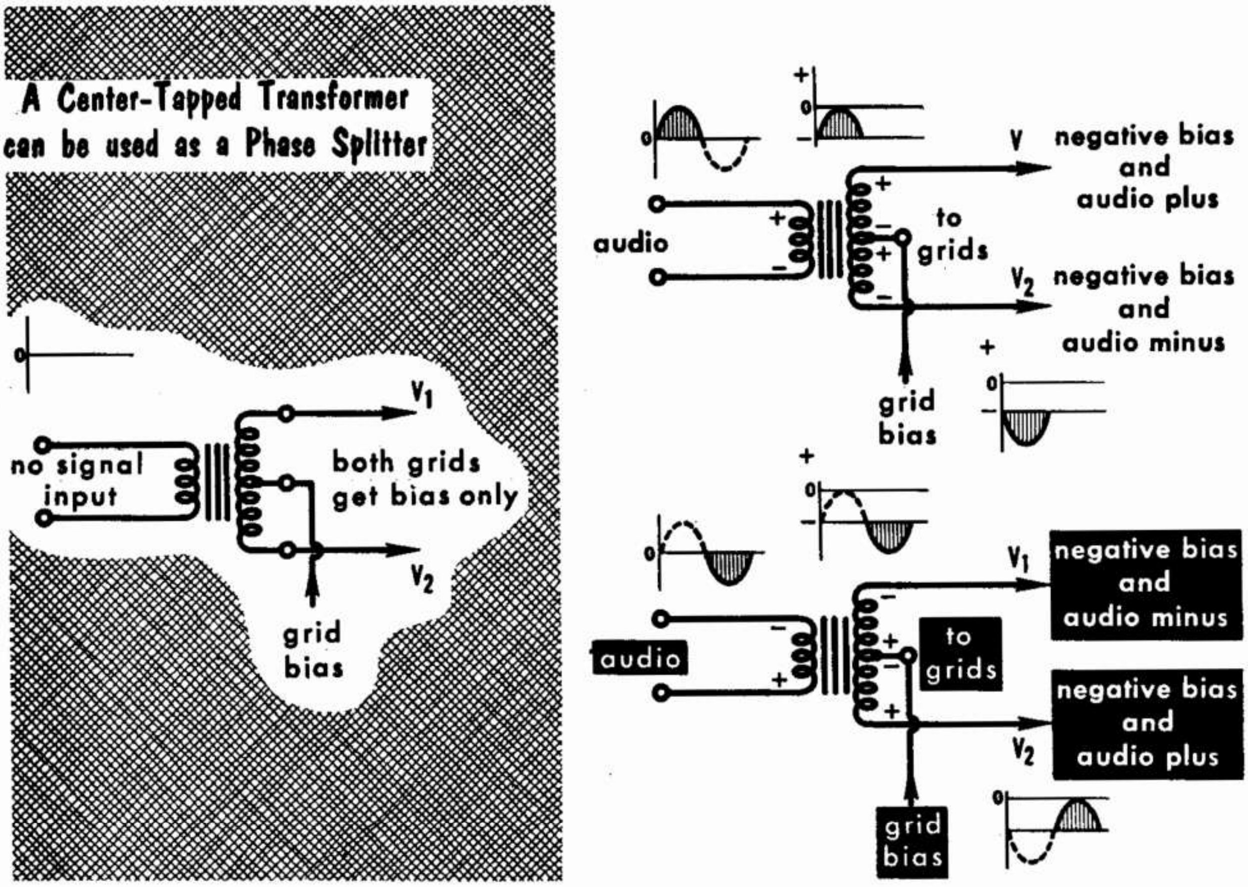
The Transformer-Type Phase Splitter

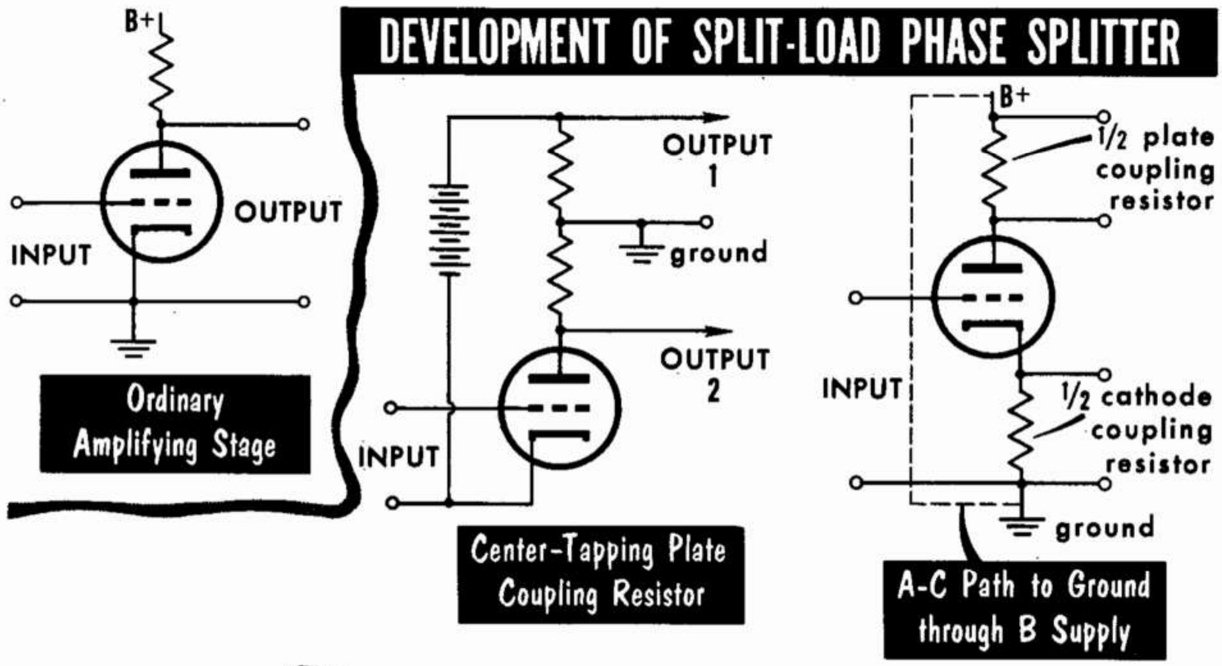
We have talked about using tubes in push-pull and said that to do this we need to have an audio input that makes one grid fluctuate positively while the other one fluctuates negatively. The question now comes, "How can we get this kind of drive or audio voltage for push-pull output tubes?" There are a number of these so-called ***phase-splitting circuits.***

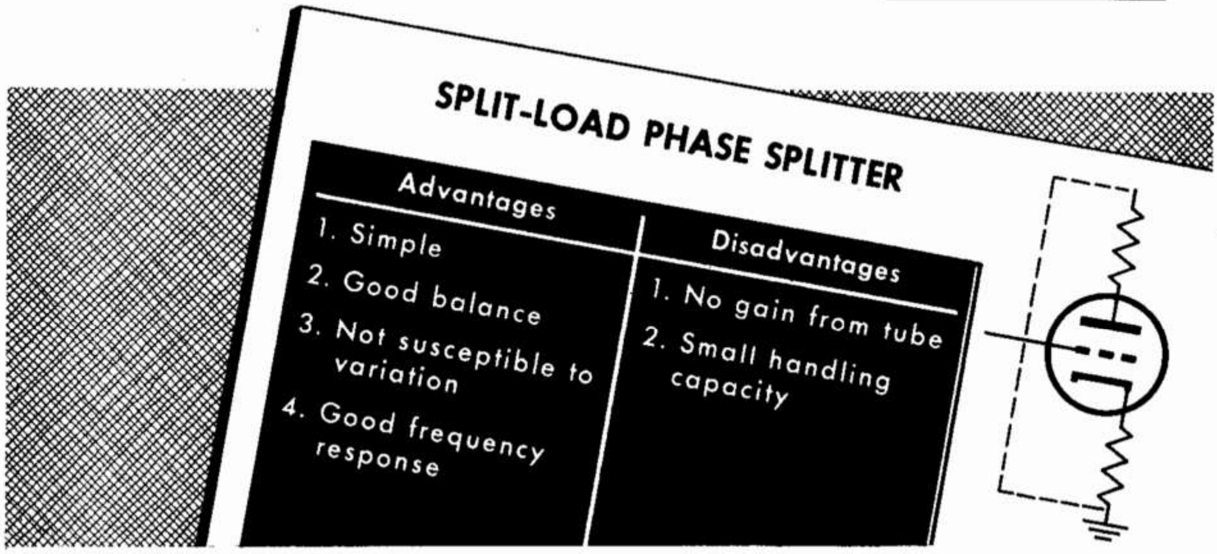


The simplest arrangement uses a variety of audio transformer similar to the output transformer. The secondary, however, has more turns than the primary and is center-tapped, like the primary winding of the push-pull output transformer. The center tap is connected to the negative grid bias voltage. When no audio is passing, both ends of the secondary winding have the negative grid bias voltage for their respective grids. When an audio voltage is presented to the primary of the transformer, one end of the winding goes positive from the bias voltage while the other one goes negative, and vice versa.

This system has some very useful features. It is simple, and it gives good balance in voltages supplied to each grid, if it is well designed. It has, however, a disadvantage when used in a feedback amplifier, as will be explained later, and for this reason various phase-splitting circuits that do not employ transformers or chokes are preferred in modern amplifiers.

The Split-Load Circuit

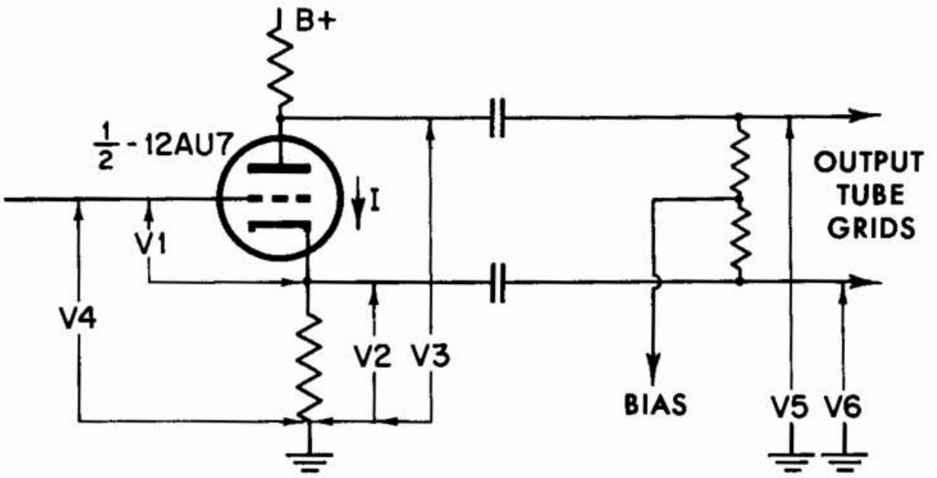




One simple way to make a phase splitter is to connect half of the plate load resistance between B+ and plate and the other half between cathode and ground. Since these resistances are equal and the same current flows through both, each will produce the same d-c voltage drop and the same audio fluctuations. When the fluctuation across the plate resistor goes positive, due to decrease in plate current, this same fluctuation will be negative across the cathode connected resistor because of the same decrease in current. This provides voltages of opposite phase, but we still must provide input to the tubes. The normal place to apply input voltage to a tube is between the grid and cathode, however, in this arrangement, half the total output voltage is between cathode and ground. This circuit uses the tube just to get phase *inversion* (to reverse the voltage between grid and plate) and does not achieve any useful amplification.

The Split-Load Circuit (contd.)

Using one-half of the 12AU7 as an example, an input fluctuation of 10 volts, measured between grid and *cathode,* will produce an output fluctuation of 100 volts—50 volts at the plate and 50 volts at the cathode. When the grid-to-cathode voltage goes 5 volts positive from its bias point, the current through the tube will increase. The cathode will go 25 volts positive from its d-c operating point, while the plate will go 25 volts negative from the d-c operating point. As the cathode has now gone 25 volts *more* positive from ground, and the grid-to-*cathode* voltage needs to go 5 volts positive to *cause*



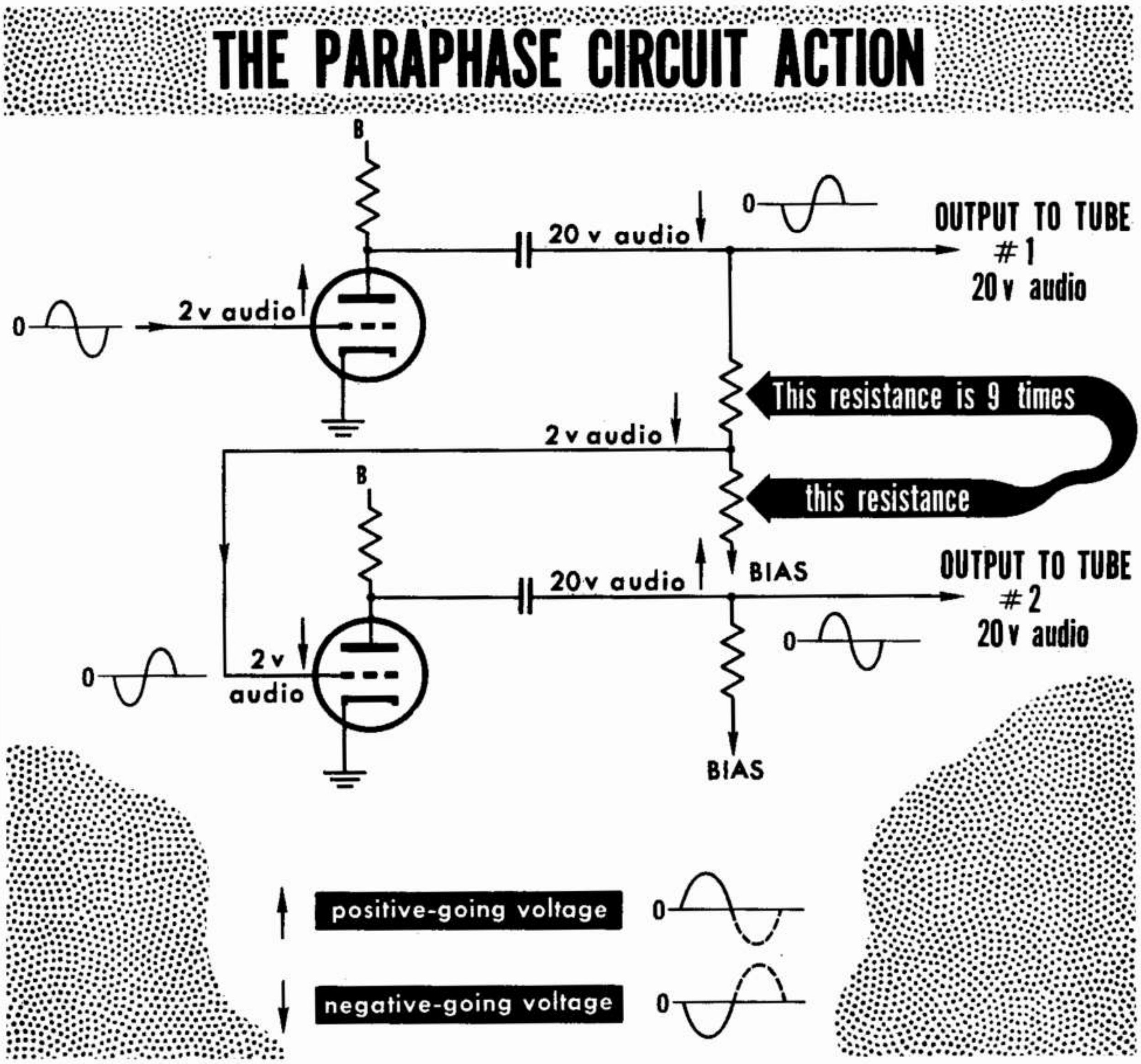
Currents and Voltages in Split-Load Circuit

Where Taken	TABLES OF VOLTAGES AND CURRENTS		
	No Audio	Positive Input Audio	Negative Input Audio
V1	−5V	0	−10V
I	5MA	7.5MA	2.5MA
V2	+50V	+75V	+25V
V3	+200V	+175V	+225V
V4	+45V	+75V	+15V
V5	BIAS	BIAS +25V	BIAS−25V
V6	BIAS	BIAS −25V	BIAS+25V

this, the grid-to-ground voltage itself must go 25 + 5, or 30 volts more positive to produce this swing. We therefore require a 60-volt peak-to-peak audio fluctuation from grid to *ground* to produce a 50-volt peak-to-peak fluctuation at plate and cathode, respectively.

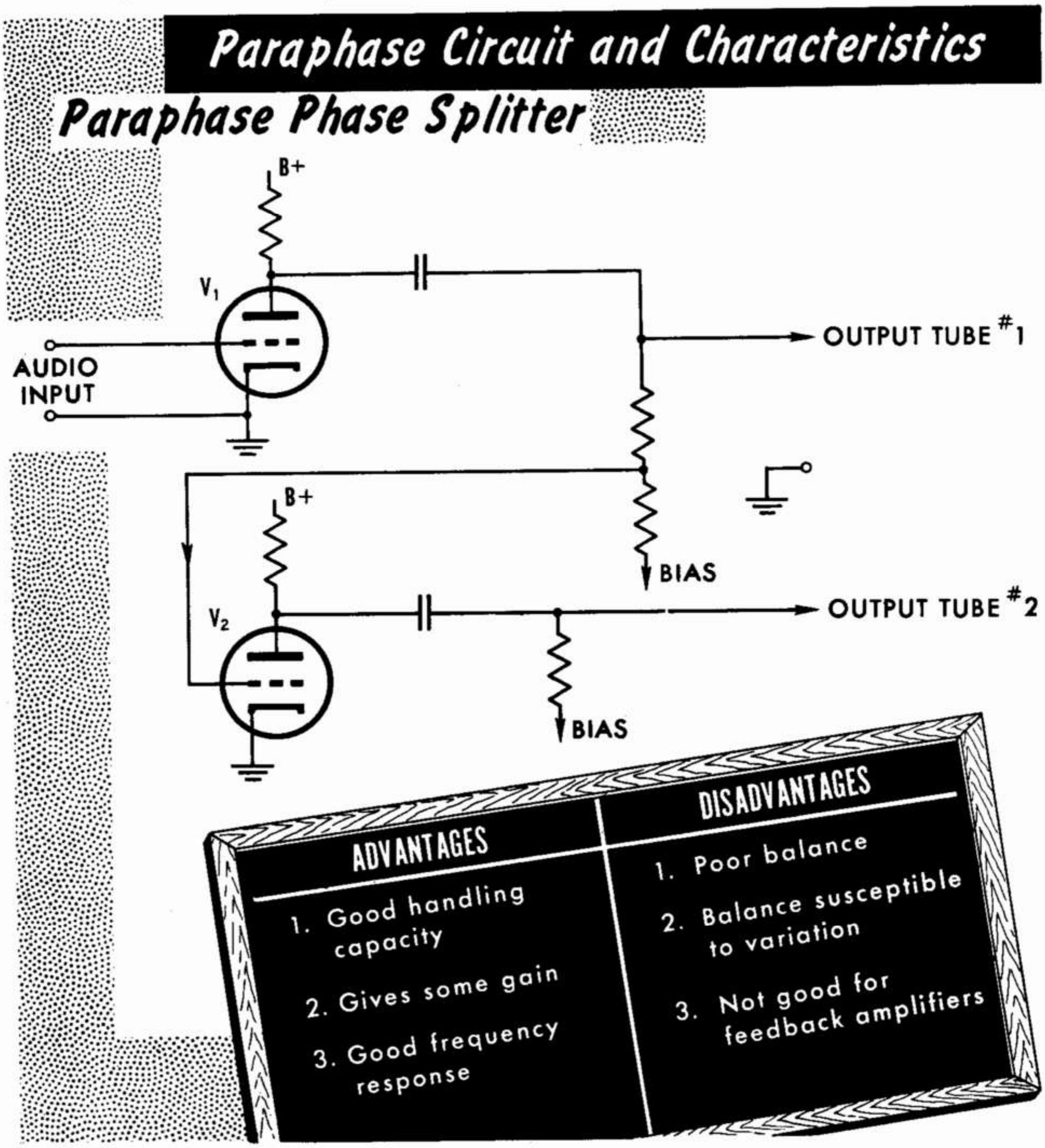
The Paraphase Circuit

Another phase-splitting arrangement is the so-called *paraphase* circuit. It uses two tubes. The output from the plate of one tube is fed by R-C coupling to the grid of one of the output tubes. From this same point, a voltage-divider arrangement cuts down the voltage and applies it to the grid of a second tube, which amplifies the voltage by as much as the resistance divider cuts it down, producing a voltage for driving the second output tube.



A positive fluctuation of 2 volts at the grid of the first paraphase tube produces a negative fluctuation at its plate of, say, 20 volts, which appears at the grid of one of the output tubes. This 20-volt fluctuation is also divided to provide a negative fluctuation of 2 volts for the grid of the second paraphase tube and becomes a positive fluctuation of 20 volts at the plate, providing positive fluctuation for the grid of the second output tube.

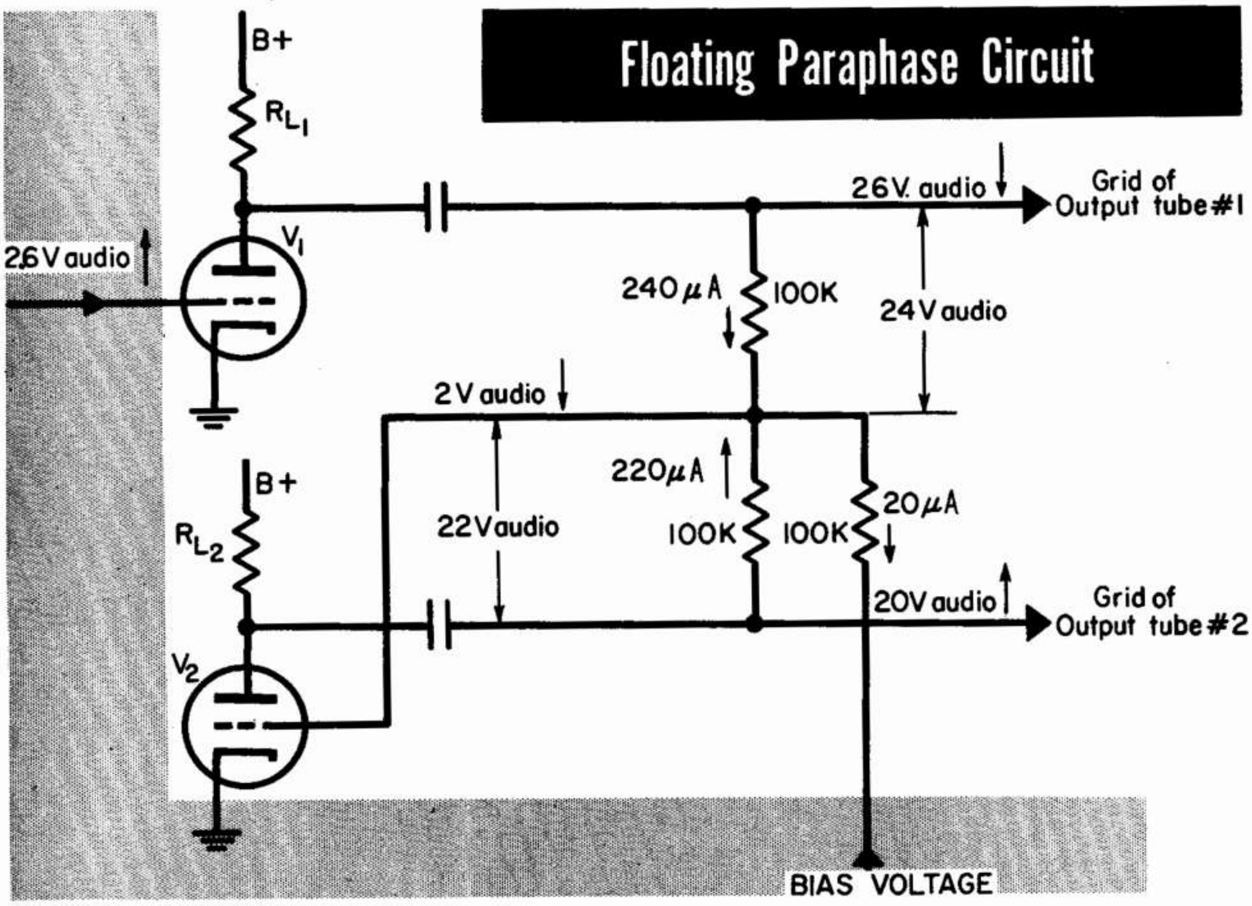
The Paraphase Circuit (contd.)



For this circuit to operate correctly, the voltage division produced by the resistors feeding the second tube must be exactly in the same ratio as the gain provided by the second tube. In the example given, the tube is multiplied by ten, and the voltage divider divided by ten. As tubes are subject to variation with line voltage, individual samples from production, and other differences, there is no guarantee that the amplification provided by the tube will be exactly the same as the voltage division provided by the resistors. The tube may amplify 9 or 11 times. Consequently this circuit is subject to deviation in its accuracy in a way that the two circuits discussed earlier were not.

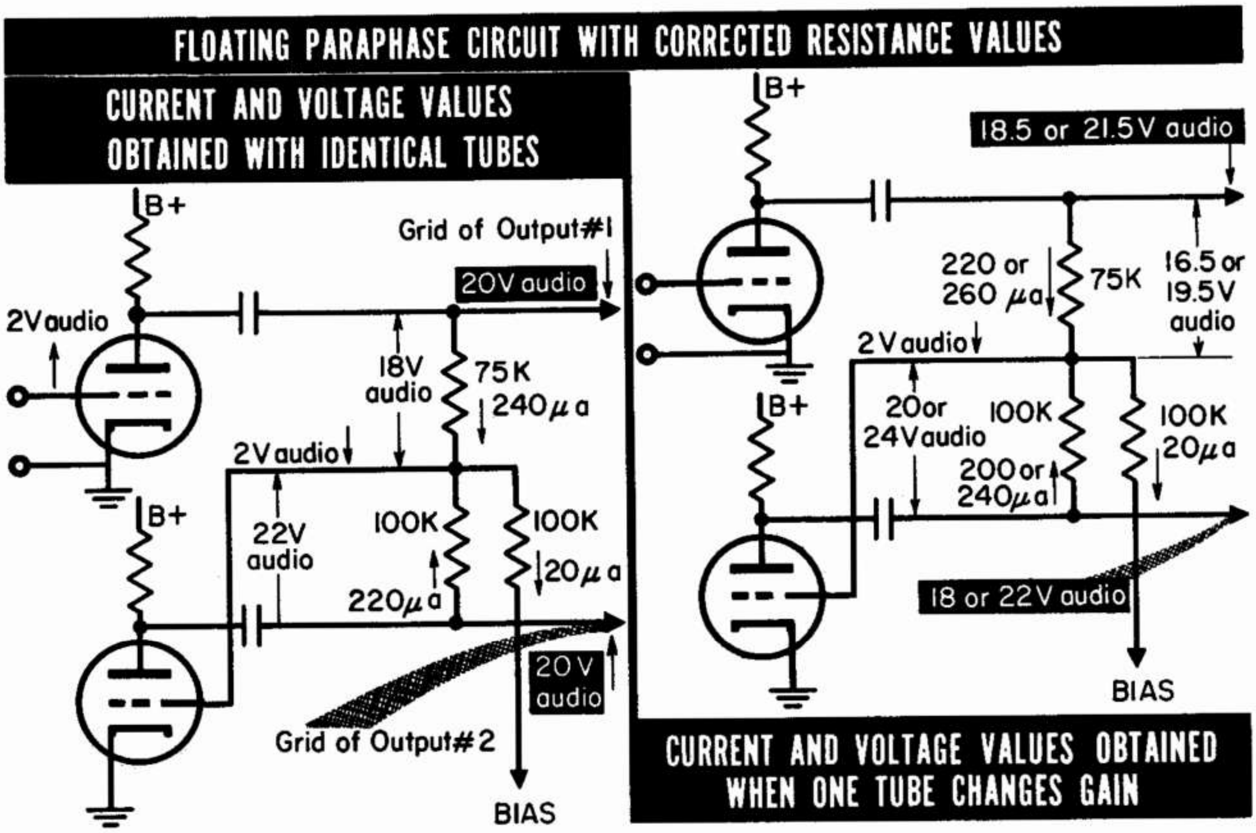
The Floating Paraphase Circuit

The next circuit aims at overcoming this problem. It is called *floating paraphase.* Instead of using a fixed voltage divider, the voltage divider is arranged to have a self-adjusting action that overcomes, to some extent, possible differences between individual tubes or changes in operating conditions. Instead of using a large resistor and a small resistor, as employed in the paraphase circuit, the tapping point used for connecting to the grid of the second paraphase tube is a junction point of large resistors from the output-tube grids and a third resistor from the bias point.



Assume that the three resistors have the same value, 100,000 ohms, and that the tubes have a gain of 10, as before. For the second tube to get its 2-volt grid fluctuation, the current through the common resistor must be 2/100,000 or 20 microamperes. The voltage at the grid of the second output tube will fluctuate 20 volts in the opposite direction, hence the resistor connecting this grid to the common point will have 22 volts across it and pass 220 microamperes. Because the resistor from the first output-tube grid joins this same point, it must have 220 + 20 or 240 microamperes flowing in it, which will produce a fluctuation voltage across it of 24 volts. As the common point is already fluctuating 2 volts in this direction, the total fluctuation at the first output tube grid must be 26 volts.

The Floating Paraphase Circuit (contd.)



The unbalance between output tube grids can be corrected by using a smaller resistance value from the first output tube, so that 240 microamps only drop 18 volts. This requires a resistor of $18/0.00024 = 75{,}000$ ohms, in place of 100,000 ohms.

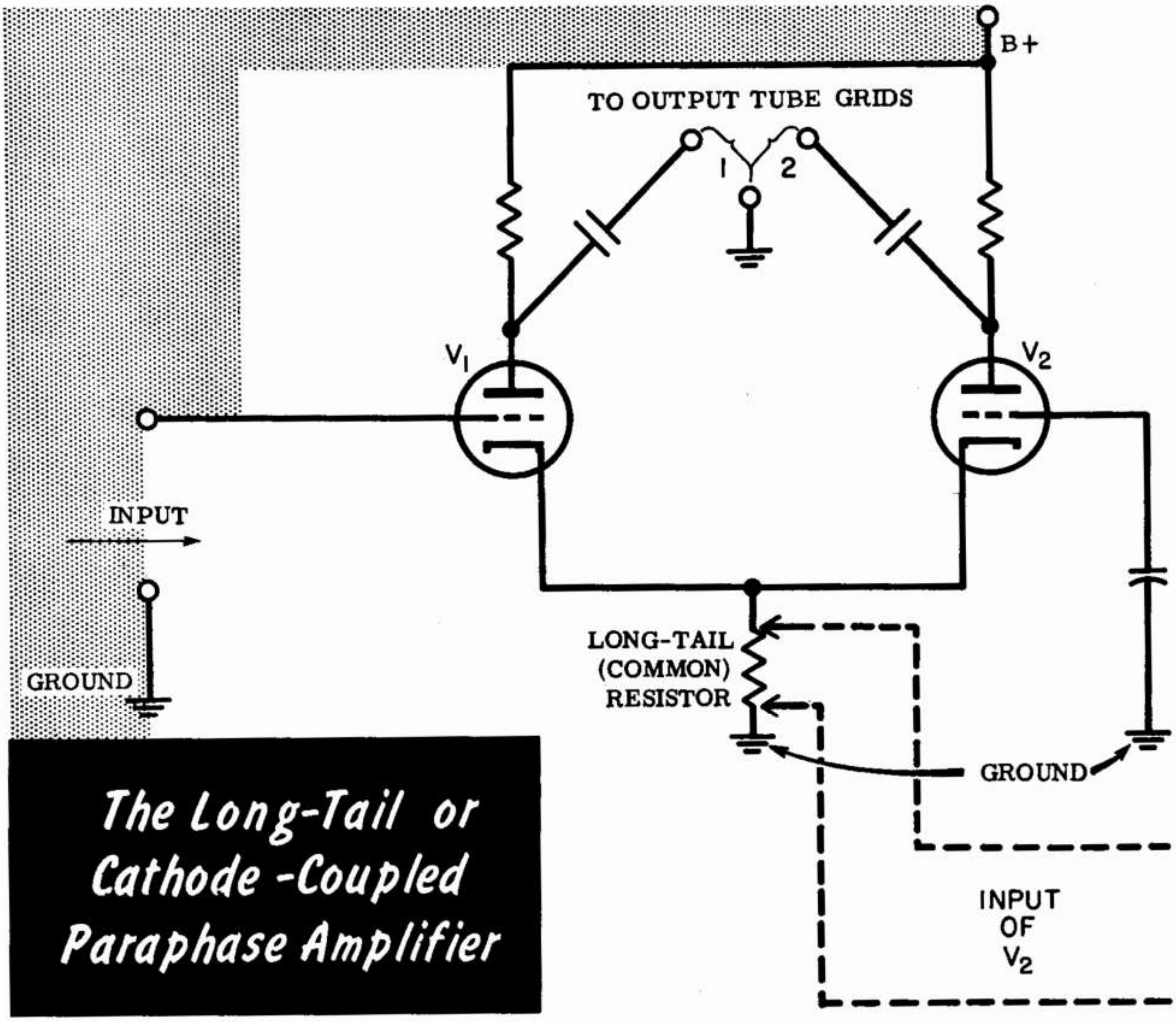
Now what happens if the second tube changes gain to either 9 or 11? If it still gets 2 volts on its grid, there will be either 18 or 22 volts fluctuation at its plate, so the current in the resistor from the second output tube grid to the common point will be either 200 or 240 microamperes. The current in the resistor from the other output tube grid will need to be 220 or 260 microamps, instead of the original 240 microamps. This means that the potential at that grid will be $(75{,}000 \times .00022)$ or 16.5 volts, or $(75{,}000 \times .00026)$ or 19.5 volts, from the grid to the common point. This represents 18.5 or 21.5 volts total fluctuation at this grid, to compare with 18 or 22 volts at the other grid.

With the ordinary paraphase, the grid of the first output tube would remain at a potential of 20 volts, while the second output tube would get 18 or 22 volts. Here, when the second tube gets 18 volts, the first has 18.5 volts; when the second gets 22 volts, the first gets 21.5 volts, which reduces the imbalance. If the first grid continued to get 20 volts, the second grid would get within 19.5 to 20.5 volts with this much change in gain, instead of 18 or 22 volts with ordinary paraphase.

The Long-Tail Circuit

Another variation puts the common resistor that carries the plate current of both tubes in the circuit between cathode and ground. The input voltage to the second tube is the audio voltage developed across this common resistor, because the second tube grid is connected to ground either directly or through a large capacitor.

It doesn't matter which way we measure a voltage, whether from grid to cathode or cathode to grid. In either case it will be the same *voltage*, different only in polarity or phase. Hence the grid voltage for the second tube will be due to the difference in the audio components of plate current in the common cathode resistor. This means that the audio plate current of the first tube must be a little higher than the corresponding component of the second tube. If identical plate resistors are used, the first tube will produce a slightly greater audio voltage than the second tube. This can again be overcome by using plate resistors of different values so that the audio voltages become equal.



The Long-Tail or Cathode-Coupled Paraphase Amplifier

QUESTIONS AND PROBLEMS

1. What are the advantages of working tubes in push-pull?

2. Explain how using tubes in push-pull enables them to be used (a) with less distortion, (b) to give more power (higher efficiency)?

3. Give the relative advantages of operating tubes in (a) class A, (b) class B, (c) class AB.

4. What is power drive, and how does it alter the requirements of the preceding stage?

5. What is the most informative way of displaying the distortion performance of an amplifier using an oscilloscope?

6. What is a phase splitter and when is it needed? Discuss the relative features of the following different types, with special reference for each to (a) accuracy of the two outputs, (b) uniformity of performance at different frequencies, (c) economical use of components:
   (i) Transformer type
   (ii) Split-load type
   (iii) Paraphase type
   (iv) Floating paraphase type
   (v) Long-tail type
   (vi) Paraphase from output transformer.

7. Compare different output circuits, using triode or pentode tubes, in various classes of operation, with regard to the power output that can be obtained for a given dissipation rating, to probable distortion content, to critical load requirements, and to the requirement of critical adjustment in operation.

8. In spite of the fact that it is evidently a good phase-splitting device, the transformer is very seldom used in modern amplifiers. Why?

9. The split-load circuit is criticized for not having any useful gain. Explain why this is. Why is its handling capacity less than some other types?

10. Describe, with numerical illustration to prove your point, why the floating paraphase maintains betters balance than the simple paraphase circuit.

11. In a floating paraphase circuit, the section of grid resistor common to both output tubes has one-half the average value of the other two, which are slightly unequal, so that when the gain of the phase-splitting tube is 20, both output tubes get equal drive. Using values to illustrate this condition, find how much error will result from the phase-splitter tube's losing working gain down to 15.