Hybrid Feedbacks for Power Amplifiers

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While feedback in most amplifiers is partially dependent on the load impedance, it is possible to eliminate this effect to a large extent with a claimed improvement in over-all performance.

MUCH INTEREST has been evinced in the system of Hybrid Feedback[1] as developed and used in the Acrosound Ultra-Linear II power amplifier. This system prevents interaction between feedback circuit and load; consequently its use results in a feedback system inherently more stable than the conventional systems now used.

The circuit has been developed from a consideration of the unique properties of the hybrid coil, a device long used in telephone communication to permit amplification in both directions on a telephone line without interaction. This property of circuit isolation is put to use in a similar manner between feedback and output circuits of an amplifier.

In its usual form, the hybrid coil is a three-winding transformer composed of a primary winding and two series-connected secondary coils of equal turns, and is shown diagrammatically at (A) in *Fig.* 1. If power is fed to the primary, it is divided equally between each load resistor, the two load resistors being of equal value. Another resistor is used to supply balance, and is shown connected between the junction of the two secondary windings. When all circuit resistors are chosen in a certain relationship, the circuit has several unique properties. A voltage placed in series with one load will not be reflected into the other load. A voltage placed in series with the balancing resistor will not appear in the primary winding of the transformer. The hybrid arrangement can then evidently be used to divide output voltage between load and feedback circuit without interaction. It would not be economical to divide power equally between load and feedback circuit, hence the section of the secondary which energizes the feedback circuit is composed of just enough turns to supply the requisite amount of feedback voltage.

The solution of a hybrid circuit where the secondary winding is comprised of two series-connected coils of equal turns is well known, and to be found in most standard texts. Where the secondaries are not of equal value, the solution is not easily available, and will be developed here. Another property of the hybrid circuit will also be developed -- one which, to the best of knowledge has not been previously disclosed.

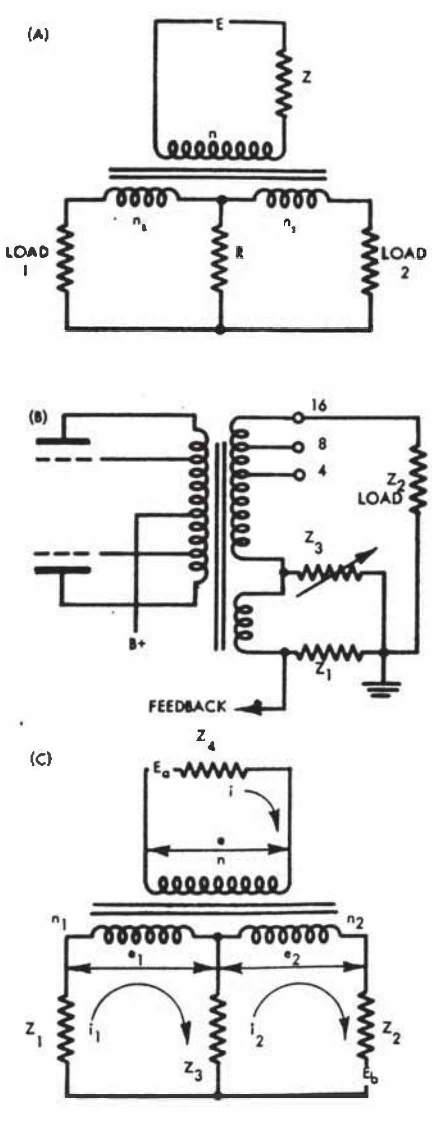

Fig. 1. Schematic of voltage and current relationships of the hybrid feedback arrangement.

As used in the Ultra-Linear II amplifier, the output transformer forms a hybrid coil, and the output circuit is shown at (B) in *Fig.* 1. The circuit of the output transformer alone is shown at (C). The voltages and impedances appearing across the various windings are as follows:

- E_a The open-circuit plate-to-plate voltage of the output stage.
- E_b A voltage introduced into the load circuit to determine its effect on the feedback voltage. It may be an equivalent voltage generated by a change in load impedance (an assumption valid by the compensation theorem), or a back emf generated by the load.
- e The voltage across the primary winding of the transformer, composed of n turns.
- e_1 The voltage across the winding section composed of n_1 turns and which connects to the feedback circuit.
- e_2 The voltage across the winding section composed of n_2 turns and which connects to the load.
- Z_1 The feedback load impedance.
- Z_2 The output load impedance.
- Z_3 The balancing resistor.
- Z_4 The plate impedance of the output tubes.

We may write the equations for the voltage drops in each loop in terms of the loop currents and impedances by Kirchoff's law, and these give relationships (a), (h), and (e) below. Equations (d) and (e) are relationships that exist in any transformer, the sum of the ampere turns in each winding being zero, and the exact proportionality between the open circuit voltage and turns in each winding.

(a) $e = E_a - Z_4 i$

(h) $e_1 = Z_3 i_2 - (Z_1 + Z_3) i_1$

(c) $e_2 = Z_3 i_2 - (Z_2 + Z_3) i_1 + E_b$

(d) $n_1 i_1 + n_2 i_2 + n_3 i_3 = 0$

(e) $\frac{e}{n} = \frac{e_1}{n_1} = \frac{e_2}{n_2}$

The relationships of (a) and (e) may be substituted into (b), (c) and (d) ot give the following three equations in which all currents are expressed in

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[1] Patent pending.