New Amplifier has Bridge-Circuit Output

D. J. TOMCIK AND A. M. WIGGINS*

A new output circuit for a high quality audio amplifier is described. It is one which eliminates switching transients, provides unity coupling of the two output tubes and has low quiescent current. A comparison is made between this and conventional push-pull circuits.

HIGH-QUALITY AUDIO AMPLIFIERS have always been the strongest link in the chain of components required in a reproducing system. Even though a high degree of excellence has been attained in most existing amplifiers, much is left to be accomplished in their application to the system. The power stage and the output transformer are the portions in which one can expect the greatest advances in materials, techniques, and circuitry.

Output Transformer Requirements

One requirement for a high-quality output transformer in a conventional push-pull circuit is that it must have negligible leakage reactance to avoid transient distortion due to collapsing currents when each tube is driven beyond cutoff. The collapsing current which causes the transient condition appears as a parasitic oscillation in the wave-form at the plate current cutoff points. A large value of leakage reactance also causes the transformer efficiency to decrease at high frequencies, resulting in a reduction in power-output capability, as well as increased distortion and poor frequency response.

Another requirement of an output transformer is that the distributed capacitance of the winding be low to insure power-handling ability of the amplifier at high frequencies. Excessive distributed capacitance also causes attenuation of the high frequencies and excessive phase shift.

Still another requirement is that the transformer have enough inductance to reproduce the lowest frequency desired.

This article describes an output circuit which relieves the output transformer of many of these limiting effects and which overcomes many of the inherent disadvantages of the conventional push-pull circuit.

Description of Circuit

Figure 1 shows a push-pull output circuit which has departed radically from the conventional circuitry. In order to show the circuit in a simplified form in the schematic, batteries are used in

* *Electro-Voice, Inc., Buchanan, Mich.*

lieu of power supplies. One of the two power supplies necessary with this circuit is connected from the plate of each tube to the cathode of the other. The d.c. plate current of each tube circulates through both power supplies *without passing through the windings of the output transformer.* Only a negligible current caused by the dissimilarity in the output tubes flows through the output transformer.

The circuit is drawn to illustrate that it is a balanced bridge under no-signal conditions. The bridge consists of the
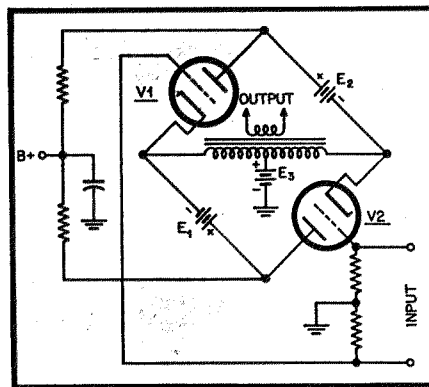

Fig. 1. Circuit diagram of output circuit showing B-supply for low-level stages.

two tubes V_1 and V_2 and the two power supplies E_1 and E_2. The output transformer is placed across the bridge from cathode to cathode and is provided with a centertap which establishes the grid-to-cathode circuits through the bias E_3. Identical operation can be had by placing an untapped transformer from plate to plate and by providing grid-to-cathode continuity with high resistances from each cathode to bias voltage E_3. In the interest of simplicity, the tubes are shown here as triodes although pentodes, tetrodes, and beam-power tubes can be used as well.

The total primary winding is presented as a load to each tube. One half of this load is in the cathode circuit and the other half is in the plate circuit. The plate load of one tube is the cathode load of the other (and *vice versa*). Since each tube looks into the same load, there is perfect load coupling between the tubes.

Though considerable leakage reactance may exist in the transformer, no switching transients can occur when either of the tubes is driven past cutoff, since both halves of the primary have the same signal current flowing through them. Thus switching transients, which are so troublesome in conventional push-pull class AB and B amplifiers, and which place severe requirements on the output transformer, are eliminated with this arrangement.

The impedance of the primary winding of the transformer in this circuit is only one-fourth the impedance of the plate-to-plate winding used in a conventional push-pull output circuit using the same type of tubes. This lower impedance primary permits the transformer to be wound with much less capacitance than would be possible with the higher impedance of a conventional circuit.

Any amount of cathode feedback can be obtained by using transformer interstage coupling and connecting the cathode lead of an interstage transformer secondary to appropriate taps on the output transformer winding. For example, in designing the amplifier it is possible to use class AB_1 operation with R-C coupling and maximum cathode degenerative feedback, as is the case in *Fig.* 1. Under these conditions the new output circuit is similar in operation to a cathode-follower type, and has a voltage gain of less than one. The cathode follower has the advantage of a large amount of feedback, with resultant low distortion along with low output impedance.

The perfect coupling between the two tubes allows the tubes to be operated with low quiescent current—almost to the point of class B operation. Operation under these conditions allows the circuit to produce more power without exceeding the rating of the tubes.

The Drive Circuit

Since the output stage gain is less than unity in a cathode-follower circuit, a higher drive voltage is needed on the grids than in a circuit with less feedback. This higher undistorted voltage can be obtained without increasing the plate voltage of the drivers with the circuit
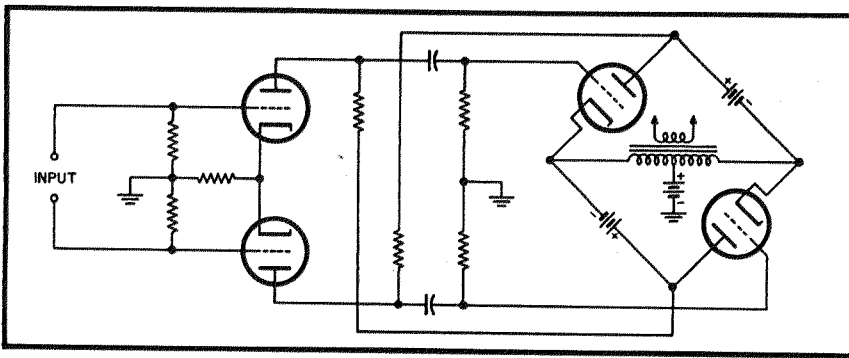
Fig. 2. Circuit diagram of output stage and driver stage.

shown in *Fig.* 2. In this circuit the B+ of the driver tubes is taken from the plates of the output tubes. This increase in B-supply due to the addition of one-half of the output signal voltage to the supply permits the driver tubes to operate linearly over a greater range of grid voltage than would be possible with the same fixed supply voltage.

B-Supply for Low-Level Stages

In the circuit diagram of *Fig.* 1 two power supplies are shown, both of which are above ground. The total output signal appears between the two power supplies while one-half the signal appears
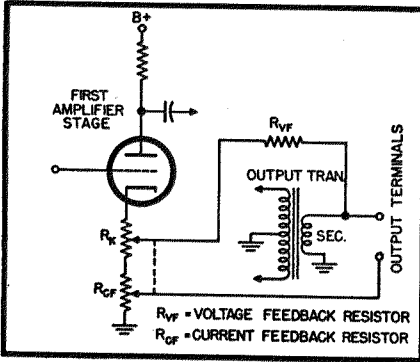

Fig. 3. Circuit diagram showing variable voltage and current feedback used to change internal impedance of the amplifier.

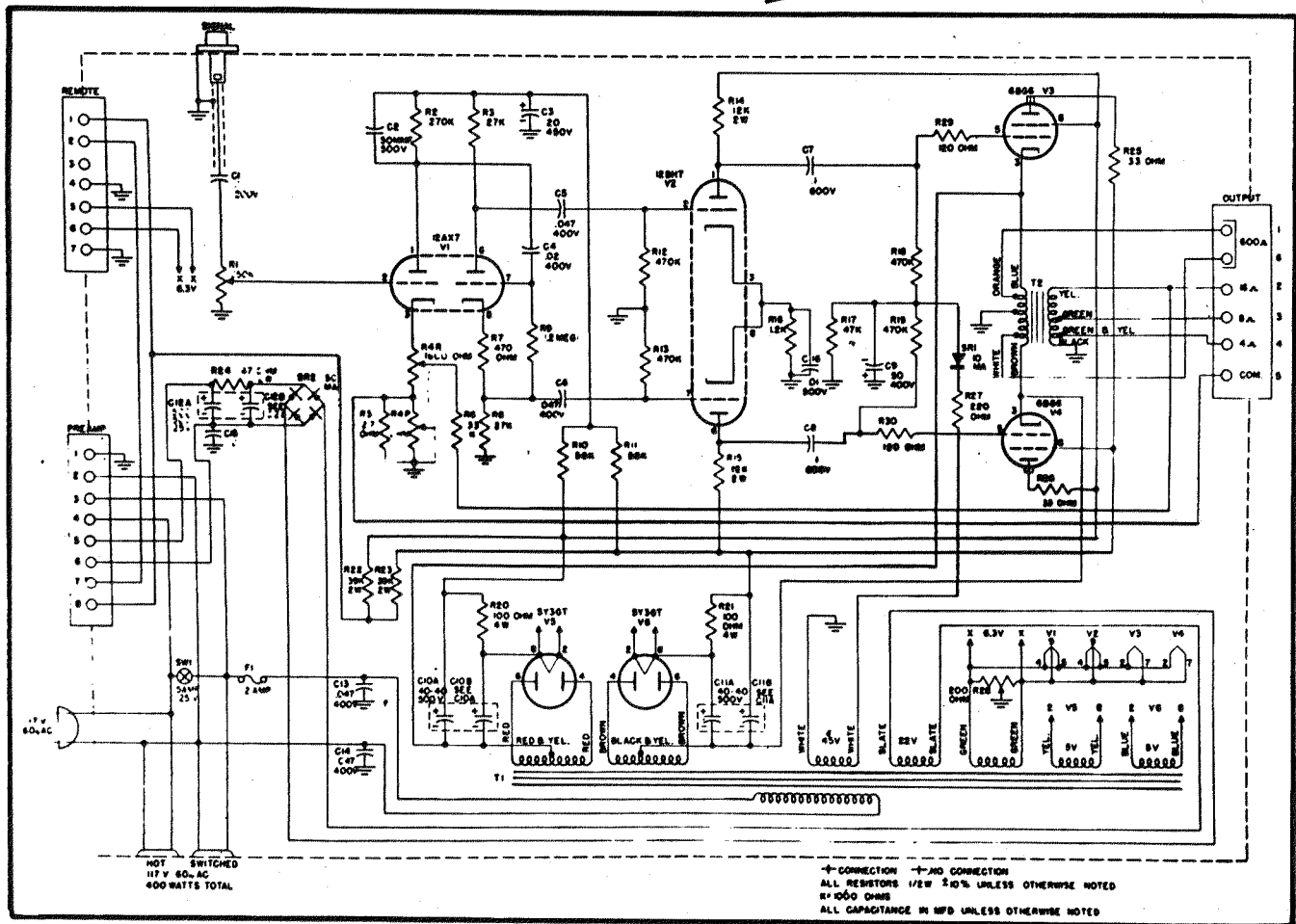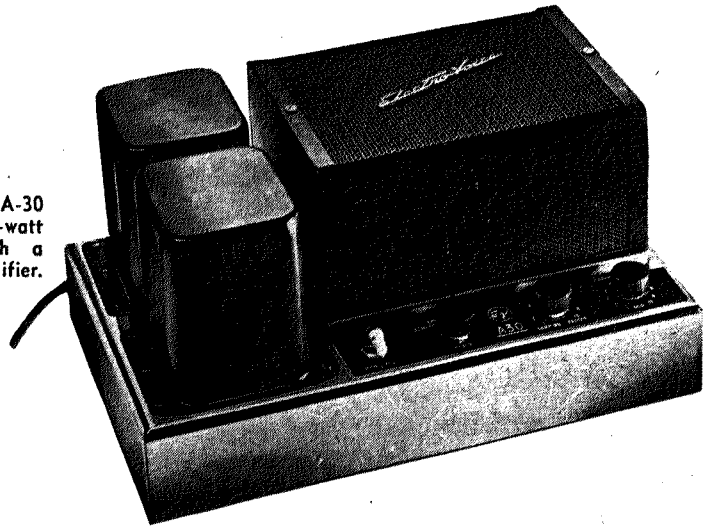Fig. 4. The A-30 amplifier, a 30-watt unit used with a remote preamplifier.

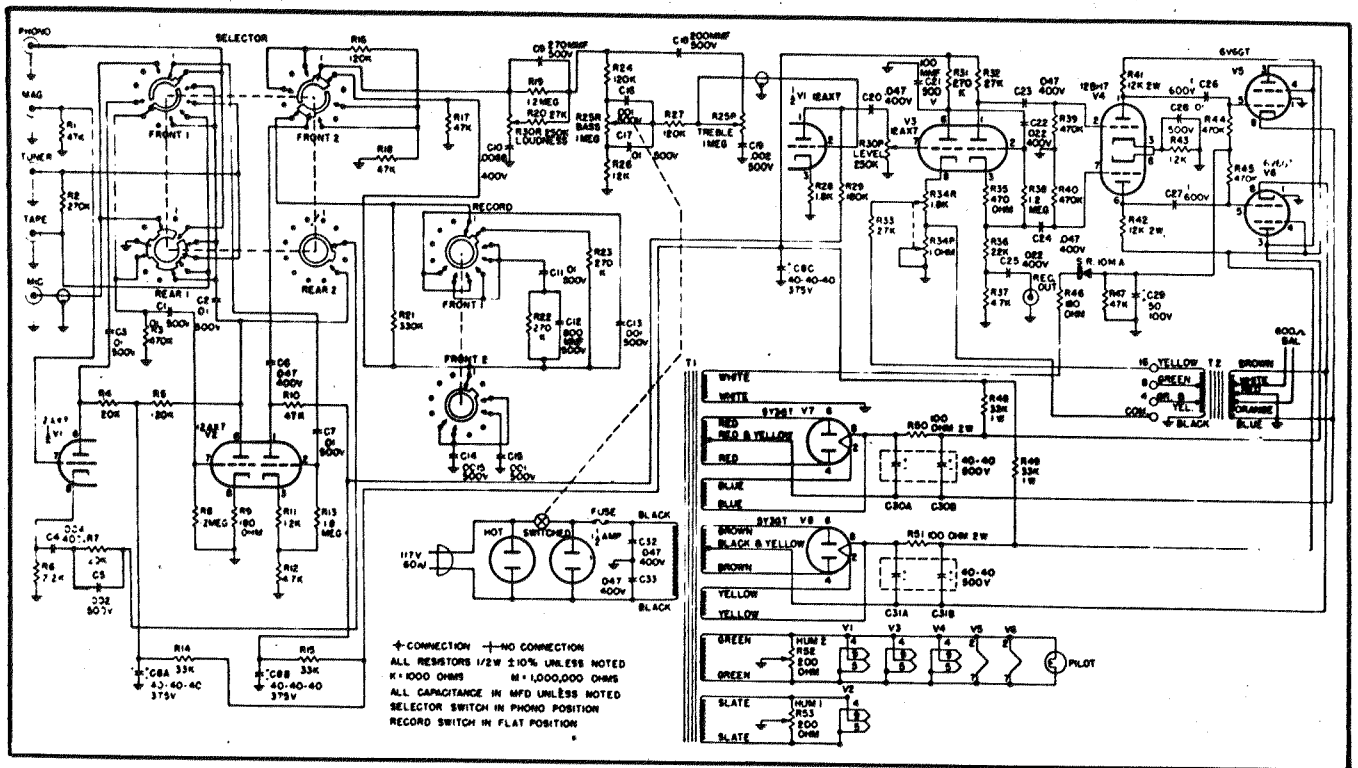Fig. 5. Schematic diagram of the A-30 amplifier.

Fig. 7. Over-all schematic of the A-20-C amplifier-preamplifier.

between each power supply and ground. The lower-level amplifier stages and phase splitter must be provided with a single power supply with the negative terminal grounded. *Figure* 1 shows how this is accomplished. Two equal resistors are connected to the two B+ voltages. At the junction of the two resistors a capacitor is connected to ground. No signal voltage exists from the junction of these two resistors to ground since the circuit is balanced. Any small out-of-balance signal is filtered by the capacitor. This provides a B+ for the lower level stages which is free from the signal in the output stage.

Variable Damping Factor

It is desirable to have the amplifier present the correct impedance to the speaker to achieve optimum speaker performance at low frequencies. This value of speaker critical damping resistance varies widely with different speakers and is dependent on such parameters as the flux density, type of enclosure, length of

conductor in the air gap, etc. In the finished model of the amplifier, means are provided which allow the internal resistance of the amplifier to be varied over a wide range. This variable internal resistance allows the amplifier to be adjusted so that it presents the optimum damping factor for critically damping any speaker combination. Damping factors greater than unity are achieved by varying amounts of negative *voltage* feedback from the output to the first stage cathode circuit as shown in *Fig.* 3. Conversely, damping factors less than unity are produced by varying amounts of negative *current* feedback obtained from the low resistance inserted in the speaker circuit. By combining the two types of feedback with the aid of a ganged potentiometer as shown, the overall feedback is maintained constant. The damping factor, however, is varied over a wide range. Needless to say, the maximum power available from the amplifier is independent of the damping factor and remains constant.

Performance

Several designs of amplifiers were developed using the basic theory explained in the preceeding paragraphs. These are currently available in the Electro-Voice, Inc. line of high-fidelity amplifiers. One of the units, the A-30, is shown in *Fig.* 4. The circuit diagram of this amplifier is shown in *Fig.* 5. It is a line amplifier designed to be used in conjunction with a remote preamplifier unit. Another unit, the A-20-C has a complete preamplifier section integral with the power amplifier, and is shown in *Fig.* 6. The operating specifications of the two units are shown in Table 1.

Figure 7 is the schematic of the smaller unit, showing the input circuitry, tone controls, and phono equalization circuits. Provision is made for both magnetic and ceramic or crystal pickups, and a high-gain "flat" input is provided for microphone input.
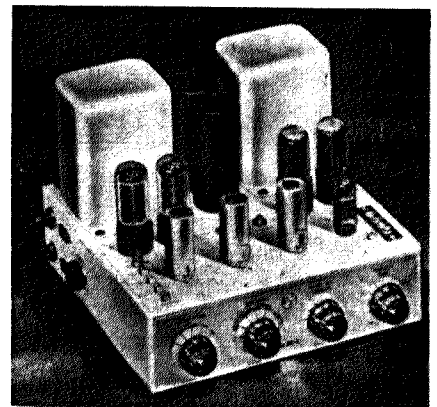
TABLE 1

AMPLIFIER PERFORMANCE

	A-30	A-20-C
Output Tubes	2-6BG6	2-6V6GT
Rated Output	30 Watts	20 Watts
Frequency Response	0.25 db	1 db
Harmonic Distortion at Rated Output	20-50,000 cps	20-20,000 cps
Intermodulation Distortion at Rated Output	Less than 1%	Less than 1%
	Less than 1%	Less than 1.5%
Hum and Noise	-90 db	-70 db
Total Feedback	31 db	33 db
Damping Factor	Between 0.1 and 15	Between 0.1 and 15

Fig. 6. The 20-watt model, A-20-C, with a complete built-in preamplifier.