Design Data (12)

R.C. COUPLING

Response at Low-Frequencies

THE method of determining the value of a coupling capacitor in a resistance-capacitance coupled stage is quite well known for the usual case of a signal of sine waveform, but the method to be applied in the case of pulse and saw-tooth waves is not so generally understood.

The usual circuit is shown in Fig. 1 and its equivalent in Fig. 2. Here R_a is the A.C. resistance of the valve modified, if necessary, by any feedback. The impedance of the H.T. supply is assumed to be negligible. It is also assumed that the frequencies or the rates of change of current and voltage are low enough for the stray capacitance to have a negligible effect.

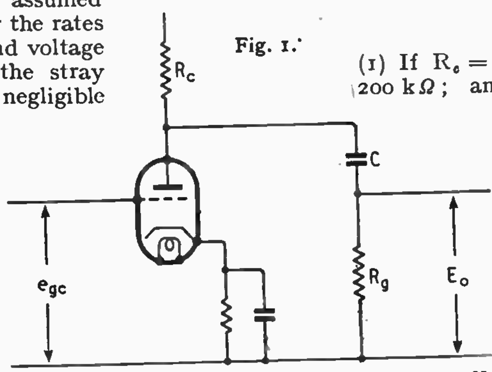

Fig. 1.

There are certain facts concealed in the formulæ which are well expressed as useful rules. They are:

1. For not more than 2 per cent distortion of a pulse or saw-tooth repetitive waveform the time constant must not be less than 50 times the pulse or saw-tooth duration. Time and time constant are to be in the same units; i.e., sec and F-Ω, msec and μF-kΩ, or μsec and pF-MΩ.

2. For a differentiating circuit the time constant should not exceed one-quarter of the pulse duration.

3. For a sine-wave input, the loss is 3 db when $T = 159/f$ (T in μF-kΩ, f in c/s).

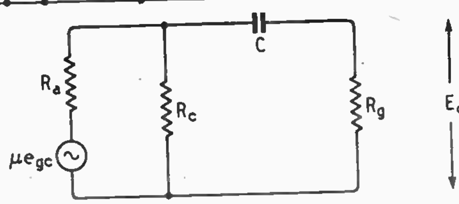

Fig. 2.

Symbols

μ = amplification factor of valve
R_a = A.C. resistance of valve (kΩ)
R_c = coupling resistance (kΩ)
R_g = grid leak of following valve (kΩ)
C = coupling capacitance (μF)
$g_m = \mu/R_a$ = mutual conductance of valve (mA/V)
T = circuit time constant = $C(R + R_g)$ (msec = μF − kΩ)
$R = R_cR_a/(R_c + R_a)$ (kΩ)
t = time (msec)
f = frequency (c/s)
$A = E_0/e_{gc}$ = voltage amplification.

Formulæ

$$A = \frac{g_m R R_g}{R + R_g} x \quad \quad (1)$$

$$x = 1/\sqrt{[1 + (159/fT)^2]} \quad \quad (2)$$

for a sine-wave input

$$x = \epsilon^{-t/T} \quad \quad (3)$$

for a unit impulse input.

For a given response at a given frequency

$$T = \frac{159}{f} \cdot \frac{x}{\sqrt{1 - x^2}} \quad \quad (4)$$

For a given response at a given time after the application of a pulse

$$T = t/(2.3 \log_{10} 1/x) \quad \quad (5)$$

and for values of x not less than 0.95

$$T = t/(1 - x) \quad \quad (5a)$$

Examples

(1) If $R_c = 20$ kΩ; $R_a = 10$ kΩ; $\mu = 20$; $R_g = 200$ kΩ; and a response of −1 db at 50 c/s is required, what coupling capacitance must be used, and what is the amplification at relatively high frequencies where C has a negligible effect?

We have $g_m = 2$ mA/V; $R = 10 \times 20/30 = 6.6$ kΩ, so from (1)

$$A = \frac{2 \times 6.6 \times 200}{206.6} = 12.9.$$ Then from (4)

$$T = \frac{159}{50} \cdot \frac{0.89}{\sqrt{1 - 0.795}} = \frac{159 \times 0.89}{50 \times 0.456} = 6.22$$

since for a response of −1 db $x = 0.89$.

Since $R_g + R = 206.6$ kΩ, $C = 6.22/206.6 = 0.03$ μF.

(2) The same amplifier is to be used for a saw-tooth wave of 50-c/s recurrence frequency, and it is necessary that the drop in output should not exceed 2 per cent. What value of C must be used? For a 2 per cent drop, $x = 0.98$ and, ignoring the fly-back time, the duration of the saw-tooth wave is $1/50 = 0.02$ sec, so $t = 20$ msec. We use (5a) since $x > 0.98$ and have $T = 20/0.02 = 1000$ for $R + R_g = 206.6$ kΩ, $C = 1000/206.6 = 4.82$ μF.

The enormously greater time constant needed for low distortion of a pulse or saw-tooth wave is apparent.

(3) With the same amplifier, a pulse of duration 10 μsec is applied, and it is desired that at the end of the pulse there should be substantially no output; that is, the circuit shall act as a differentiator. What value of C is now needed?

This is most easily solved from (3), and it is necessary to assume some arbitrary small value for x—say about 0.02. A table of exponentials gives $t/T = 4$ (about) for $\epsilon^{-t/T} = 0.02$. Therefore, $T = t/4 = 10/4 = 2.5$ μsec = 0.0025 msec, and $C = 0.0025/206.6 = 0.0000121$ μF = 121 pF.