



An Improved Split-Load Phase Inverter

Here's a new phase inverter design that avoids some of the shortcomings of the original circuit.

By Robert Bennett

The split-load phase inverter is a time-honored circuit used in audio amplifiers as early as the mid-1930s¹. It has the virtue of simplicity and economy, using, as it does, only one triode. It has, however, a few undesirable features:

- (a) It has no gain—in fact, the output is only about 95% of the input;
- (b) The two outputs tend to become unbalanced at high frequencies;
- (c) The two outputs have different impedances—low for the cathode output and high for the anode output;
- (d) A load applied to the cathode output causes a higher output on the other (anode) output, but not vice versa.

FIXES

Now the lack of gain is easily dealt with by using another amplification stage. In Adriaan Hammer's article², a 12AX7 double triode is used for amplifier and phase splitter. Good HF balance between outputs can be obtained by loading the cathode output with a small capacitor—a very neat solution (**Fig. 1**). However, (c) and (d) are not so easily dealt with, and often cause trouble if the output valves draw grid current on a signal peak.

If the input to the phase splitter is made between grid and cathode rather than grid and earth, all these undesirable features are eliminated. A neat way of doing this is shown in **Fig. 2**. By means of a capacitor, the "top" end of the pentode's load resistor is connected to the cathode of the phase splitter. This means that the output of the pentode is applied between the triode's grid and cathode—exactly as required. The pentode's gain is unaffected by such treatment because its anode resistance is much greater than the load resistor.

The triode gain is half of the normal amplifier gain because it is divided

between the two outputs. This way of analyzing the circuit is easier—in my opinion—than the alternative of considering it as a feedback circuit³. The overall voltage gain for the circuit of **Fig. 2** will be greater than 200, compared to the 70 or so for the circuit of **Fig. 1**.

Figure 2's circuit has been referred to as a bootstrap circuit, and is believed to have been invented in the late 1940s⁴. Single triode phase splitters with floating microphone inputs⁵ and phase splitters in superhet (erodyne) radio circuits where the detector was floating⁶ were described earlier.

Note: A power supply of about 250V would be suitable for the circuits of **Figs. 1 and 2**. Good regulation is not required, but a well-filtered supply is essential to avoid hum.

Some people consider pentodes "beyond the pale" because of extra noise or distortion compared with triodes. You can replace the pentode with a "cascode" combination of two triodes as shown in **Fig. 3**. This should reduce the noise. Whether or not the distortion produced by a cascode circuit is any better or worse than that produced by a pentode is a matter of opinion.

In **Fig. 2**, the triode grid is capacitor-coupled to the pentode anode. You can use direct-coupling of the triode to the pentode, which

would be desirable if negative feedback is incorporated. To do this, the resistor R9 should be a 5k Ω potentiometer, and you must carefully adjust the bias.

Negative feedback can be provided in the same way as **Fig. 1**, by inserting a 100 Ω resistor in the cathode circuit.

One aspect of phase splitter design not often mentioned, but which requires careful attention, is the heater-cathode circuit. V2 in **Figs. 1 and 2**, and V2 and V3 in **Fig. 3** have their cathodes "away up in the air" and if their heaters are at earth potential there is a considerable potential difference between heater and cathode (100-150V). This can cause heater to cathode breakdown and can also cause annoying hum.

To avoid this, the heater circuit can be biased positive to reduce the potential difference between heater and cathode. If a separate heater winding is available on the transformer, then you could use

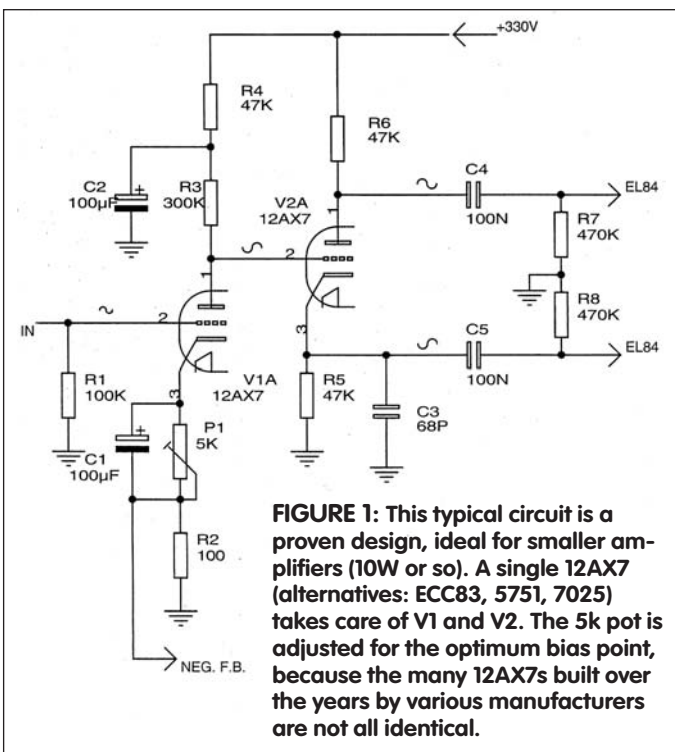


FIGURE 1: This typical circuit is a proven design, ideal for smaller amplifiers (10W or so). A single 12AX7 (alternatives: ECC83, 5751, 7025) takes care of V1 and V2. The 5k pot is adjusted for the optimum bias point, because the many 12AX7s built over the years by various manufacturers are not all identical.

a bias of +100V, or join the heater to the cathode. If this is not possible, you could use a smaller bias of +50V without straining the heater to cathode insulation of the other valves too much.

Notes on the valve types mentioned are given in a footnote⁷. **aX**

Robert Bennett was born in England and raised in Christchurch, New Zealand. He studied chemistry at Canterbury University, graduating M.Sc. in 1984. Since then he has worked as an analytical chemist

in various places in New Zealand. He currently lives in Auckland with his partner and two children, and works for an industrial water treatment firm. He has been interested in radio and electronics since he was 15.

REFERENCES

1. *Radio Constructor's Guide*, National Magazines Ltd. Wellington NZ (1936), p. 134. Circuit used 24A (tetrode) driving a 56 phase splitter driving push-pull 50s (see footnote 7 for notes on valve types mentioned).

2. *audioXpress* September 2003, pp. 56-57.

3. F.Langford-Smith (ed.) *The Radiotron Designer's Handbook*, 4th edition (1954), p. 523.

4. E. Jeffery, *Wireless World* 53(8), p. 274 (August 1947).

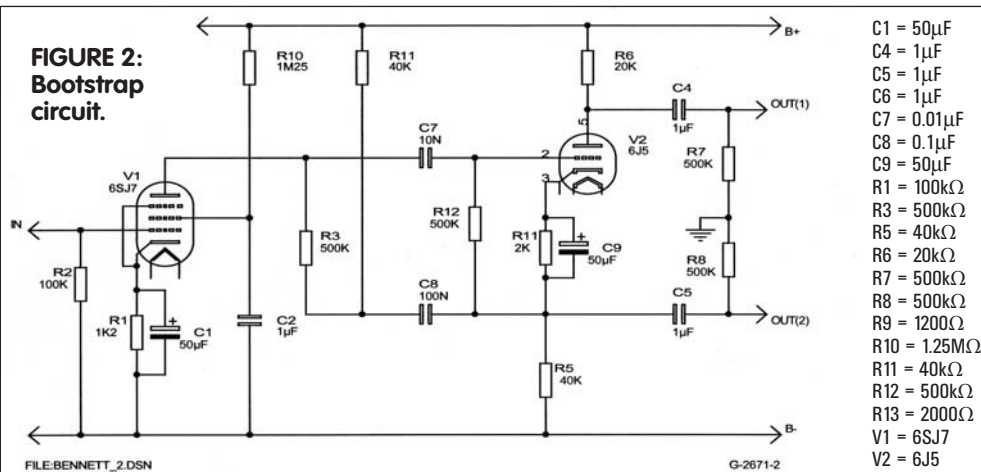
5. *Radio Constructor's Guide*, National Magazines Ltd. Wellington NZ (1936), p. 135. Circuit developed by *Wireless Weekly* magazine (Australia); used a 57 (triode connected) as phase splitter driving push-pull 56s driving push-pull 50s.

6. *RCA Receiving Tube Manual RC-13* (1937), p. 185. Circuit used a 6H6 detector driving a 6F5 phase inverter driving push-pull 6F6s or 6L6s.

7. The 57 is a pentode with a 2.5V heater, having characteristics similar to the later types 6C6 and 6J7, and fairly similar to the much later EF86/6BR7. Used as a triode, by connecting the screen and suppressor grids to the anode, it has a medium mu-factor of 19.

The 56 is a general-purpose triode with a 2.5V heater. It has a mu of 13.8.

The 50 is a large, directly heated (7.5V filament) triode output valve



Electric Guitar Amplifier Handbook

By Jack Darr

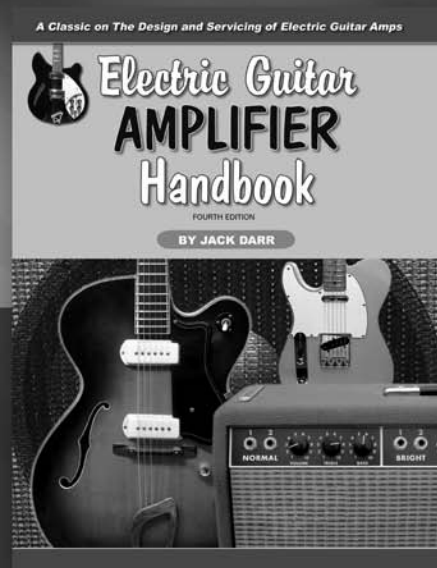
New reprint of the 4th edition of this book, originally published in 1973. Contains three sections—'How Guitar Amplifiers Work,' 'Service Procedures and Techniques,' and 'Commercial Instrument Amplifiers.' Everything you need to know about how each part of the amp works and what to do about it if it doesn't work. The final section of the *Handbook* is full of schematics for many of the guitar amplifiers in use at the time including models from Ampeg, Bogen, Baldwin, Fender, Gibson, Gretsch, and others. Line drawings and photos. 2006, 1973, 384pp., softbound, ISBN 1-882580-48-6. Sh. wt: 3 lbs.

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with a μ of 3.8.

The 24A is a tetrode with a 2.5V heater, having characteristics roughly similar to the later pentode types 57, 6C6, and 6J7. It was normally used as a RF amplifier rather than an audio one. Because of the lack of a suppressor grid, the anode characteristics have a nasty kink at low anode voltages: to avoid this, the working anode voltage needs to be at least 50V higher than the screen voltage.

The 6F5 is a high- μ triode with characteristics similar to one section of an ECC83/12AX7.

The 6H6 is a double diode with separate cathodes. Most consumer radio circuits used a double-diode-triode such as a 6Q7 as combined detector and amplifier, but then this phase splitter circuit would not have been possible.

The 6F6 is an output pentode with an anode dissipation of 10W, an octal-based version of the earlier types 2A5 and 42.

Its characteristics were roughly similar to those of the later beam power valve type 6V6.

The 6L6 was the original earliest beam power valve in production. Beefed-up versions of the 6L6 are still available (6L6GC). The original version had a maximum rating of 19W anode dissipation.

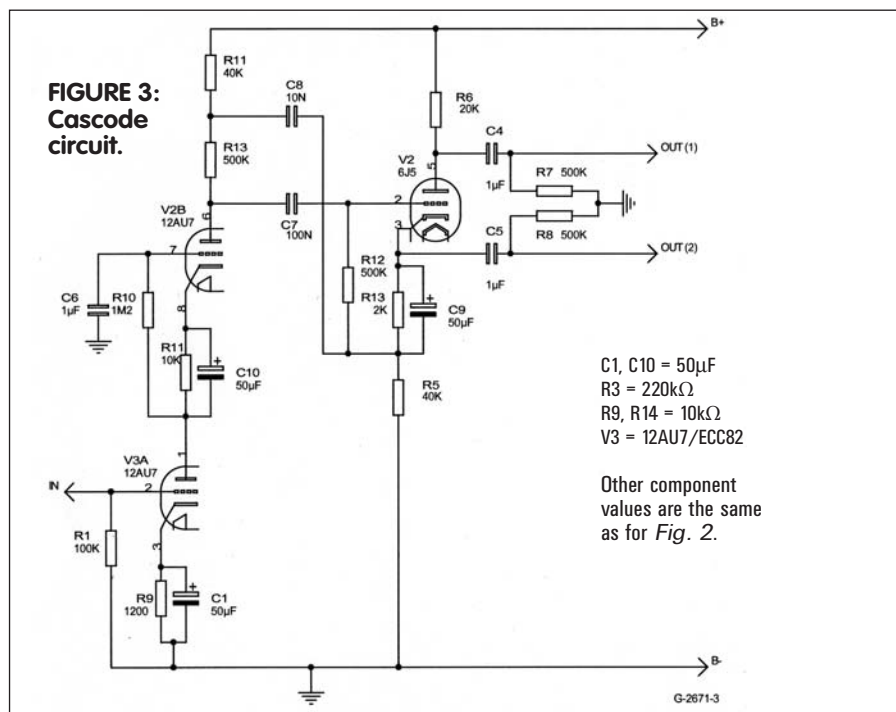
The 6SJ7 was a later, single-ended version of the 6J7 octal-based pentode, with slightly higher gain.

The 6J5 is a general-purpose triode with characteristics very similar to one section of a

6SN7 or a ECC82/12AU7 double triode.

The 12AU7/ECC82 is a double triode with a medium μ factor of 17.

The 12AX7/ECC83 is a double triode with a high μ factor of 100.



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