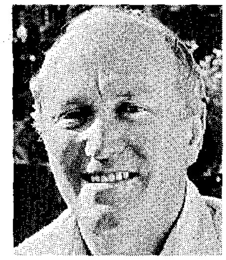
VINTAGE RADIO

By JOHN HILL



The importance of grid bias

Correct grid bias is vital if valve radio receivers are to function properly. Here's a rundown on how it works and what to look for when restoring vintage receivers.

Many years ago I built a little 2-valve battery receiver called "Tom Thumb". It was an old "Radio and Hobbies" project that incorporated a 1T4 regenerative detector, followed by a 3S4 audio amplifier which drove a pair of high impedance headphones. It was built from the circuit diagram only, without instructions, using a small output transformer and low impedance phones instead of the specified 2000Ω headphones.

There was one part of the circuit that, at the time, made no sense to me at all. Why have a parallel connected 1500Ω resistor and 10μF electrolytic from "B" battery negative to chassis? (see Fig.1.). What could such an arrangement possibly do when "B" negative usually went straight to chassis. Well, it had on my previous home built 1-valve receivers.

In my "wisdom", I chose to leave out this part of the circuit and connected "B" negative directly to chassis due, in part, to the fact that neither a 1500Ω resistor or a 10μF electrolytic were on hand at the time. Besides, their inclusion seemed so unnecessary.

The set was built and it worked reasonably well. Just as I thought – the extra components were put into the circuit to confuse novice receiver builders.

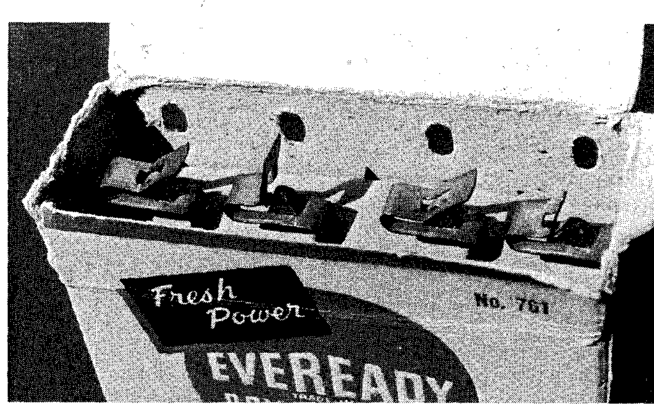
However, while listening to my new creation it was noticed that the 3S4 output valve was decidedly warm. This caused some concern because I knew, even back then, that battery valves didn't normally run hot.

The circuit was checked and everything was in order except for the two "unnecessary" components.

When a milliamp meter was placed in series with the 90V "B" battery it indicated a drain of 20mA. That is perhaps more "B" battery current than a valve portable would draw while driving a loudspeaker. Could it be that those unnecessary components had something to do with the problem?

After the 1500Ω resistor and its accompanying 10μF capacitor were added to the receiver, three changes were immediately apparent: (1) the B battery current dropped to less than 5mA; (2) the output valve operated at a much lower temperature; and (3) a degree of audio distortion (originally assumed to be normal for such a simple set) vanished. The mystery components were not as unnecessary as originally thought!

At the time, my lack of knowledge



This old Eveready "C" battery contains three size "D" cells wired in series. The close-up view (above) shows the battery connections. The terminals, from left to right, are 0V, -1.5V, -3V and -4.5V.

regarding basic theory prevented me from knowing what the resistor/capacitor combination actually did. Accordingly, I made a very bad error of judgement by leaving them out – but learnt a good lesson by doing so.

Negative grid bias

As some readers would be aware, the reason for the resistor was to create a negative bias voltage for the control grid of the output valve. This would allow the valve to work under the conditions for which it was designed. Without grid bias, the valve overheated, consumed large amounts of "B" battery current and, most important, created considerable distortion. Correct grid bias is important!

This matter of grid bias raises two broad questions. Why do valves require a negative potential on the control grid or, more accurately, between grid and cathode. And, secondly, how are negative volts obtained when the main supply voltage – from the "B" battery – is positive? These are good questions and I will try to answer them as best I can.

First, why is the grid voltage necessary? If one spends time looking through valve data books, a lot of reference is made to "characteristic curves". In simple terms, a characteristic curve is a line plotted on a graph which shows the relationship between changes in grid voltage and changes in plate current. Each type of valve has its own set of characteristic curves for a given range of plate voltages.

A characteristic plot is not uniform: it has a curved section at the bottom (the "toe") and another curved section at the top (the "shoulder"). Between these two sections is a substantially "straight" section.

If a valve is correctly biased (typically at the midpoint), the voltages on the grid will be confined to the straight section of the curve and the valve will operate with minimal distortion. It will also draw the specified amount of plate current. However, if the valve has insufficient bias, the plate current will increase and there will be distortion.

Conversely, if it has too much bias, there will be insufficient plate current and this will also give rise to distortion. This distortion is particularly serious in the case of output valves.

Note that the grid potential – in fact the potential of all valve electrodes – is always measured in relation to the cathode. Almost all valves need some negative bias on their control grids in order to function properly. Ignoring this fact, as I did with the previously mentioned "Tom Thumb", can lead to all sorts of problems.

Of course, there are exceptions. Some special high-mu (high gain) type valves are designed to function with minimum plate current without negative bias. They are designed for class B operation in push-pull output circuits.

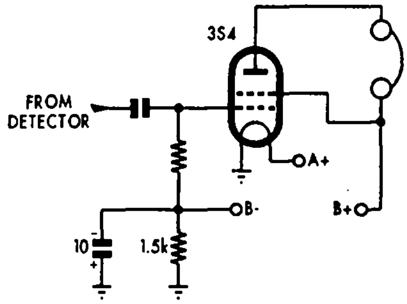


Fig.1: the back-bias circuit of the "Tom Thumb" radio receiver used a 1500Ω resistor in parallel with a 10μF capacitor.

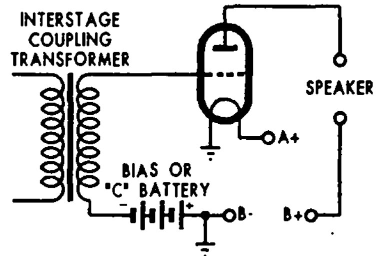


Fig.2: many battery valve sets used a "C" battery to apply negative bias voltage to the control grids.

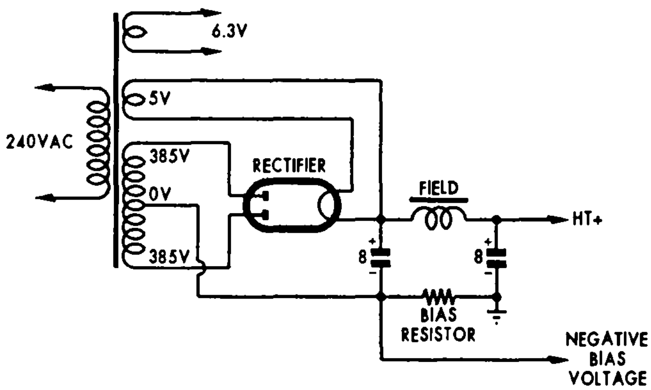
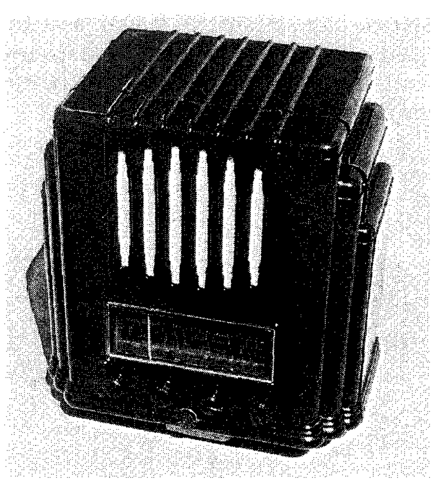


Fig.3: a typical back-bias circuit as used in many AC-powered receivers.



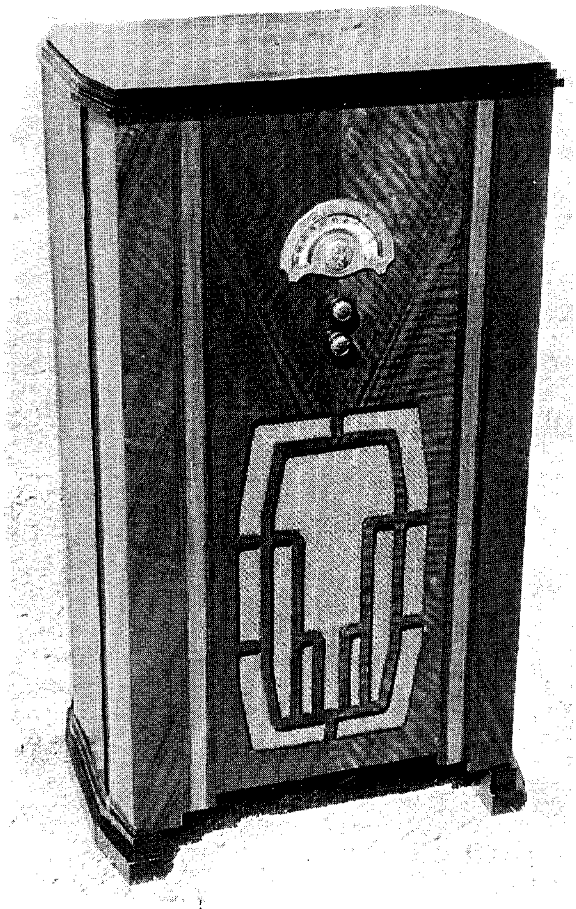
This battery-model late 1930s Radiola uses a 4.5V tapped "C" battery for its grid bias requirements.

Battery bias

This brings us to the second point in this discussion; the exact circuit mechanism by which an appropriate negative voltage can be applied to the grid(s). There are a variety of arrangements but one point is paramount – the basic requirement is to apply the required negative voltage to the grid with respect to the cathode.

Valves have always needed to be correctly biased but, back in the dim past, in the era of battery receivers in the 1920s, the need for correct bias was not always fully understood. If it was used at all, the usual procedure was to add a separate bias battery (typically 4.5V) to the circuit. This battery was referred to as the "C" battery and it was connected as shown in Fig.2.

Battery bias is referred to as "fixed



bias" because the bias voltage remains constant regardless of the slowly diminishing "B" voltage, which is not the ideal situation. There is virtually no current drain from a "C" battery. Its sole purpose is to supply the control grid with a negative potential.

It is easy to understand battery biasing – one only has to look at the circuit diagram of Fig.2 to see where the negative volts come from. If "B" negative and "C" positive are at the common point, then the negative end of the "C" battery must be at a negative potential with respect to this point.

Checking the value of bias resistors is part of any radio restoration. Shown here is a restored early 1930s 6-valve superhet receiver made by Eclipse Radio.

Back bias

However, not all battery receivers used a "C" battery. Many, such as the previously mentioned Tom Thumb, have a back-bias arrangement whereby the negative voltage is produced by the voltage across a resistor (Fig.1). In this back-bias circuit, the voltage across the resistor is negative at the grid end with respect to chassis and can be used as a source of bias for one or more grids.

Looking at this another way, "B" battery negative is the most negative point in the system, which means that the chassis is positive by the voltage across the resistor. This in turn means that the valve filament (cathode) must be positive with respect to the grid by the same amount.

The amount of bias produced by a back-bias circuit is proportional to the total high tension current – not necessarily the current of the valve or valves being biased. Negative voltages produced by back-biasing are produced at the expense of "B" battery voltage. In other words, if a receiver has a 90V "B" battery and the back-bias resistor supplies a 5V negative bias, then the effective "B" battery voltage is reduced to 85V. You don't get something for nothing!

Back biasing is also used in some AC-type receivers. This involves adding a resistor in the high tension centre-tap lead of the power transformer (see Fig.3). Once again, the negative bias voltage is produced at the expense of the overall high tension voltage.

Any form of grid bias that does not use a battery requires a resistor to produce the bias voltage. It is common practice to place a capacitor across the bias resistor to suppress any unwanted signals.

Self-bias

Another form of biasing often used in AC-powered sets is cathode biasing, sometimes referred to as self-biasing (Fig.4). Cathode bias makes use of the cathode current through the valve. The cathode current is the sum of the plate and screen currents and if a resistor is placed between the cathode and chassis, then the cathode current flows through this resistor.

This current flow through the cath-

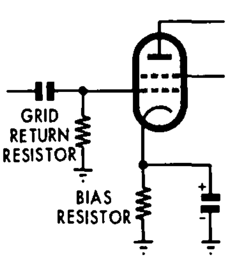


Fig.4: a typical self-bias circuit. The bias voltage is applied to the grid via the grid return resistor.

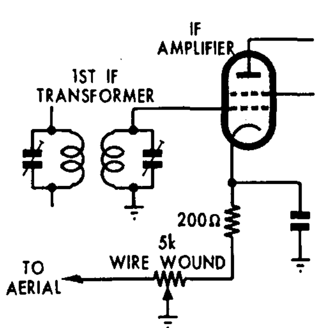


Fig.5: this variable bias circuit is used as a volume control.

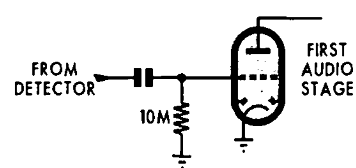
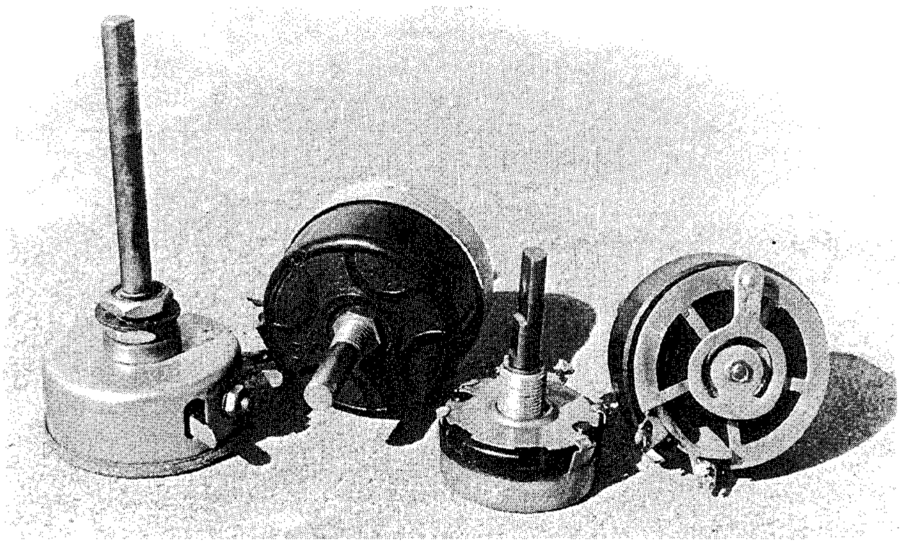


Fig.6: this grid leak bias system relies on a small amount of grid current which flows through a 10MΩ resistor.



Wirewound potentiometers were used as variable cathode bias resistors in many old radio receivers. When used in conjunction with variable-mu valves, variable cathode bias was an effective volume control.

ode resistor produces a voltage across it and so a positive potential is developed at the cathode with respect to chassis. Because the grid is normally connected to chassis via a resistor, it follows that the grid must be negative with respect to the cathode.

The term "self-bias" is used here because the bias voltage is proportional to the total current flow through the valve being biased.

Another form of cathode biasing involves using a variable resistor instead of a fixed resistor. Many receivers from the 1930s used such a system as a volume control, with the potentiometer in the cathode circuit of a variable-mu IF amplifier valve (see Fig.5).

In its simplest form, only one terminal and the moving arm connections are used. Connecting the other potentiometer terminal to the aerial is a trick to improve the range of control but has nothing to do with the bias function.

Automatic volume control

If one goes probing around with a voltmeter underneath the chassis, it soon becomes apparent that there are many points in the circuit that will register negative voltages. Some of these potentials vary in magnitude depending on the strength of the signal being received. These variable bias voltages are produced by the automatic volume control (AVC) circuit.

AVC voltages are negative and are directed at the grids of the front end valves; ie, the radio frequency (RF) amplifier, the mixer and the intermediate frequency (IF) amplifier.

These valves have variable mu-characteristics and their amplification factor is controlled by changes in grid bias. In the case of the AVC circuit, the bias produced is proportional to the signal strength. As the signal strength becomes greater, so too does the bias voltage which automatically restricts the amplification provided by the RF valves.

Basically, AGC is just another form of grid biasing and is a variable bias.

Still another form of grid biasing can be found in some first audio stages and is referred to as grid leak bias. This involves connecting a high-value resistor between the grid and chassis (Fig.6). It is normal for a small amount of grid current to flow, the exact amount depending on several factors. These include the type of valve and its operating conditions.

In practical terms, this bias system is suitable for use with high-mu triode valves handling low-level input signals. Running the weak grid current through the 10MΩ resistor produces the desired bias. The amount of bias is small but can be sufficient to set the operating point on a straight portion of the characteristic curve. Provided the input signal level is held within limits, very little distortion will be generated.

Bias problems

Some would argue the pros and cons of various bias methods but, as far as vintage receivers are concerned, it matters little. What is important is that the bias circuits are working as the designer intended but that is not always the case.

One problem with old carbon resistors is that they often go high with age. When a bias resistor goes high so too does the bias voltage and that means that the grid can swing outside the straight part of the characteristic curve. This could cause the valve to operate near-cut off in extreme circumstances. When restoring a vintage radio receiver, it is therefore important to check the bias resistors and replace them where necessary. The bypass capacitors should be checked as well.

Finally, note that when checking bias voltages, it is advisable to measure the voltage across the bias resistor itself; checking from cathode to grid can give misleading readings. Note that it's also best to use a digital multimeter. Using a low-impedance analog meter can give a false indication, due to the current through the meter. **SC**