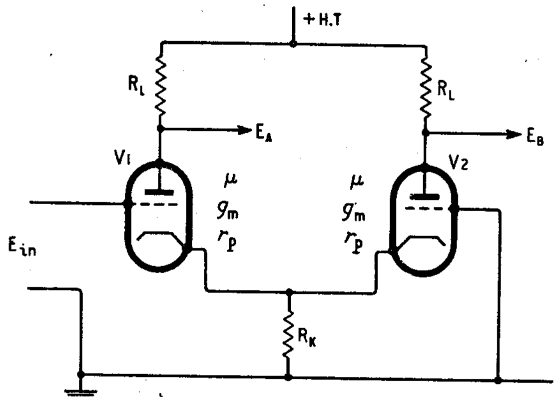
design which would make most effective use of an output transformer of non-critical design—one which would make the best use of any output transformer built into it—it soon became clear that some major changes in " conventional " circuitry would be required. A feedback loop to support a high level of corrective feedback which would include the output transformer and go back at least to the phase-inverter stage seemed a minimum reasonable requirement, and with conventional circuitry this leads to something very much like the basic " Williamson " layout. With the low gain of most popular phase-inverter stages, and the high drive requirements of the output stage, at least one driver stage is required between the phase inverter and the output stage, and an additional stage which may be either before or after the inverter. One direct coupling between stages (as in the Williamson scheme) is quite practicable, but more than one adds serious complications to the power supply and isolation filter problems. The result is a feedback loop which contains two R-C coupling networks and the output transformer, with a possible maximum phase shift of 270°. Stability of the amplifier requires that the loop gain be reduced to less than 1 before the phase shift reaches 180°, and, in view of the phase-shift and attenuation characteristics of the couplings and the transformer, the frequency range over which feedback can be kept high must be considerably smaller than the usable range of the transformer itself[5]. The search for a reasonable way out of this vicious circle of conflicting constraints led to the analysis of the cascode and the cathode-coupled phase-inverter, and finally to the combination of the two—the " long-tailed cascode pair " (l.t.c.p.).

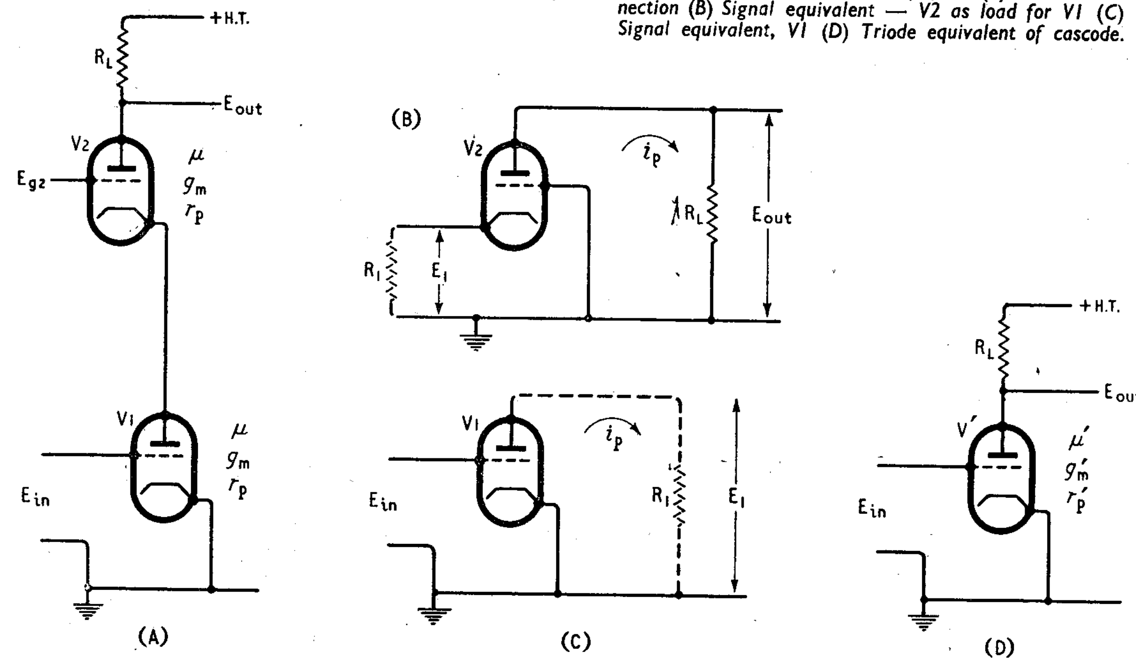
The cathode-coupled phase-inverter is well known and has been extensively used (Fig. 1). The un-by-passed common-cathode resistor provides degenerative feedback to the input tube as well as driving potential for the grounded-grid inverter. The anode-to-anode output of this stage is independent of the value of the



$$E_{AB} = E_{in}\frac{\mu R_L}{R_L + r_p}$$

Fig. 1. Cathode-coupled phase-inverter (long-tailed pair).

Below:— Fig. 2. The cascode amplifier. (A) Cascode connection (B) Signal equivalent — V2 as load for V1 (C) Signal equivalent, V1 (D) Triode equivalent of cascode.



(B)

$$E_1\mu = i_p(r_p + R_L) + E_1 \quad (1)$$

$$i_p = \frac{E_1(\mu+1)}{r_p + R_L} \quad (2)$$

$$R_1 = E_1/i_p = \frac{r_p + R_L}{\mu + 1} \quad (3)$$

(A)

$$-E_{in}\mu = i_p(r_p + R_1) \quad (4)$$

$$i_p = \frac{-E_{in}\mu}{r_p + R_1} \quad (5)$$

$$i_p = \frac{-E_{in}\mu}{\frac{R_L + r_p}{\mu + 1} + r_p} = \frac{-\mu(\mu+1)E_{in}}{R_L + (\mu+2)r_p} \quad (6)(3\,\&\,5)$$

$$\frac{E_{out}}{E_{in}} = \frac{i_p R_L}{E_{in}} = \frac{-\mu(\mu+1)R_L}{R_L + (\mu+2)r_p} = \frac{-\mu' R_L}{R_L + r'_p} \quad (7)$$