RADIOTRONICS

BULLETIN No. 113 June, 1941

CATHODE BYPASSING

Derivation of Mathematical Formula

In the Radiotron Designer's Handbook (chapter 4, page 27) a formula is given for the response of a single stage due to the effect of the cathode bypass condenser. The derivation of this formula in the more convenient, explicit form is now given and the result shown to be identical with that previously obtained. For convenience, a family of curves is also given for response against frequency, with capacitance as parameter, for type 6J7-G valves operated under standard conditions.

Analysis

The notation to be used is as follows :

e_i = Instant. a-c. input voltage.
e_g = Instant. a-c. grid voltage with respect to cathode.
e_k = Instant. a-c voltage developed across self-bias resistor with respect to cathode.
e_p = Instant. plate voltage with respect to cathode.
e_o = Instant. *effective* output voltage.
R_K = Resistance of self-bias resistor.
C_K = Capacitance of cathode bypass condenser.
R_L = *Effective* a-c plate load resistance.
μ = Valve amplification factor *at the operating point.*
g_m = Valve mutual conductance *at the operating point.*
r_p = Valve plate resistance *at the operating point.*
ω = $2\pi f$ rad./sec.
f = Frequency of operation (c/s.).
M = Stage amplification with self-bias resistor *completely* bypassed.
M'' = Stage amplification with self-bias resistor *incompletely* bypassed.

In Fig. 1 the circuit is shown of a conventional self-biased stage, together with the instantaneous A.C. voltages developed across the valve electrodes and associated circuits, when an instantaneous a-c input voltage e_i is applied. The plate load impedance is assumed to be *non-reactive*

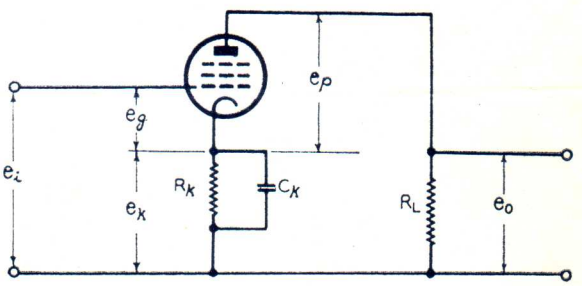


Fig. 1.

and the relative phases of all voltages referred to that of the cathode. It is then evident that

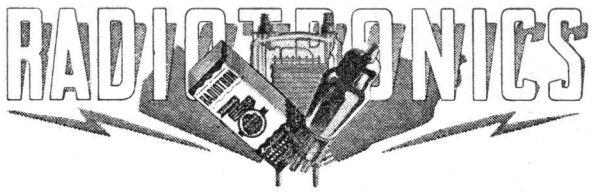
$$e_p = e_o + e_k \quad \ldots\ldots\ldots (1)$$

$$e_i = e_g - e_k \quad \ldots\ldots\ldots (2)$$

$$\text{and } e_k = e_o \cdot \frac{Z_k}{R_L} \quad \ldots\ldots\ldots (3)$$

where Z_k is the parallel impedance of R_K and C_K at the frequency ω rad./sec.

(Continued overleaf, column 1.)



TECHNICAL BULLETIN, No. 113

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(Continued from page 39.)

$$\text{Since } e_p = -\mu.e_g.\frac{R_L + Z_k}{R_L + Z_k + r_p} \quad \ldots\ldots (4)$$

$$\therefore\ e_o = -\mu.e_g.\frac{R_L}{R_L + Z_k + r_p} \quad \ldots\ldots (5)$$

$$\text{Also, } e_i = e_g.\left(1 + \frac{\mu.Z_k}{R_L + Z_k + r_p}\right) \quad \ldots (6)$$

The *degenerative* stage amplification M'' with the impedance Z_k in the cathode circuit is then given by—

$$M'' = \frac{e_o}{e_i} = \frac{-\mu R_L}{R_L + r_p + Z_k(\mu + 1)} \quad \ldots (7)$$

When $Z_k \rightarrow 0$ at the frequency ω rad./sec., i.e. when the self-bias resistor R_K is *completely bypassed at this frequency,* the *normal* stage amplification M is given by—

$$M = \frac{e_o}{e_g} = \frac{-\mu R_L}{R_L + r_p} \quad \ldots\ldots\ldots (8)$$
$$(Z_k \rightarrow 0).$$

Hence the ratio to which the stage amplification is reduced *at the frequency* ω *rad./sec.* due to incomplete cathode bypassing is—

$$\frac{M''}{M} = \frac{1}{1 + \dfrac{\mu + 1}{R_L + r_p}.Z_k} \quad \ldots\ldots\ldots (9)$$

Substituting for Z_k

$$Z_k = \frac{R_k}{1 + j\omega C_k R_k} \quad \ldots\ldots\ldots (10)$$

and putting

$$\frac{\mu + 1}{R_L + r_p} = \gamma \quad \ldots\ldots\ldots (11)$$

the expression (9) becomes

$$\frac{M''}{M} = \frac{1}{1 + \gamma \cdot \dfrac{R_k}{1 + j\omega C_k R_k}} \quad \ldots\ldots (12)$$

of which the *modulus* is

$$\left|\frac{M''}{M}\right| = \sqrt{\frac{1 + (\omega C_k R_k)^2}{(1 + \gamma R_k)^2 + (\omega C_k R_k)^2}} \quad \ldots (13)$$

which gives *explicitly* the *exact scalar ratio* to which the voltage amplification of a stage is reduced at the frequency ω rad./sec. due to incomplete cathode bypassing.

The *attenuation* in decibels is then—
Attenuation—

$$(db) = 20 \log \sqrt{\frac{1 + (\omega C_k R_k)^2}{(1 + \gamma R_k)^2 + (\omega C_k R_k)^2}} \quad \ldots (14)$$

In the Radiotron Designer's Handbook (Chap. 4, page 27) the formula given is

$$\left|\frac{M''}{M}\right| = \sqrt{\frac{1 + (\omega C_k R_k)^2}{(1 + \alpha M R_k)^2 + (\omega C_k R_k)^2}} \quad \ldots (15)$$

$$\text{where } \alpha = \frac{1}{M(R_L + r_p)} + \frac{1}{R_L} \quad \ldots\ldots (16)$$

and the other symbols are as defined in the present notation. This formula is in an implicit form but on substituting the expression (8) for M in the first term in the denominator, it is seen that—

$$\alpha M = \frac{\mu + 1}{R_L + r_p} = \gamma$$

and the two formulae become *identical.*

In the case of *high-mu pentode valves,* generally

$$r_p >> R_L$$
$$\& \ \mu >> 1$$
$$\text{so that } \gamma \doteqdot g_m \quad \ldots\ldots\ldots$$

and the *exact* expression (13) may be written as the more immediately applicable *approximation*—

$$\left|\frac{M''}{M}\right| = \sqrt{\frac{1 + (\omega C_k R_k)^2}{(1 + g_m R_k)^2 + (\omega C_k R_k)^2}} \quad \ldots (17)$$

which is usually sufficiently accurate for most practical purposes.

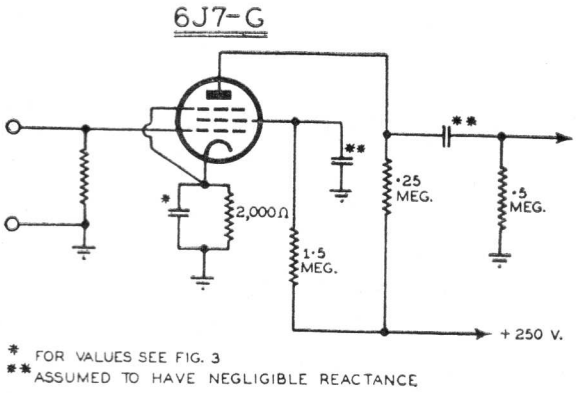

Fig. 2.

Owing to the number of independent variables involved, it is difficult to represent the formulae (13) or (16) in convenient, general graphical form. A useful set of curves, however, is obtained by plotting a family of curves of C_k for $\left|\frac{M''}{M}\right|$ or 20 log $\left|\frac{M''}{M}\right|$ against f for relevant valve types, when operated under specified standard conditions.

In Fig. 3, the latter family of curves has been plotted for type 6J7-G (6C6, 1603) when operation is under the following conditions:

E_b = 250 volts
R_L (DC) = 0·25 megohm
R_G = 0·5 megohm
R_S = 1·5 megohms
R_K = 2,000 ohms
g_m = 750 μmhos
r_p = 4·0 megohms approx.

The *effective* A.C. plate load resistance R_L is given by

$$R_L = \frac{R_L(D.C.) \times R_g}{R_L(D.C.) + R_g}$$

$$= \frac{\cdot 25 \times \cdot 5}{\cdot 25 + \cdot 5} = \cdot 167 \text{ Megohm.}$$

$$\text{and } \gamma = \frac{\mu + 1}{R_L + r_p} = \frac{g_m \cdot r_p + 1}{R_L + r_p}$$

$$= \frac{(750 \times 10^{-6})(4 \times 10^6) + 1}{\cdot 167 + 4} \ \mu\text{mhos}$$

$$= \frac{3001}{4 \cdot 167} \ \mu\text{mhos}$$

$$= 720 \ \mu\text{mhos}$$

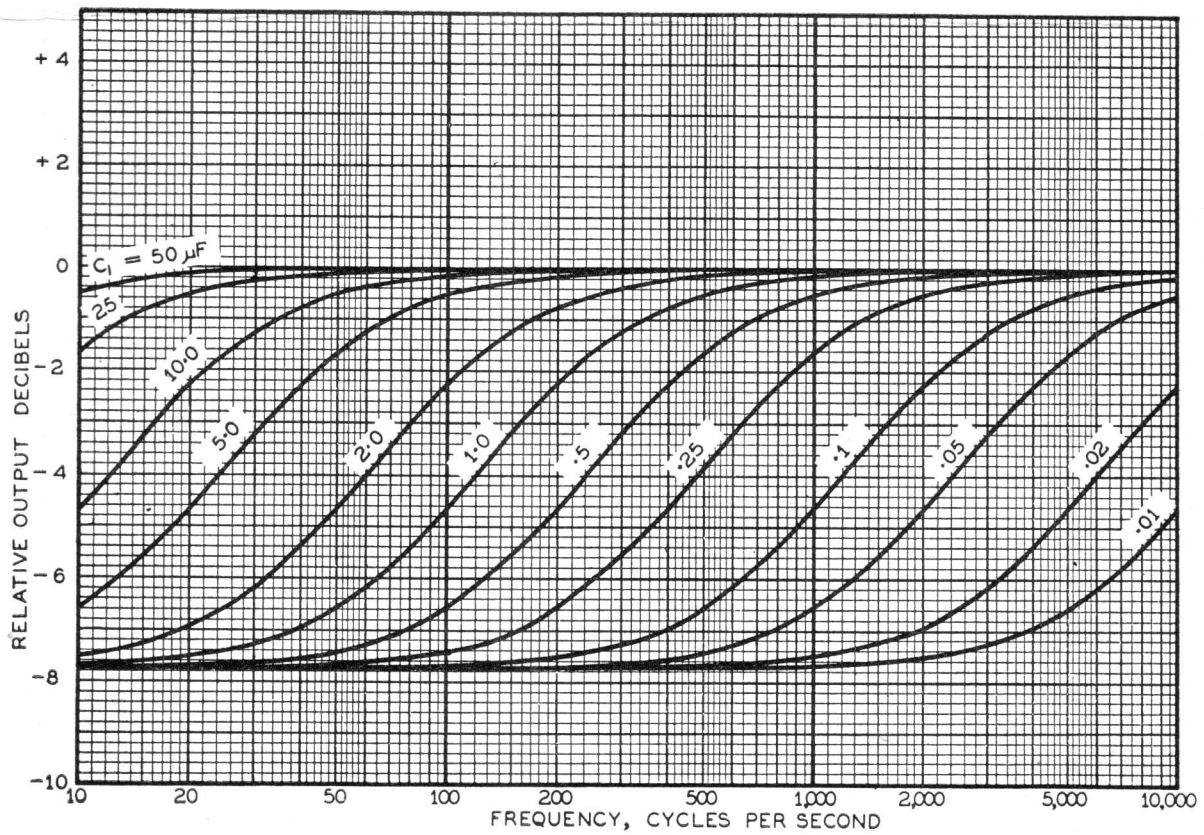

Fig. 3.

RADIOTRON NEWS

Radiotron 1B5/25S is not at present in production and it is suggested that type 1H6-G might be used as a replacement type in urgent cases. This replacement will involve a change of socket, but the electrical characteristics of the two types are identical.

Radiotrons 5V4-G, 83V and 47 are not at present in production and production is not expected to re-commence before September.

Radiotron 6X5-GT: The whole factory output of this type is at present being supplied for defence needs and there is no indication that commercial orders for this type can be met earlier than the end of July.

Radiotron 85: Production on this type has been suspended and it will cease to be available when present stocks are exhausted. However, type 6B8-G connected as a triode is electrically almost identical with type 85 and may be substituted for it in all normal applications. A change of socket will, of course, be necessary but the electrical circuit will not need to be modified.

Advice has been received that further supplies of the following types will not be forthcoming from U.K.:—

Radiotron U52/5U4-G: Rectifier.
Radiotron D63/6H6-G: Duplex diode.
Radiotron L63/6J5-G: Triode.
Radiotron N14/1C5-G: 1.4 volt power pentode.
Radiotron X64/6L7-G: Mixer.

RADIOTRON EQUIVALENT TYPE CHART

Stocks of the present issue of the Radiotron Equivalent Type Chart are now almost exhausted and it may cease to be available for a short period. The valve position has changed considerably since the chart was first issued and considerable modification appears to be necessary in order to maintain the maximum utility of the chart.

In the meantime the new "Radiotron Replacement Guide" may be consulted.

RADIOTRONICS SUBSCRIPTIONS

A Change of Policy

The present issue of Radiotronics, No. 113, is the final one in the current subscription period. Those wishing to receive further copies should complete the subscription card enclosed with this issue and post it, together with a postal note, to reach the Head Office of the Company not later than Saturday. 21st June. Names and addresses submitted after this date cannot be included in the July posting.

It will be noted that the amount called for is three shillings, which covers the cost of postage and handling for the 18 month period July, 1941 to December, 1942. Subsequent subscription periods will be from January to December of each year instead of from July to June as in the past.

A further change is that subscriptions will, in future, cover technical charts and leaflets in addition to Radiotronics Bulletins and Valve Data Sheets. Owing to the extreme pressure of more essential work it is becoming increasingly difficult to devote the necessary time to the preparation of original articles and the scope of Radiotronics Bulletins may have to be restricted somewhat. However, it is hoped to maintain regular postings of technical material in one form or another, but there is indication that the number of releases will be reduced by about 25%.

NEW RADIOTRON CHART

A new Radiotron publication entitled "The Radiotron Replacement Guide" is now in the course of preparation and should be available for general distribution in the near future.

The "Radiotron Equivalent Type Chart" issued in September, 1940, proved extremely popular, but owing to the large number of types listed, the information about any one type was necessarily restricted.

In "The Radiotron Replacement Guide" illustrated above over one hundred types are selected and more or less detailed instructions given for replacing these types with valves of Australian manufacture.

The Australian-made range of receiving valves is listed for reference and a supplementary list shows approximately sixty other types which can be directly replaced by Australian-made valves.

Copies of this chart will be mailed to all subscribers to Radiotron Technical Publications. Copies will also be available free on application to the Head Office of the Company or at a cost of threepence posted to non-subscribers.

DATA SHEETS

Four Data Sheets are released concurrently with this issue of Radiotronics. These are:

Radiotron 1K7-G curves, Sheets 2, 3 and 4.
Receiving Valve Ratings according to R.M.A.

The curves for type 1K7-G are substantially the same as those issued earlier for type 1K6, but the new sheets incorporate a number of minor corrections and are generally easier to read. The old 1K6 curves should be regarded as out-of-date and removed from the Data Handbook.

The sheet, "Receiving Valve Ratings According to R.M.A.," supersedes the earlier sheet headed "Receiving Valve Ratings According to New R.M.A. System" and issued in February, 1940. The latter sheet should be removed from the Data Handbook.