

The gain with feedback will therefore be

$$A' = \frac{A}{1 - \beta A} = \frac{A}{1 + A}$$

$$\text{Therefore } A' = \frac{\mu R_k}{(\mu + 1)R_k + r_p} \quad (1a)$$

which may be written in the form

$$A' = \frac{\mu}{\mu + 1} \cdot \frac{R_k}{R_k + r_p/(\mu + 1)} \quad (1b)$$

Equation (1a) may also be written in the form

$$A' = \frac{R_k}{\left(\frac{\mu + 1}{\mu}\right)R_k + \frac{1}{g_m}} \quad (1c)$$

where  $g_m$  = mutual conductance in mhos.

If  $\mu \gg 1$ , the gain with feedback will be approximately

$$A' \approx \frac{g_m R_k}{1 + g_m R_k} \quad (2)$$

$R_k$  is the resultant of all resistances between cathode and earth, whether internal or external to the amplifier itself. There is very little increase in gain through making  $R_k$  greater than about twice  $r_p$ ; provided that  $\mu$  is not less than 10, then the increase of gain through any further increase in  $R_k$  is always less than 5 per cent. (It is assumed that the input voltage is small enough to avoid grid current and/or plate current cut-off).

#### Charts giving gain

Voltage gain (exact) based on  $\mu$ ,  $R_k$  and  $r_p$ —Ref. C19.

Voltage gain (approx.) based on  $g_m$  and  $R_k$  for pentodes—Ref. C21.

Gain in decibels (approx.)—Ref. C24.

#### (B) Effective plate resistance ( $r_p'$ ) at low frequencies

The effective plate resistance in the arrangement of Fig. 7.7, as with any case of voltage feedback, is equal to  $r_p$  divided by  $(1 - \beta\mu)$ , i.e.

$$r_p' = \frac{r_p}{1 - \beta\mu} = \frac{r_p}{1 + \mu} = \frac{1}{g_m} \cdot \frac{\mu}{\mu + 1} \quad (3)$$

$$\text{If } \mu \text{ is very much greater than } 1, \quad \text{then } r_p' \approx 1/g_m \quad (4a)$$

with an error not exceeding 5 per cent. if  $\mu$  is not less than 20.

As with the gain, so too with the effective plate resistance, there is very little change brought about by an increase in  $R_k$  beyond  $2r_p$ , provided that  $\mu$  is not less than 20. Chart of  $r_p'$  (approx.)—Ref. C24.

#### (C) Equivalent valve characteristics

The results obtained with a cathode follower (e.g. eqn. 1b) are equivalent to those which would be obtained from an equivalent plate-loaded triode\* having:

- plate resistance =  $r_p' = r_p/(\mu + 1)$
- amplification factor =  $\mu/(\mu + 1)$
- mutual conductance =  $g_m$  (unchanged)
- and working into a load resistance  $R_L = R_k$  (unchanged).

#### Example 1: type 6J7 (triode connection)

For 250 volts between plate and cathode,  $\mu = 20$ ,  $g_m = 1900$  micromhos and  $r_p = 10\,500$  ohms. The value of  $R_k$  for greatest power output may be assumed to be approximately equal to  $2r_p$ , so that a value of 20 000 ohms may be adopted (see Sect. 5 for graphical treatment). The effective plate resistance is therefore

$r_p' = r_p/(\mu + 1) = 10\,500/21 = 500$  ohms,  
and the gain will be

\*See Sect. 5(i) for graphical treatment.