CATHODE PHASE INVERSION

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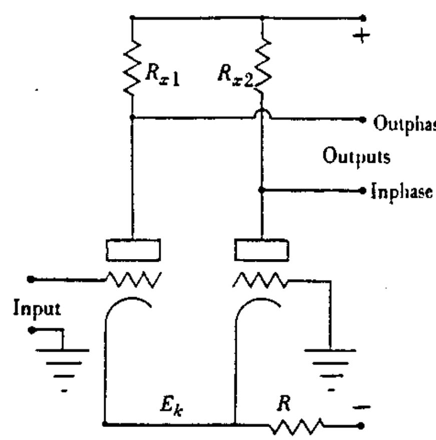
[*MS. received* 19 *November* 1937]

ABSTRACT. A simple method for phase inversion which introduces little distortion, yet amplifies considerably, is described. The input is at earth or any chosen positive potential; outputs are symmetrical with respect to earth. Linear amplification is obtained throughout the audio frequency range for outputs up to the potential of the anode supply.

Several methods of phase inversion have become popular in the past few years, some depending upon coupling between anode of a signal valve and grid of an inversion valve, others upon equal but out-of-phase voltage drops in resistors inserted in anode and cathode circuits of special inverter valves. These methods have proved useful but have obvious drawbacks; the first type requires accurate adjustment of feedback and often introduces phase and amplitude distortion while the latter introduces attenuation instead of amplification in the inversion process and tends to give excessive hum with normally filtered anode supply and with A.C. operated filaments.

An interesting variant to these methods is that illustrated in the sketch. Two identical triodes or a duplex triode such as the 6A6 or 6N7 are arranged much as they would be for conventional push-pull operation with self-bias, except that one of the grids is earthed and the common cathode is connected through a large resistance to a considerable negative bias voltage. Since a supply of negative potential (50–200 v.) is usually available in modern amplifiers, this bias requirement does not cause any great difficulty.



Cathode phase inversion circuit

In operation, a positive increment in potential to the first grid causes an increase in anode current through that triode and a consequent potential decrement at the outphase output. Meanwhile the increase in cathode current has effectively increased the bias to the second triode, causing a decrement of its anode current accompanied by the usual increment in potential to the outphase output.

As will be shown directly, there is a slight magnitude asymmetry in the outputs which is negligible so long as *RM* (a quantity which will be defined) is kept large as compared with unity. If it is desired either to compensate this slight error or if only very limited bias is available, the formulae developed below will permit simple calculation of a slight change in load resistance which will compensate this asymmetry.

For purposes of design, the following technique has been found quite satisfactory provided at least twice the normal bias of the valve is available. First with the aid of characteristic curves, the mean anode current and voltage at which each triode is to operate is decided. R_{x1} and R_{x2} are chosen such that they will pass the desired current with applied voltage equal to the difference between the supply voltage and the chosen anode voltage. To determine R, the arithmetic sum of the available bias and the correct bias for the valve as operated is divided by the total anode current through the two valves.

The mathematical development is as follows. M the net mutual conductance of one triode is given by the expression

$$M=M_g\frac{R_a}{R_a+R_x} \qquad \ldots\ldots(1),$$

where M_g is mutual conductance, R_a is anode resistance, and R_x is load resistance.

Suppose an increment in input potential E_{in}. This will occasion an alteration of cathode potential E_k amounting to

$$E_k=(E_{in}-E_k)\,M_1R-E_kM_2R \qquad \ldots\ldots(2),$$

from which

$$E_{in}=(1+M_1R+M_2R)/M_1R \qquad \ldots\ldots(3).$$

Now usually the overall mutual conductance of the triodes will be equal, and we can put $M=M_1=M_2$, thus equation (3) becomes

$$\frac{E_{in}}{E_k}=\frac{1}{MR}+2 \qquad \ldots\ldots(4).$$

We have also

$$E_{g1}=E_{in}-E_k \quad \text{and} \quad E_{g2}=E_k \qquad \ldots\ldots(5).$$

Eliminating E_{in} and E_k we get

$$\frac{E_{g1}}{E_{g2}}=1+\frac{1}{MR} \qquad \ldots\ldots(6).$$

For perfect balance, MR should be infinite, but allowing a tolerance of 10 per cent between anodes, then MR must be $\geqslant 10$ unless it is to be otherwise corrected.

Now with ordinary valves, the usual value of M is about 5×10^{-4}, hence to make $1/MR\geqslant 0{\cdot}1$ R must be at least 20,000 Ω. with a total anode current of 2 ma.; this requires a bias of 40 v. less the normal bias of perhaps 5 v., or 35 v. Suppose however that only 25 v. is available. Dividing the resulting bias of 30 v. by the total anode current of 2 ma. R will now be 15,000 Ω. Then, by equation (6)

$$\frac{E_{g1}}{E_{g2}}=1+\frac{1}{1{\cdot}5\times10^4\times5\times10^{-4}}=1{\cdot}13.$$

To correct this inequality, the load resistance of the first valve may be tapped in the ratio 1 : 1·13 and the output taken from the tap or the total gain of the first valve may be decreased by reducing the resistance of its load. As an alternative, the asymmetry might be removed by elevating the grids to a positive potential of about 10 v. provided the input permitted of this arrangement.

In practice compensation will seldom be required, as sufficient bias can be had or a choke can be inserted in the cathode lead. It may be needed however where the D.C. amplification is desired and where utmost symmetry is to be preserved.

It will be obvious from the symmetry of the circuit that hum in either anode or bias supply cancels nearly completely so that very crudely filtered current can safely be used. Also since the cathode is very near earth potential, there will be little hum introduced here nor will there be severe capacitative muffling.

This circuit is particularly well suited for the operation of cathode ray oscillograph sweep and deflection circuits where large anode voltage excursions are required with a minimum of amplitude and frequency discrimination. It allows of admirable baseline adjustment by the introduction of small potentials on the grid ordinarily earthed.

It is well to note that in addition to acting as a phase inverter this circuit also amplifies the signal approximately to the same extent as similar valves would in the simple connexion. In one cathode-ray oscillograph application using 6A6 valves with 600 v. power supply, 100,000 Ω. plate resistors, and R equal to 50,000 Ω., a gain of 27 was realized with an undistorted output over 500 v.