a suitable point on a potential divider network in exactly the same manner as FIGURE 1. Anode 22' is connected to a suitable output load 45 and is connected through conductive impedance 46, to B plus. In this modification, conductive impedance 46 (which in practice may consist of a simple load resistor) is distinct from output load 45 which may be one or more impedances to insure good load transfer characteristics. Resistor 34' is connected between B plus and cathode 20'.

In the circuit illustrated in FIGURE 2, the stage may be used for handling a band of frequencies in a television channel. Capacitor C_n may be adjusted for neutralization at say the middle of the band. However the channel band is wide enough so that neutralization is not effective at the edges of the band. A tuner operating with such a cascode stage not having resistor 34' will thus exhibit a notching wherein the middle of the band is substantially suppressed while the edges of the band are passed to top tube 11' in case tube 10' cuts off first.

A circuit embodying the invention has been found to reduce substantially cross-modulation type of interference. Such an interference results from the non-linear operating characteristics of the vacuum tubes and is accentuated in relatively sharp cut-off tubes with certain values of A.G.C. potential on the control grid of the lower tube.

It may be desirable to counteract the increased sharpness of cutoff of composite gain of the entire cascode stage with changes in A.G.C. potential when resistor 34 is used. This may be obtained by connecting resistor 48 between the cathode and control grid of the upper tube. With zero grid bias on grid 21' (with reference to cathode 20') resistor 48 will have little if any potential across it. However, as A.G.C. potential on grid 21' becomes more negative, the bias potential between control grid and cathode of the upper tube increases, and the current through resistor 48 increases. This current increase tends to reduce the bias potential between the control grid and cathode of the upper tube exerting a negative feedback type of regulation of the potentials on the upper tube. This tends to make the cutoff characteristics of the upper tube and that of the cascode stage as a whole more remote. By changing resistor 48 to a higher resistance value, the regulating and remoting action obtained will be reduced.

A typical circuit embodying the invention as illustrated in FIGURE 2 may have the following component values.

Tubes 10' 11'	6BS8
B plus potential ---volts--	260
Resistor 14' ---ohms--	100
Capacitor 15' ---mmf--	330
A.G.C. resistor ---ohms--	22,000
Capacitor C_n ---mmf--	3.3
Capacitor 43 ---mmf--	12
Resistors 25', 28', each ---ohms--	820,000
Resistor 48 ---do----	68,000
Capacitor 26' ---mmf--	1,000
Resistor 34 ---ohms--	330,000
Capacitor 27' ---mmf--	47

Inductors 40, 41 and capacitor 43 as a group and load 45 are selected to provide desired resonance at a TV channel in the V.H.F. band. The cascode stage as a whole may be designed along conventional lines apart from resistors 34 (or 34') and 48. The bypass capacitors for B plus are conventional. Tolerances are usual plus or minus 10%.

Referring now to FIGURES 3 to 5 inclusive, curves A illustrate the characteristics of conventional cascode circuits, such as in FIGURES 1 and 2 with resistors 34, 34' and 48 omitted. In FIGURE 3 the mutual transconductance (G_m) of the lower tube is plotted against the bias on the control grid of the lower tube of a cascode connected circuit. In this circuit resistors 25 and 28 are equal. In FIGURE 4 the mutual transconductance of the overall cascode connected tube is plotted against the bias on the control grid of the lower tube. FIGURE 4 shows the corresponding curves where the y-axis values are in terms of mutual transconductance of the cascode stage.

In both figures, the A curves show the generally sharp cutoff characteristics of a conventional circuit. Curves B show what happened when resistor 34' was added. The lower tube cutoff was made more remote (FIGURE 3) while the over-all cutoff of the cascode stage was sharpened (FIGURE 4). When resistor 48 was added (both resistors 34' and 48 are now in) the lower tube cutoff characteristic as shown by curve C was sharpened with reference to curve B (FIGURE 3). The cutoff characteristics of the entire stage was rendered more remote by adding resistor 48, as shown by curve C in FIGURE 4.

FIGURE 5 shows the corresponding curves A, B and C for cutoff characteristics of the upper tube 11 (or 11'). In this figure, the bias on the control grid of the lower tube (10 or 10') is plotted against the bias on the upper tube (11 or 11').

In curve A, the negative bias on the upper tube reaches a steady maximum value after the bias on the lower tube reaches about —5 volts. In curve B (resistor 34' added) the bias on the upper tube increases very fast with increase of lower tube bias, simultaneously causing very fast cutoff of the upper tube plate current. Curve C shows the moderating effect on the fast cutoff of the upper tube when resistor 48 is added.

In connection with FIGURES 1 and 2, it is understood that a resistor between cathode 20 and grid 21 of upper tube 11, corresponding to resistor 48 in FIGURE 2 may be added.

In fact FIGURES 1 and 2 differ principally in the circuits to which the invention may be applied. In all cases, a resistor 34 or 34' is essential. Resistor 48 may be added if desired. By controlling the absolute values of resistors 34 (or 34') and 48 as well as controlling the

relative values of resistors 25 and 28, the operating points of the tubes and general circuit design factors, a wide range of operating characteristics may be provided. The values given for circuit components and characteristic curves are merely exemplary. The particular curves refer to circuits having the component values tabulated.

This is a continuation of our abandoned application Serial No. 677,320, filed August 9, 1957.

What is claimed is:

1. For use in a TV receiver, a cascode stage for operation in conjunction with a tuner, said stage having a lower triode with a cathode, control grid and anode, said cathode being grounded for high frequencies, the signal and gain control input being between control grid and ground, tuning means connected between the anode and ground, said tuning means including at least one inductor between the anode and a grounded capacitor, a neutralizing capacitor connected between the anode circuit and control grid, said lower tube operating at high gain and being neutralized at about the middle of the frequency band for which the stage is tuned, an upper triode having its cathode connected through an inductor to the anode of the lower tube, the upper tube anode being connected to one terminal of the cascode output, the other output terminal being grounded, means including a source of B potential having one terminal grounded and the other terminal connected to the upper tube anode, voltage dividing means connected across the B potential source and having an intermediate potential point connected to the upper

tube control grid, a grounded capacitor connected to said upper tube grid, said cascode stage thus far being conventional and exhibiting an undesirable notching, whereby a strong signal on the lower tube input may cause lower tube cut-off, said lower tube inter-electrode capacitances permitting signals to go through at unneutralized frequencies near the limits of the tuned band of frequencies, and means for suppressing said notching effect while still retaining the lower tube circuit advantages, said means comprising a resistor connected between the other B terminal and cathode of the upper tube, said resistor having a sufficiently high value in comparison to the upper tube cathode to plate resistance to provide desired cut-off characteristics for the lower tube under operating conditions.

2. The circuit according to claim 1 wherein a second resistor is connected between the grid and cathode of the upper tube whereby the sharpness of cut-off for the entire cascode stage is reduced.

3. The circuit according to claim 2 wherein said lower tube tuning means includes two inductors in series between the lower tube anode and grounded capacitor.

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