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SUPERCHARGED CATHODE FOLLOWER CIRCUIT

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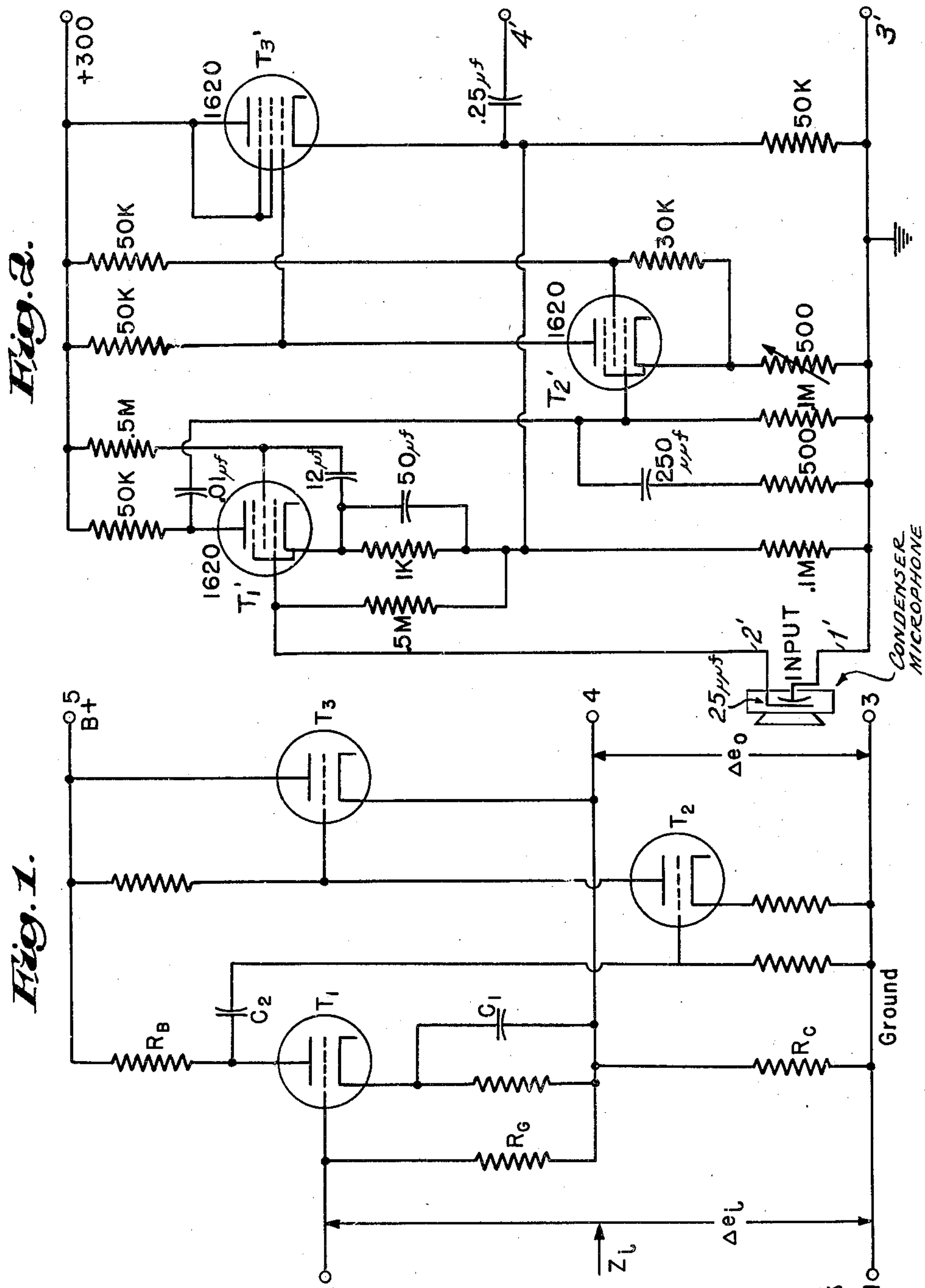

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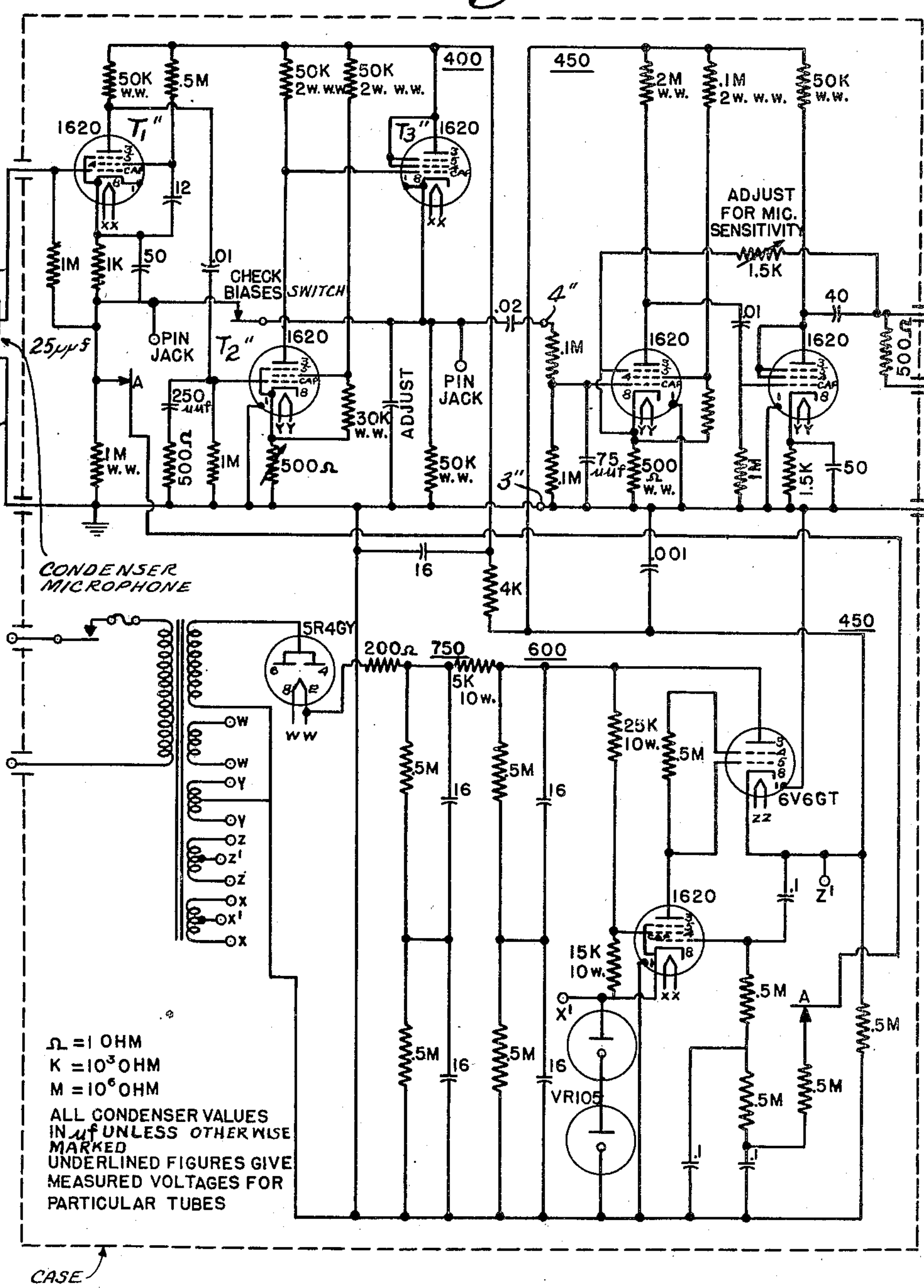
Fig. 3.



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SUPERCHARGED CATHODE FOLLOWER CIRCUIT

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4 Claims. (Cl. 179—171)

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This invention relates to an improved cathode follower circuit for use especially as a preamplifier or impedance transformer of unity voltage gain, between a high-impedance voltage source and a load; also it is used for supplying, if necessary, a stable bias voltage to the high-impedance voltage source.

With a simple cathode follower, the largest input impedance which may be obtained is of the order of 100 times the value of the grid resistor, unless one uses special high transconductance tubes whose properties are not otherwise suitable. Where, for example, it is necessary to connect the source to the cathode follower by means of a flexible cable or other extension, the largest factor by which the stray capacitances of the cable or extension can be reduced by feedback from the cathode follower is of the order of 100.

Thus, if the high impedance source is a condenser microphone, a high input resistance to the preamplifier is required to maintain a low low-frequency cutoff, and any extension cable for the microphone must have a low effective capacitance if the sensitivity is not be decreased. To maintain satisfactory high input resistance one must use an undesirably high value for the grid resistor of a conventional cathode follower; the stability of operation thus suffers.

In accordance with the invention, I have devised a supercharged cathode follower circuit in which the effect of feedback in increasing the input impedance is much greater, and in which, also, the performance of the cathode follower is less sensitive to the magnitude of the load.

In the accompanying drawings:

Fig. 1 is a schematic view illustrating the circuit of the invention in one simple form.

Fig. 2 is another schematic view illustrating another form of the circuit reference characters used in the first figure being primed and applied to corresponding parts; and

Fig. 3 is still another schematic view illustrating the circuit combined with additional circuit elements for one specific adaptation, parts referred to by reference characters in the other views having similar characters double primed.

Attention is directed to the simple circuit indicated in Fig. 1. In this figure a complete amplifier circuit specially suited to a condenser microphone is shown, having input terminals 1 and 2, to which the terminals of the condenser electrodes of the microphone are to be directly connected, the first being at ground and the second led directly to the grid of a first tube T_1. The output of this circuit is at terminals 3 and 4, the latter being

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at ground and terminal 3 being connected directly to the cathode of a second cathode follower T_3, and to an intermediate point in the cathode-to-ground resistance of the tube T_1, with a capacitor coupling C_1 to the cathode of the last-named tube. The grid return of the first tube is through resistor R_G to the same intermediate point last named. In this way part of the cathode resistance becomes effective in the grid-to-ground return, and a comparatively small amount of resistance is required in the resistor R_G, at the same time that feed back from the cathode followers T_1 and T_3 is made more than ordinarily potent at the input. While tube T_1 is utilized as a cathode follower, it combines conventional amplifier action by the inclusion of a plate resistor R_B and a coupling of the plate by capacitance C_2 to the grid of a conventional amplifier tube T_2. In general, the principle of operation of the circuit involves feeding a signal from a plate load R_B, connected to the cathode follower T_1, to additional amplifying means T_2—T_3, and then feeding back the amplified signal in proper phase to the cathode of the cathode follower T_1 to increase the input impedance.

The circuit includes three tubes T_1, T_2 and T_3. Tube T_1, if its plate load R_B were short-circuited, would constitute a conventional cathode follower with output appearing across terminals 3 and 4, as will be apparent from an inspection of the circuit arrangement of Fig. 1. The signal from T_1 is, however, amplified there and fed capacitatively from the T_1 plate to the T_2 grid, and from the T_2 plate by a direct lead without inserted impedance to the T_3 grid. The latter tube is a conventional cathode follower, except in the manner in which it is connected to the cathode-to-ground and grid-to-ground resistances of tube T_1. A very high gain is therefore attained at output 3—4, representing the amplified potential from T_2 and power gain of T_3, supplemented by the cathode output of tube T_1, with the tubes T_2 and T_3 constituting amplifying means. The resulting amplified signal is then fed back in proper phase directly from the cathode of tube T_3 to the cathode of the tube T_1. This feed back therefore becomes effective as added impedance in series parallel with the grid resistor R_G and upper portion of the cathode resistance.

It is an important function of the device that with the parameters and voltages indicated in Fig. 2, or Fig. 3, the voltages derived at the two cathode follower outputs are equal, and for adjusting these a "check biases switch" may be used as in Fig. 3, to enable separate adjustment.

For this, adjustment of the output at tube T_3, T_3' or T_3'' is sufficient, and this may be accomplished by varying the cathode resistance of tube T_2, T_2' or T_2''. The values indicated in Fig. 2 are appropriate for one specific application, but for other purposes, instruments, etc., different values might be chosen; see for instance, Fig. 3, hereinafter described.

Analysis of the circuit shown in Fig. 1 gives the following expression for the input impedance

$$R_i=\frac{1}{1-G}$$

where G is the incremental gain from input to output; G will be less than unity. If R_1 is to be large, then G will be close to unity. It is shown in the analysis that if the gain of the intermediate amplifier, T_2, is infinite,

$$G=\frac{\mu}{\mu+1}$$

where μ is the amplification factor of T_1.

For a simple cathode follower,

$$G=\frac{\mu}{\mu+1}\frac{R_c}{R_c+\frac{r_p}{\mu+1}}$$

where R_c= the cathode resistor used with T_1, and r_p is the plate resistance of T_1. For a triode, where R_c can easily be made very much larger than r_p, the ratio

$$G=\frac{\mu}{\mu+1}$$

is easily approached. However, this cannot be done for a pentode. Therefore, while the circuit promises less improvement for a triode, a considerable improvement can be achieved when T_1 is a pentode. It should be borne in mind that μ for a triode may be in the order of 20, while for a pentode, μ may be about 1,000.

It is also shown that for T_1 as a pentode

$$R_i=R\frac{u}{1+\frac{r_p}{AR_B}}$$

where A is the amplification of the intermediate amplifier T_2 and R_B is the resistor in the plate circuit of T_1.

It is clear that if R_1 (or impedance, however contrived) is to be large, then AR_B must be made as large as possible. When this is true, a large input impedance can be obtained without the use of an impractically large grid resistor. This has been made practicable in this invention by returning the cathode of tube T_3 to the point intermediately of the cathode-to-ground resistance and grid-to-ground resistance, at the first tube, and by the capacitor coupling of the first cathode to the last-mentioned return, as described, and as is embodied in all the figures of the drawing.

The capacitance from grid to cathode will be reduced by the same factor that the input resistance is increased. Since this factor is much larger than can be obtained with a simple cathode follower, the circuit has the advantage of permitting the use of a long extension cable between a microphone and the preamplifier. Furthermore, sufficiently large values of input impedance can be obtained using this circuit without using a grid resistor greater than 1 megohm. This contributes greatly to the stability of the bias voltages.

The invention may, for example, take the form indicated in Fig. 2, including a condenser microphone of 25 $\mu\mu f$ capacity used with a grid resistor of .5 megohm. The combination of 25 $\mu\mu f$ and .5 megohm without cathode follower action has a cutoff frequency (3 db. down) of 13,000 C. P. S. With the pentode cathode follower conventionally used, the cutoff frequency is reduced to 150 C. P. S. When the supercharger is added, the system is flat to 20 C. P. S. It will thus be seen that in addition to other advantages mentioned, the invention effects an extension of the lower limit of frequency response which may be utilized in a preamplifier. This makes it possible to take better advantage of the high quality response of the condenser microphone than would be the case where dependence is placed mainly on resistors for the impedance. To test the effect of the addition of a flexible extension cable, a capacity of 1000 $\mu\mu f$ was connected from grid to cathode. The resulting insertion loss was 1 db. for frequencies below 10,000 C. P. S. The input impedance of the supercharged cathode follower is therefore increased by a factor of about 300.

The supercharged cathode follower circuit furnishes an excellent basis for the design of a sound pressure meter whose purpose is to give a direct reading of sound pressure level when the source is a condenser microphone and the final load is an electronic voltmeter.

In Fig. 3 I have indicated a schematic diagram for a sound pressure meter. The arrangement shown includes the supercharged cathode follower circuit at the upper left side of the figure (identical with Fig. 2, except that a higher plate supply voltage is indicated), additional amplifying means at the upper right-hand side of the figure, and internal power supply means at the lower side of the figure.

It will be apparent that several novel features are present. A regulated power supply may be included within the sound pressure meter and the entire device may be A. C.-operated and self-contained. The control amplifier in the regulated power supply receives its signal through a filter directly from the point whose voltage is to be controlled, namely, at the base of the grid resistor of the first tube, which voltage is the bias on the condenser microphone. Therefore, the condenser polarity bias is automatically maintained and should require only infrequent checking unless tubes are changed. An additional amplifier has been included, (1) to provide an amount of gain equal to the correction term which is normally required to convert voltage output in microvolts to sound pressure levels (4–6 db.); (2) to provide a very low output impedance so as to make the gain of the instrument substantially independent of load or cable length; (3) to isolate the supercharger circuit from load impedance; (4) to provide sufficient output power to operate directly into filters. The entire instrument can be built into a case approximately 10″ x 6″ x 5″. Various other applications and modifications may be practised in keeping with the scope of the invention, as defined by the appended claims.

It will be noted from Fig. 1 that the parameters have been so selected and combined that a direct coupling is made practicable between the amplified signal output of the second tube in the circuit of Fig. 1 and the ultimate cathode follower; so that the output of the latter may be utilized effectively as a part of a simple voltmeter device, the supercharged cathode follower circuit becoming a part of the means for rendering, in a direct current reading, the equivalent of an alternating current input. This enables the voltmeter to be calibrated in decibels or other units to fit various situations. At the same time that the high input impedance is achieved with small value resistors effective, as explained, the well understood advantages of low output impedance are retained.

Having thus described my invention, what I claim is:

1. A supercharged cathode follower preamplifier circuit of high input impedance and low output impedance for condenser microphones comprising first and second cathode follower tubes and an intermediate conventional amplifier tube, the first cathode follower and the amplifier having respectively first and second cathode resistances returned to ground a direct connection from the cathode of the second cathode follower to a mid-point of the cathode-to-ground resistance of the first cathode follower, a capacitor bridging the cathode end of said last-named resistance, the grid of the first cathode follower having a resistor to said mid-point, a plate potential source connected to the said tubes with interposed resistance plate loads for the first cathode follower and amplifier only, a capacitative coupling between the plate of the first cathode follower and the grid of the amplifier, a direct connection between the plate of the amplifier and grid of the second cathode follower, input leads direct to the grid of the first cathode follower and ground, and output leads respectively direct from the cathode of the second cathode follower and ground.

2. The structure of claim 1 wherein the parameters of the tubes are proportioned in values so that a common voltage level is independently maintained at the said mid-point of the said cathode-to-ground resistance of the first cathode follower and at the cathode of the second cathode follower.

3. The invention of claim 2 wherein the said cathode resistor of the amplifier is variable whereby correction of potential balance between the cathodes of the two cathode followers may be effected by variation of grid bias of the amplifier.

4. In a preamplifier system for a condenser microphone the circuit as set forth in claim 1, a power supply therefor having grid-controlled electron tube amplifiers including a control tube having an anode, a cathode, and a control grid and means to automatically regulate the polarity bias across the said input leads comprising a connection between ground and said mid-point of said cathode-to-ground resistance of the first-named cathode follower in a control grid circuit of said control tube.

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