# The fixed-bias Story

*Is fixed bias really better? Tube data say yes;*
*comparative listening may say no.*
*Who's right and why?*

### by Herbert Ravenswood

*Words of wisdom from 1958…*

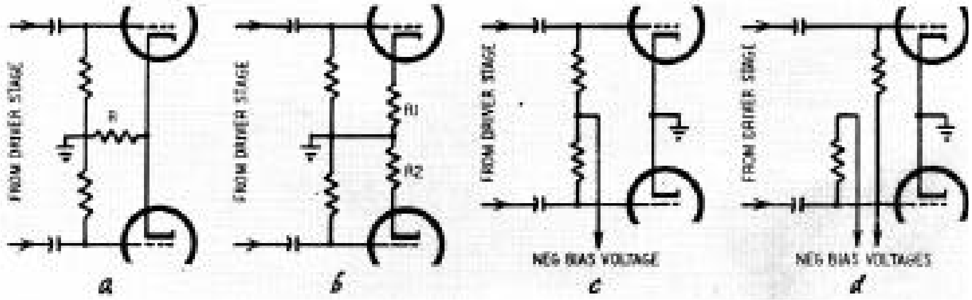

Fig.1—Basic methods of biasing: a, b—self-bias; c,d—fixed bias

If we examine typical output tube data, we find that it is often profitable to use fixed bias, as opposed to self-bias, in an output stage. Fig. 1 is a comparison of the two basic circuits. Figs. 1-a and -b show automatic or self-bias circuits using common and separate resistors, respectively (common resistor R and separate resistors R1 and R2). Figs. 1-c and -d show fixed-bias circuits (without the supply; its exact circuit is not important). This too can use common voltage (Fig. 1-c) or separate voltages (Fig. 1-d). Let's see what difference is involved for some typical output tube types.

Take first the Mullard EL84/6BQ5, which is a miniature output pentode intended for high-power auto-radio and similar uses. Some manufacturers work two of these tubes in push-pull for a small power amplifier output, about 15 watts. The conditions stated by the manufacturer list the same power output, whether self- or fixed bias is used, with a 300-volt plate supply and pentode operation. For each, maximum power output is 17 watts.

Plate and screen currents at maximum output are 92 and 22 ma, respectively, whichever method of operation is used. The big difference is in the quiescent, or zero-signal, plate and screen currents. For fixed bias these are 72 and 8 ma.

While both the circuits give the same maximum power output, considerable economy is possible in the design of a power supply, as well as in power consumption during operation, by using the fixed-bias arrangement.

Next let's look at the 6L6, 5881 and 807. Using self-bias and operating a pair in class AB1, the maximum output for any of these tubes is 24 watts. The 6L6, using fixed bias, will go to 26.5 watts in AB1 or 47 watts in AB2. The 5881 will also put out 47 watts by driving into the positive grid region. The 807, with 600 volts on its plate and 300 volts on its screen, will deliver 80 watts in AB2.

We have some tubes that exhibit an even bigger difference. The 6550, working as a pentode with self bias, using a 400-volt plate supply and a 275-volt screen supply, gives a maximum of 55 watts. Going over to fixed bias, with 600 volts on the plate and 300 volts on the screen, we can get 100 watts.

### Why the difference?

The reason for the difference is not too difficult to deduce. We could undoubtedly set up a circuit, with any of these tubes, to give the same maximum output on self-bias, using the same plate and screen voltage supplies that are permissible for fixed bias. The tubes would be quite OK while delivering maximum output. As soon as the input signal is removed, bias will drop considerably, allowing plate and screen current, under the zero-signal condition, which will exceed the permissible dissipation of the tube. Fixed bias keeps the tube within its dissipation rating all the way from zero signal to maximum output.

These are the figures from tube manufacturers, and countless engineers in different companies have set the tubes up and verified these operating conditions. Many amplifiers have been built, using fixed-bias conditions to get a bigger output. But, for all this evidence of the advantage of fixed bias, probably an even larger number of people have made comparative tests of amplifiers using these different circuits. Their impressions frequently contradict the test-bench figures.

Many readers have asked the reason for differences they have observed. And I have been present several times at comparative tests that have shown the same thing. What is the reason? Why should listening tests contradict, sometimes dramatically, the carefully conducted engineering tests?

First, the difference in the measured output is not more than 3 or 4 db, even in the most drastic cases, and this represents just about an audible difference. But surely, even then, we should be able to hear that the maximum output of the fixed-bias amplifier is just a little bit louder than that of the self-bias amplifier, before it goes into distortion? The difference appears to depend upon how it goes into distortion.

When you make comparative tests on the output of two amplifiers feeding the same speaker you naturally tune the gain control up until you hear something happen that suggests it is “reaching the top.’ The reason for the big observed difference in performance is due to just what happens when these amplifiers reach the overload point.

Practically all modern amplifiers use resistance-capacitance coupling between the driver and output stages. True, there are types which do not and we shall come to these a little later. However, the comparisons in which the observed difference seem to contradict the measurements are those in which the drive stage is R-C coupled to the output stage.

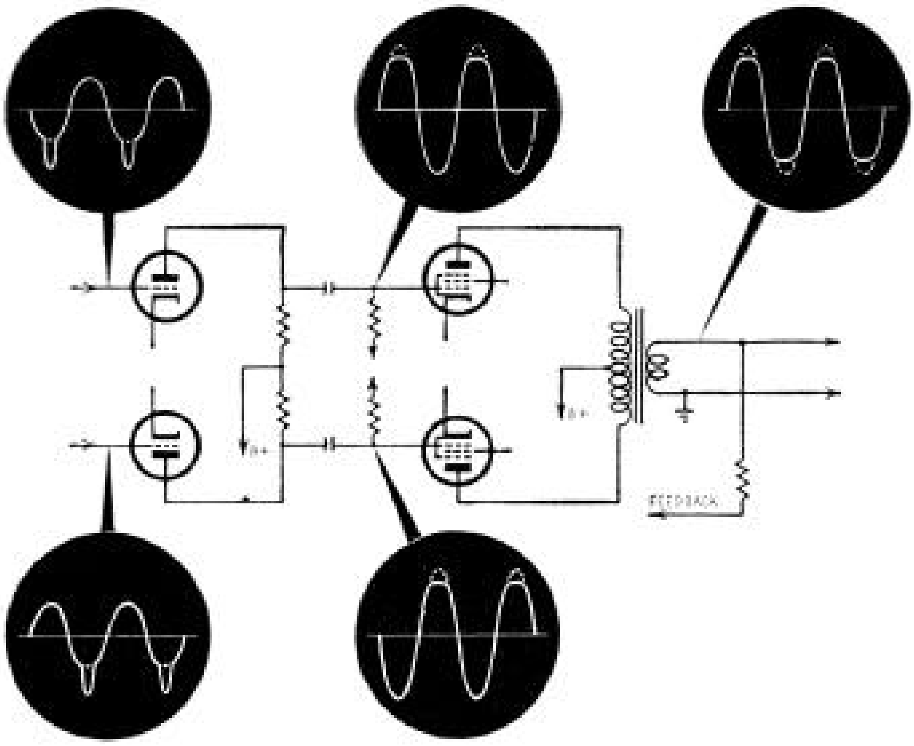

Fig.2— How feedback aggravates the changes brought about in any amplifier when clipping begins

As soon as the output stage reaches the clipping point, in either type of amplifier, the output grids start to conduct current. At the same time the loading effect of this current on the driver stage considerably reduces amplification of audio voltage beyond this grid-current point. This means the feedback is reduced. Consequently, the input voltage received by the driver rises in a more rapid peak. This causes a rapid increase of grid current at the output stage grid. This is illustrated in Fig. 2 (The circuit if Fig. 2 does not show biasing arrangements, because the action depicted occurs whichever method of bias is used.)

This positive grid current causes other things to happen, too. As soon as it begins, it produces a negative bias, due to the charge on the output side of the coupling capacitor between driver and output stages. So, as soon as the clipping point is reached, very little extra input is reached, very little extra input will produce a considerable negative bias voltage due to this grid current. Now for the difference caused by different methods of biasing.

### Biasing effects

In the fixed-bias circuit, this additional negative voltage usually biases the tubes back well beyond cutoff. The fixed bias is already chosen to operate the tubes in AB, if not nearer to a true class B. So a big piece of extra negative bias pushes them beyond cutoff, causing crossover distortion. Pushing the output tubes back further toward cutoff also reduces the current drain on the B-supply which, if regulation happens to be not too good, will cause the voltage to rise. This may slightly increase the gain of the amplifier's earlier stages and results in an even bigger grid drive to the drive stage. Thus on several counts the effect is cumulative. As soon as a little bit of clipping starts, in a fixed-bias amplifier, the waveform almost jumps from a practically pure sine wave to the kind of wave shown in Fig. 3.

The sudden change is because the effect is cumulative. As soon as a little bit of grid current starts to flow, the gain of the earlier part of the amplifier is boosted by a rise in B-voltage. The feedback disappears as soon as grid current starts to flow and causes the driver stage's input voltage to rise more rapidly. The whole thing acts almost like a triggered oscillation. As you turn the input to the amplifier up very slowly, you fond the waveform goes steadily up until clipping quite suddenly goes from a nice sine wave to a severely distorted one. Then, as you turn the input down again, the level at which it reverts to a sine wave is considerably below that at which it became distorted.

Removing the feedback reduces some of the cumulative effect but makes crossover distortion worse because feedback does

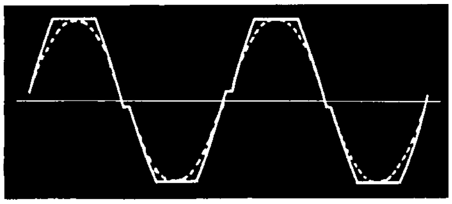

Fig.3—The kind of distortion that starts suddenly in a fixed-bias amplifier, with feedback.The solid line represents a very slight increase of input from the sine wave.

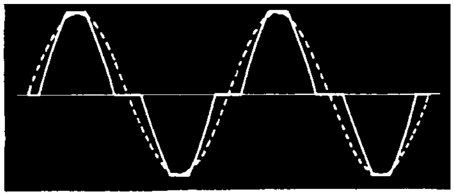

Fig.4—Removing feedback from a fixed-bias amplifier produces this change in waveform when clipping starts

help reduce crossover distortion although it exaggerates clipping distortion. Thus, without feedback, the same fixed-bias amplifier would produce a waveform more like that in Fig. 4. Obviously, neither of these waveforms (Fig. 3 and 4) will sound very good.

In the fixed-bias amplifier, however, when this new source of negative bias due to clipping comes along, plate current naturally drops. This means the self-bias component of the negative grid voltage (actually positive cathode voltage) is reduced to compensate for the added negative voltage at the grid. The plate current will be somewhat less than before grid current commenced, but not enough to produce the exaggerated crossover distortion that occurs with fixed bias. Consequently, the effect of clipping is to readjust the bias and avoid a continuation of clipping on successive waves.

Due to the slightly increased bias, gain of the output stage is reduced throughout the entire waveform and the clipping does not become too severe. This means the self-bias amplifier can probably handle from 3 to 6 db more maximum input before running into the serious kind of distortion that occurs with the fixed-bias amplifier.

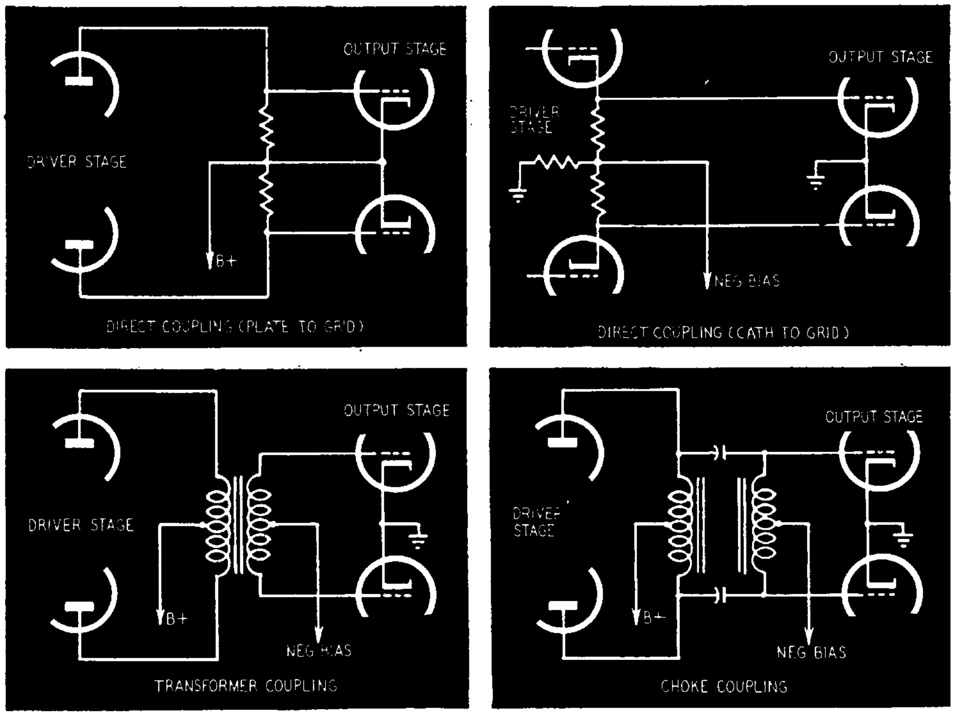

Fig.6—Types of coupling that avoid “slide-back” effect of fixed-bias circuits

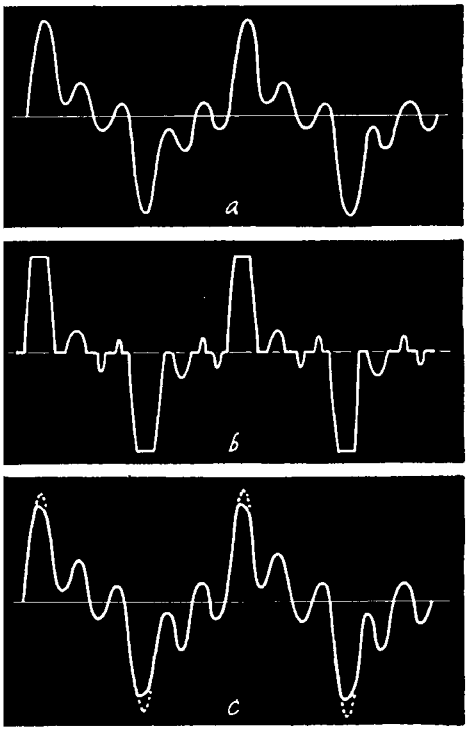

Fig.5—Comparison of fixed-bias and self-bias amplifiers on a composite wave: a—input waveform, undistorted; b—output waveform just beyond distortion point, fixed bias; c—output waveform just beyond distortion point, self-bias. Dotted portions represent main distortion

Numerous tests have shown that we do not judge the loudness of a particular program by the maximum signal level on peaks, but by the average or rms level of the whole programs. So, if we can turn the average loudness up by 6 db on a self-bias amplifier before distortion begins to show, while there is practically no margin on a fixed-bias amplifier, the self-bias job will obviously sound a little louder.

In other words, the self-bias amplifier tends to exert a sort of avc action on the peaks to avoid distorting them too much, provided they are not too big. The fixed-bias amplifier, on the other hand, almost triggers itself into a form of distortion as soon as the maximum level is reached.

Notice that the use of feedback over the fixed-bias amplifier does not materially improve the situation. It alters the kind of distortion rather than eliminates it,and the kind of distortion that shows is actually exaggerated by the feedback rather than reduced.

A further reason for the difference in sound between fixed-bias and self-bias circuits is that the fixed bias goes into distortion and stays there until bias is restored to normal, a little while after the overload

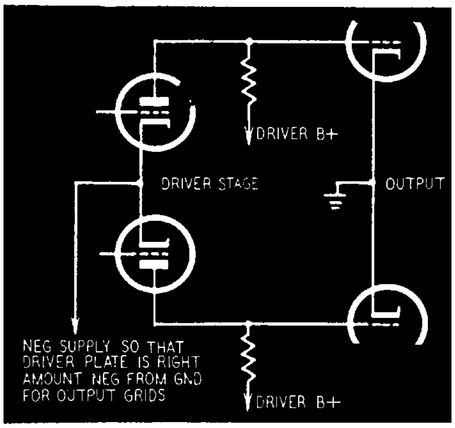

Fig.7— The problem of direct coupling is the number of extra power supplies needed and obtaining the right bias for the output tubes

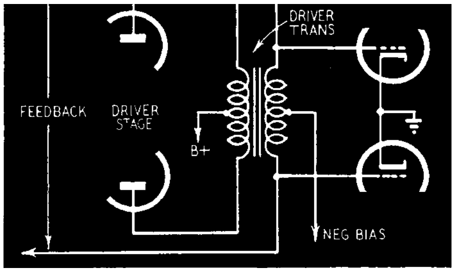

Fig.8—Possible approach to improved design using transformer coupling from driver stage and feedback taken from driver transformer

point has gone. Therefore, the smaller parts of the waveform following the peak signal in an actual audio program are distorted as much as the peak signal. With self or automatic bias, this is not so. If distortion occurs at all, it is only on the peaks. As soon as the slide-back biasing effect has passed, the automatic bias action of the cathode resistor readjusts the circuit and avoids excessive distortion of the in-between signal. This difference is illustrated by Fig. 5.

### How to use fixed bias

There is just one kind of circuit in which fixed bias can profitable get bigger output. This is shown in Fig. 6. If direct, transformer or choke coupling is used between the driver and output stages, this additional grid-bias effect does not occur. In such a circuit, appropriate design of the driver stage permits power drive or class-AB2 operation and gets the high maximum outputs that are available with such circuits.

However, this kind of circuit has become unpopular due to the difficulty in applying feedback over an amplifier with two transformers in it. The alternative of direct coupling is difficult because it involves us in supply troubles. The supply voltage of the drive stage also has to provide the fixed bias for the output stage (Fig. 7). However, if the voltages of such an amplifier can be satisfactorily stabilized, the amplifier can then use overall negative feedback and will give the maximum rated output of the fixed-bias arrangement without the tendency to drastic distortion we have discussed.

Transformer and choke-coupling methods were quite popular in amplifiers a little before feedback came so much to the fore. In those days I remember class-B amplifiers without feedback which had a very acceptable output waveform. One of these delivered 250 watts audio, using a pair of transmitting triodes for output tubes with only 100 watts dissipation each. Both driver and output transformer needed very careful design and were costly to produce, but not too costly when the large output is considered. The distortion right up to the maximum of 250 watts was well within 5% (this without any feedback, because feedback was not applied in those days).

Contrary to some belief on the subject this kind of amplifier does not prove at all critical of loading. Any load value, higher than the nominal resistance which absorbed 250 watts at maximum output, would give a satisfactory output waveform. If load resistance was doubled, the power it received would be approximately halved but the waveform would be just as good.

The principal reason why such a circuit would not be used today is that it is not practical to apply feedback over such an amplifier, with its two transformers. it is not impossible to reduce distortion considerably by applying feedback from the driver stage to some earlier point in the amplifier, thus still using only one transformer in the feedback network (Fig. 8). This could serve to minimize the distortion caused by grid current loading in the drive stage. This may be “heresy’ but it's an idea we have not seen tried.

However, this approach could not be expected to get the distortion figure down to the fraction of 1% that is popular for modern amplifiers. But it is not impossible that such an amplifier might sound even better than some of the modern amplifiers due to a more satisfactory overload characteristic.

Reasons have been given why standard test signals, such as a pure sine wave at steady intensity or the kind of waveform delivered by an intermodulation test set, so not represent the behavior of the amplifier on audio program material. What we have discussed in this article reaffirms this inadequacy from another angle and emphasizes the importance of trying the amplifier out on actual program material before concluding that the engineering test means we have a better amplifier. END