

Fig. 6. Operating conditions actually used in the 12BH7 for the MC-30 amplifier, showing how the bootstrap increases the available swing the tube can handle, by a factor much more than it increases its gain.

four times the d.c. value, in this particular example. In other cases it may be more or less according to the degeneration produced in the cathode circuit of the output stage.

This improves the available swing in two steps. First it increases the operating plate voltage and current by allowing a lower actual value of resistor to be used. Then it increases the available audio swing by raising the effective value of this coupling resistor. This is illustrated by means of dynamic load lines in Fig. 6.

Another way of viewing this is that in a sense now the driver stage only has to provide the grid-to-cathode swing in its plate circuit, instead of the complete grid swing. This being the case one would imagine at first sight that the positive feedback would undo some of the beneficial results of the negative feedback. The reason this does not happen is that the positive feedback is not effectively so great as the negative feedback, although at first sight it might appear this way, because of the change of the effective value of resistance in the plate circuit of the driver tube. Also the positive feedback is not materially dependent on output loading, as is the negative feedback.

In this particular case the plate resistance of the drive tube is in the region

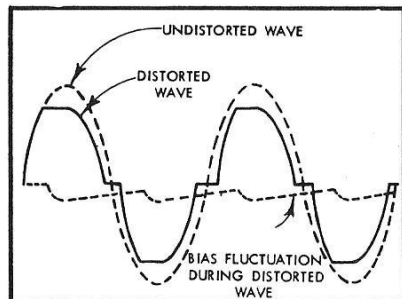


Fig. 7. Kind of distortion often produced in a fixed-bias amplifier, due to grid current biasing back.

of 7500 to 8000 ohms and the plate coupling resistor is 12,000 ohms. This means the realizable gain of the tube, without positive feedback, would be approximately 3/5 of its amplification factor. So increasing the effective resistance of the plate coupling resistor by positive feedback can only increase the gain of the drive stage by a maximum of 5/3 (assuming the effective value is increased to infinity).

Bootstrap Circuit

While this bootstrap circuit only increases the available gain of the drive

need to have close tolerance to maintain uniform operating points.

It has often been noted that class-B output circuits often do not seem to give so much output as circuits using nearer to class-A operation, using automatic or cathode-bias circuits. The reason for this is traced to what happens when overload begins to occur. The automatic-bias circuit self-compensates for overload by producing cathode degeneration of the overload component of the signal. With fixed-bias circuits, which have to be used for class-B operation, the cathode circuit returns to ground. If the grids make any excursion positive at all, this will produce a negative charge momentarily on the coupling capacitor from the driver plate. This will invariably overbias the tubes for a period of more than the average audio cycle and thus produce quite noticeable distortion very quickly.

Usually the grid resistor has to be of fairly high value to prevent loading down the drive stage. This is still true with unity coupling. Although a 12,000-ohm resistor produces an effective value of 48,000-ohms due to the positive feedback, the grid resistor has to be returned virtually to ground (actually to fixed bias negative) and consequently its effective value is the same as its actual value. If a large value resistor, in the region of 330k, which is usually recommended for this position, is used, the biasing-back effect will last for at least

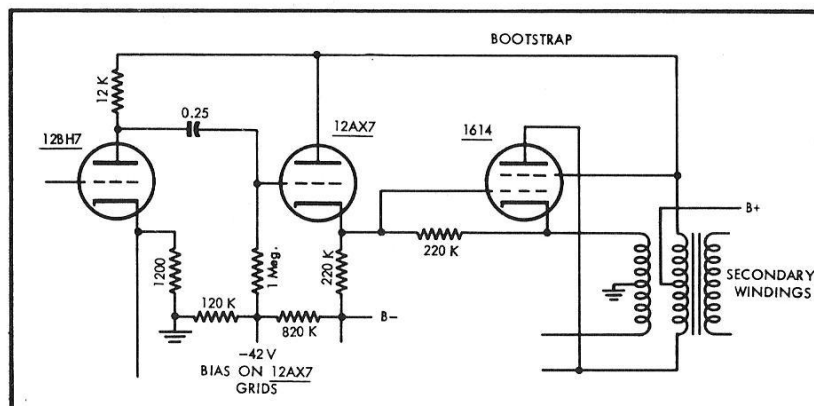


Fig. 8. Interposing a cathode follower (the 12AX7) between the bootstrap drive (12BH7) and the output tube (1614) grids completely prevents the kind of distortion shown in Fig. 7.

stage by approximately 50 per cent it increases its available swing to considerably more than double, because it virtually extends the region of linear operation by allowing a greater grid input swing to be effective. The steeper slope of the 12,000-ohm load line runs into cutoff much sooner than the shallower slope of the 48,000-ohm load line.

The plate resistors for the bootstrap drive circuit need to be of adequate power rating, because the increased efficiency of the circuit raises the available plate-circuit dissipation. They also

a cycle of the audio waveform, consequently the next excursion through crossover will show crossover distortion, as illustrated at Fig. 7.

This can be avoided by using a capacitor value such that the discharge time is shorter than one period of the audio waveform but this would mean an excessive low-frequency loss due to the combination of coupling-capacitor and grid-resistor values. This may be offset to some extent by the over-all negative feedback, but it increases the demand on