Design of Class-B Drivers

The design of a transformer-coupled class-B driver is simplified by this author's approach

By W. H. ANDERSON, VE3AAZ

OPERATORS of amateur phone stations are often confronted with the problem of selecting a suitable driver and driver transformer for class-B audio amplifiers or modulators. The most common solution is to select, from a catalog or manufacturer's literature, a transformer designed for use with the particular combination of driver and modulator tubes being used. This method is not practical when:

1. The tubes are operated under conditions other than those specified by the transformer manufacturer;
2. The driver-modulator tube combination is not listed;
3. Driver-to-line and line-to-grid transformers are to be used.

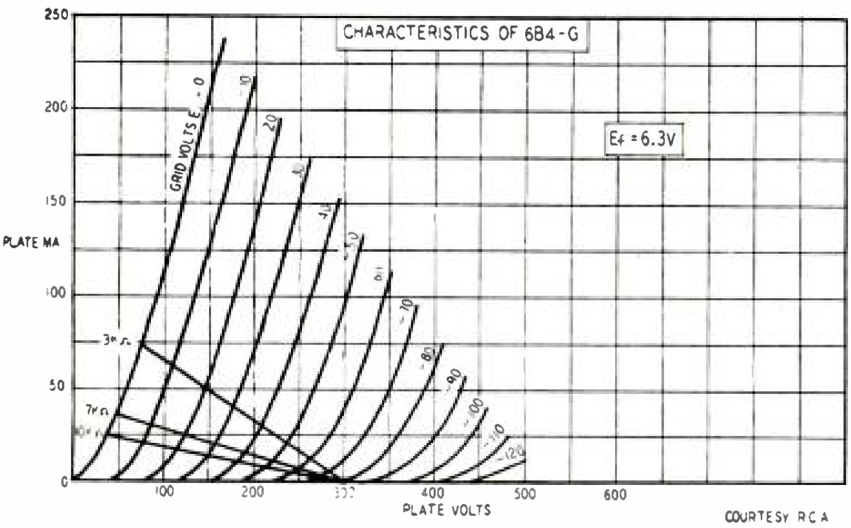

Fig. 1—Curves for this and other receiving tubes are in your tube manual.

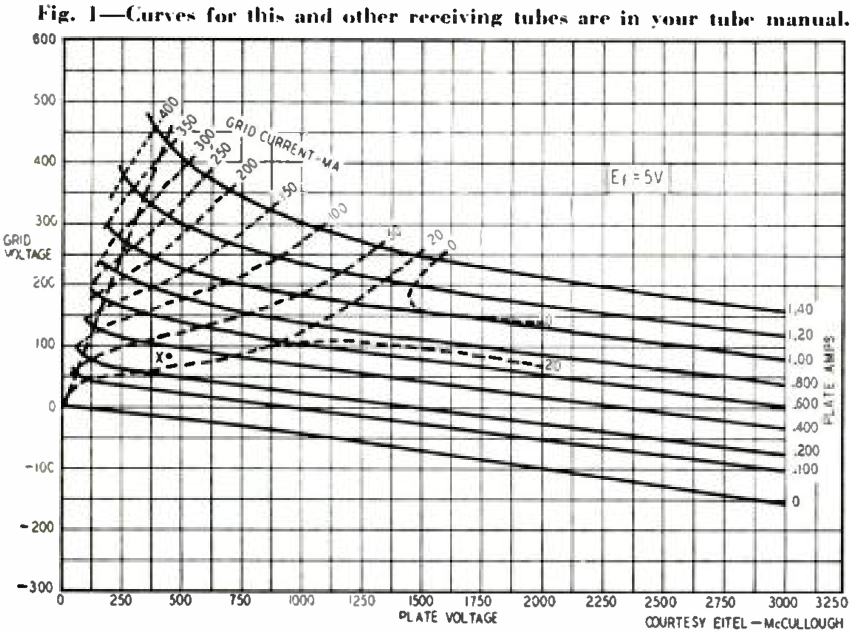

Fig. 2—Constant-current characteristics of the Eimac 75TH transmitting triode.

Consider a typical case where push-pull 6B4-G's are used as drivers for a class-B 75TH amplifier or modulator. Tube data shows that the 6B4-G's will deliver 15 watts of power when the effective load impedance (plate-to-plate) is 3,000 ohms, the plate voltage is 300, and 68 volts of grid bias is supplied from a fixed source. The 75TH's require 3 watts of grid drive when operated with 90 volts of grid bias and 2,000 volts on the plates. The peak grid-to-grid driving voltage is 350. Since there is a difference in the power in the primary and secondary of the driver transformer, transformer ratios cannot be calculated by comparing the primary and secondary voltages.

The grid circuit of a class-B stage presents a constantly varying load to the plate circuit of the driver stage. During one excitation cycle, the impedance of the grid circuit varies from a very low value to almost infinity and causes distortion which is intolerable in some instances. Distortion from this source is minimized by reducing the source impedance as much as possible. The driver transformer determines the impedance ratio between the driver plates and class-B grids; therefore, the greater its step-down ratio, the smaller will be the source impedance as seen by the grids.

We have found at VE3AAZ that distortion is minimized when the driver is designed to deliver just enough power to drive the class-B stage when its (the driver's) grids are fully excited—driven to zero volts by the speech amplifier. This condition is met by raising the driver plate-to-plate load impedance far above its normal value. This provides for a higher than normal step-down ratio between the driver plates and class-B grids. Increasing the driver load impedance decreases the voltage developed across the secondary load. It is important to remember that, while the voltage ratio varies directly as the turns ratio, the impedance ratio varies as the square of the turns ratio. Thus when a transformer is selected to deliver just enough voltage to drive the class-B grids, the source impedance (driver plate resistance) will be lowest —a requirement for good regulation.

The 75TH's require 3 watts of grid drive. Since in this case—as in most others—the grid driving power is stated as an r.m.s. value, peak driving power will be twice as great or 6 watts. This power is delivered to first one grid, then the other, and is provided by one-half the voltage developed across the entire secondary. Knowing the grid power and voltage, the grid impedance can be calculated by Ohm's law. Since the peak grid-to-grid voltage is 350, each half of the secondary winding will develop 175 volts and the grid impedance (E^2/W) is $175^2/6$ or 5,104 ohms.

The next step is to draw trial load lines on the characteristic curves of a 6B4-G as shown in Fig. 1. One end of each load line is the point where the plate-voltage line intersects the zero-current line and the other end is on the Ec (grid voltage) = 0 curve. The resistance of a load line is determined by subtracting the minimum plate voltage from the maximum plate voltage and dividing the result by the maximum current. Refer to the 3,000-ohm load line on Fig. 1. Note that maximum plate voltage is 300 and minimum 75. As the voltage swings from 300 to 75, the plate current changes from zero to 75 ma so the resistance of the load line is 300—75/.075 = 3,000 ohms.

Peak power output from a given load resistance is determined from the familiar I^2R relationship, where I is the plate current at the point at which the load line intercepts the Ec = 0 grid bias curve. The 75TH grids require 6 watts peak power for full output. However, since the power loss in the driver transformer may run to 20%, the driver must be designed for approximately 7.5 watts peak output. Since the 7,000-ohm load line intercepts the Ec = 0 curve at 32 ma, the power output is $(.032)^2 \times 7{,}000$ or 7.18 watts.

The load resistance for a single tube being 7,000 ohms, the plate-to-plate load will be four times 7,000 or 28,000 ohms for a push-pull stage. The grid impedance is 5,104 ohms, so the transformer turns ratio (primary to one-half secondary) is

$$\sqrt{\frac{28{,}000}{5{,}104}} = 2.3 \text{ to } 1.$$

If the speech amplifier-driver combination is located at a point remote from the class-B stage, a plate-to-line and line-to-grid transformer combination will be required. Disregarding the power loss in the second transformer, the over-all turns ratio should remain the same. Assuming a 500-ohm transmission line, the plate-to-line transformer will have a turns ratio of 7 to 1 and the line-to-grid transformer will have a ratio of 2.3 to 7 between the primary and one half of the secondary.

Calculating driver requirements

Manufacturers do not always list grid-drive requirements, and this must be calculated from available data. Consider the class-B operating data for the 75TH:

D.c. plate voltage	2,000
Max. signal d.c. plate current	225 ma
D.c. grid voltage (negative)	90
A.f. grid voltage	350

Each tube is carrying 112.5 ma or one-half the total plate current; however since the stage is operating class B, the peak instantaneous plate current will be three times as high or approximately 336 ma. The peak instantaneous grid voltage will be one-half the a.f. grid voltage minus the d.c. bias or 350/2—90 = 85 volts.

The crest operating point X (Fig. 2) is the intercept of the peak grid voltage and the peak plate current values. This point shows the peak grid current to be 35 ma. Knowing that this grid current is produced by the voltage across half the driver transformer secondary, we can compute driving power as the product of 175 volts and .035 ampere (35 ma) or 6.1 watts. Similarly, we compute the grid impedance as 175/.035 = 5,000 ohms. Note that these values agree with those used in previous calculations, but the grid-drive factor does not take into account the power loss in the driver transformer.

Cathode-followers as drivers

Occasionally, a push-pull cathode-follower stage (Fig. 3) is used as a driver for a class-B amplifier. This arrangement does a good job because of the high degree of degenerative feedback due to coupling between the input and output circuits. The major disadvantage of this circuit is that the input signal must equal the sum of the bias and desired output voltages.

Load impedance calculations generally consist of finding a combination of plate voltage and a reasonably low load impedance that will provide the required output. The stability or voltage regulation of a cathode-follower is such that the load impedance has little effect on the output voltage.

The excellent voltage regulation of a cathode-follower can be seen when its performance is compared to that of a conventional plate-loaded amplifier operating with identical loads and plate and bias voltages. If the regulation of an amplifier is perfect, the output voltage will vary in direct proportion to the input voltage.

Take two amplifiers using triode-connected 6L6's, one connected as a conventional plate-loaded amplifier and the other as a cathode-follower. Consider what happens in each when the signal voltage is halved and the reflected plate load changes from 2,000 to

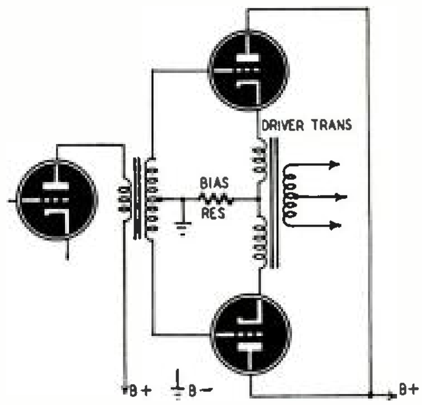

Fig. 3—A cathode-coupled driver stage.

5,000 ohms (8,000 to 20,000 ohms plate-to-plate), as it might when the class-B stage stops drawing grid current. The change in circuit performance is shown in Fig. 4 (characteristic curves for triode-connected 6L6's with 2,000- and 5,000-ohm load lines drawn in) and in the table below.

Drive (volts)	Reflected load (ohms)	Output (volts)	Point (Fig. 3)
Cathode-loaded amplifier			
20	2,000	130	A
10	5,000	115	B
Plate-loaded amplifier			
150 (20+130)	2,000	130	A
75	5,000	72	C

That the cathode-follower provides better voltage regulation is evident when we realize that the output voltage should have dropped to 65 (one-half its initial value) in both cases when the drive voltage was halved.

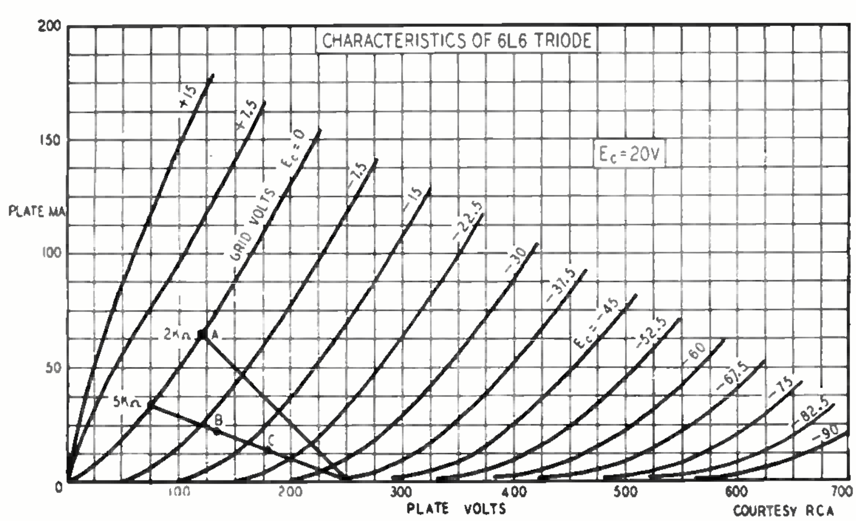

Fig. 4—Load lines compare performance of plate- and cathode-loaded amplifiers.