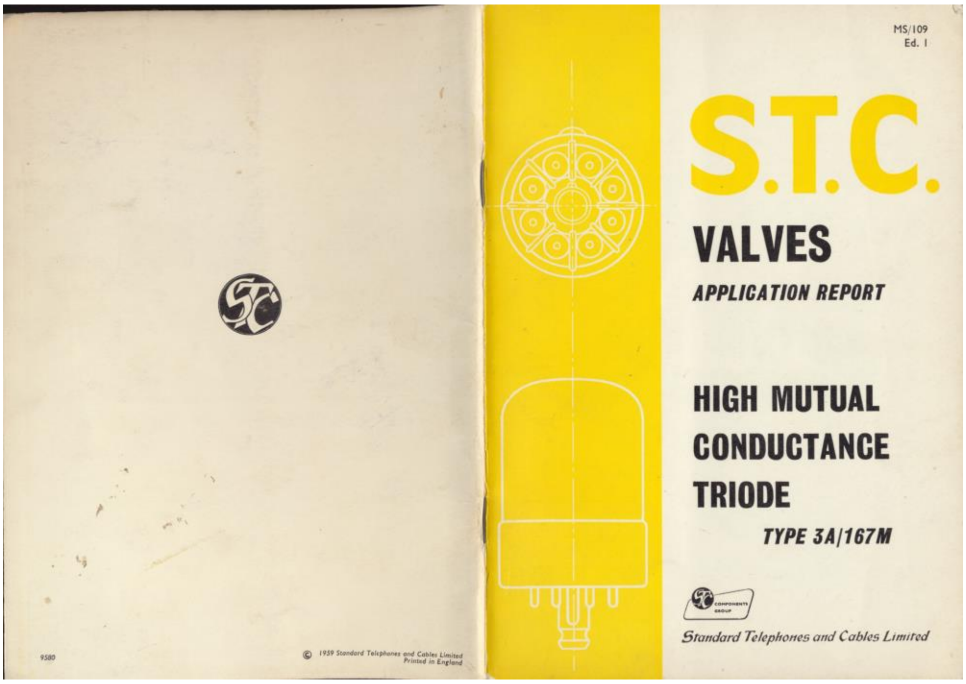
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VALVES

APPLICATION REPORT

HIGH MUTUAL CONDUCTANCE TRIODE

TYPE 3A/167M

COMPONENTS GROUP

Standard Telephones and Cables Limited

9580

" . . . for steeply rising pulses and fast trigger action, small anode loads and high slope valves operated at high currents must be used, . . . In the practical balance between performance and economy lies the art of the designer" F. J. M. Farley, Elements of pulse circuits. Methuen, London.

HIGH MUTUAL CONDUCTANCE TRIODE

Applications include

- Wide-band amplification
- Low noise amplification
- V.H.F. cascode amplification
- Pulse amplification
- Low distortion amplification
- Low noise triode mixing

COMPONENTS GROUP

Standard Telephones and Cables Limited

Registered Office: CONNAUGHT HOUSE, 63, ALDWYCH, LONDON, W.C.2.

SPECIAL VALVE SALES DEPARTMENT, FOOTSCRAY, SIDCUP, KENT

Available in the U.S.A. exclusively from Intelex Systems Inc.
(formerly International Standard Trading Corporation)
22 Thames Street, New York, 6.N.Y.

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CONTENTS *(continued)*

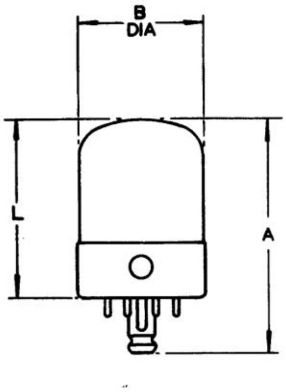
1 INTRODUCTION

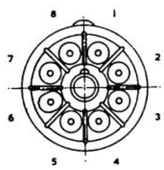
The 3A/167M (CV5112) is a high performance, long-life triode, which has been designed to satisfy the stringent requirements of repeater applications. There is, however, a much larger field of possible applications and this report presents data necessary for circuit design, examples of applications and the performance which can be expected.

Characteristic behaviour at the recommended working point is high anode current, high mutual conductance and high figure of merit, representing a considerable improvement upon previously existing triodes. It is also characterised by low noise and low distortion of signals in amplifier applications.

These improved characteristics have been obtained primarily by using a gold-plated, "frame" type of control grid. Very fine grid wires are wound under mechanical tension on a rigid frame, to give a firm grid construction which permits very small grid-cathode spacing. It is used in conjunction with an oxide-coated cathode, which is normally operated at low current density to give long life. The cathode base metal, known as ST nickel, is noted for its very low rate of development of interface impedance, consequently measurable impedance is not likely to develop in less than 10,000 hours of operation.

2. MECHANICAL DATA





BASING

1. HEATER
2. I.C.
3. N.C.
4. ANODE
5. CATHODE
6. I.C.
7. GRID
8. HEATER

DIMENSIONS

DIM.	MILLIMETRES	INCHES
A	54·8 MAX.	2 5/32 MAX.
B	30·2 MAX.	1 3/16 MAX.
L	41·3 MAX. 34·9 MIN.	1 5/8 MAX. 1 3/8 MIN.

NOTE: BASIC FIGURES ARE IN INCHES
NET WEIGHT: 22g (0·8 oz)

3. ELECTRICAL DATA

The 3A/167M is an electrical equivalent of the U.S.A. type 437A.

3·1 CATHODE

Indirectly heated, oxide-coated			
Heater voltage	V_h	6·3	V
Heater current	I_h	0·45 ± 0·025	A

3·2 CHARACTERISTICS *

Mutual conductance	gm	47 ± 9	mA/V
Anode impedance	r_a	1,000 ± 300	Ω
Anode current	I_a	40 + 4·5 − 2·5	mA
Grid bias voltage min.	V_{gk}	− 0·8	V
Fall of mutual conductance (V_h = 5·7V) max.	Δ gm	15	%

3·3 MAXIMUM RATINGS

	Direct anode voltage (I_a=0)	V_{ao}	400	V
	Direct anode voltage	V_a	350	V
	Direct anode current	I_a	45	mA
	Direct anode dissipation	P_a	6·5	W
	Peak anode current	$I_{a,\,pk}$	200	mA
	Peak positive grid voltage	$V_{gk,\,pk}$	0	V
	Heater to cathode d.c. voltage (heater positive)	V_{hk}	0	V
**	Heater to cathode d.c. voltage (heater negative)	V_{hk}	30	V
	Heater to cathode external resistance	R_{hk}	20	kΩ
**	Grid leak resistance (R_k = 270 Ω)	R_g	0.5	MΩ
	Bulb temperature*** (hot spot)****	T bulb	135	°C

* Measurement conditions V_a = +160V, V_g = +9V, R_k = 262 Ω
** Recommended maximum values for long life applications
*** Temperature — dissipation curve, page 14.
**** Bulb hot spots directly face the anode, midway between the supporting micas.

3·4 CAPACITANCES*

		cold	hot	
(a)	Grounded cathode			
	Input capacitance	c_{in} 12 ± 2·5	17·5 nom.	pF
	Output capacitance	c_{out} 2·5 ± 0·7	2·7 nom.	pF
	Grid to anode interelectrode capacitance.	c_{ga} 4·2 ± 0·8	4·0 nom.	pF
(b)	Grounded grid, heater earthed			
	Input capacitance	c_{in} 17·3 nom.	23 nom.	pF
	Output capacitance	c_{out} 6·5 nom.	6·4 nom.	pF
	Cathode to anode interelectrode capacitance.	c_{ka} 0·32 nom.	0·46 nom.	pF
(c)	Grounded grid, heater live			
	Input capacitance	c_{in} 14 nom.	19·5 nom.	pF
	Output capacitance	c_{out} 6·3 nom.	6·2 nom.	pF
	Cathode to anode interelectrode capacitance	c_{ka} 0.35 nom.	0·52 nom.	pF
(d)	Other capacitances			
	Grid to cathode interelectrode capacitance	c_{gk} 11 nom.	16·5 nom.	pF
	Grid to heater + base shield + NC + IC pins	c_{gb}	1·0 nom.	pF
	Heater to cathode interelectrode capacitance	c_{hk}	4·7 nom.	pF

*Measured at 1Mc/s with connections as specified in Joint Service Specification K1001, Appendix III.

3·5 RECOMMENDED OPERATING CONDITIONS

Direct anode voltage	V_a	160	V
Direct anode current	I_a	40	mA
Direct grid voltage	V_g	+9	V
Cathode resistor	R_k	262	Ω

For a typical valve and a cathode resistor R_k = 270Ω ± 5%, an anode current I_a = 39 ∓ 1·7 mA, and a mutual conductance gm = 46·3 ∓ 1 mA/V are obtained.

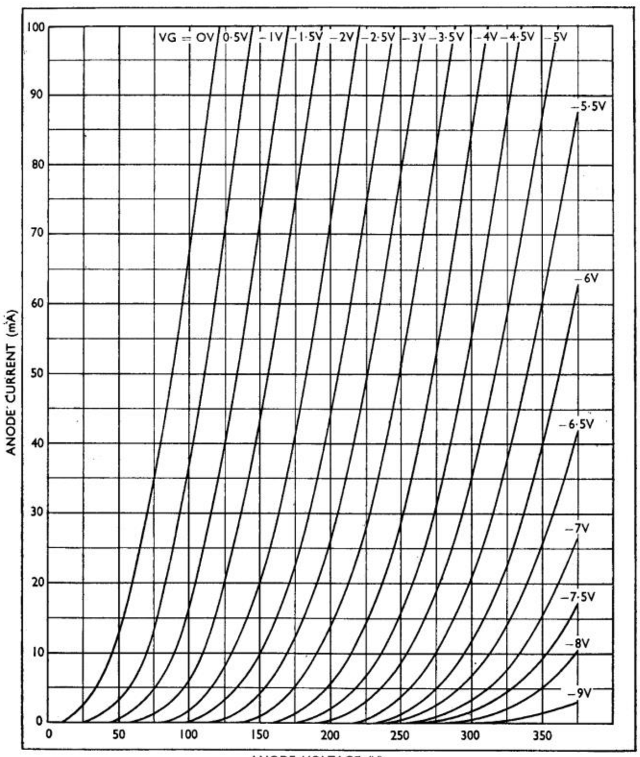


Fig. 1 Anode characteristic curves.

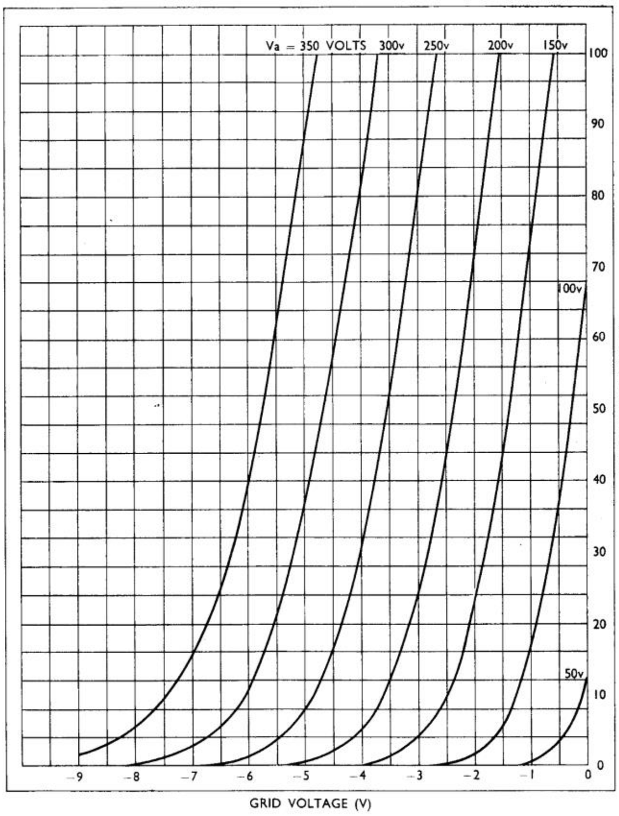


Fig. 2 Mutual characteristic curves.

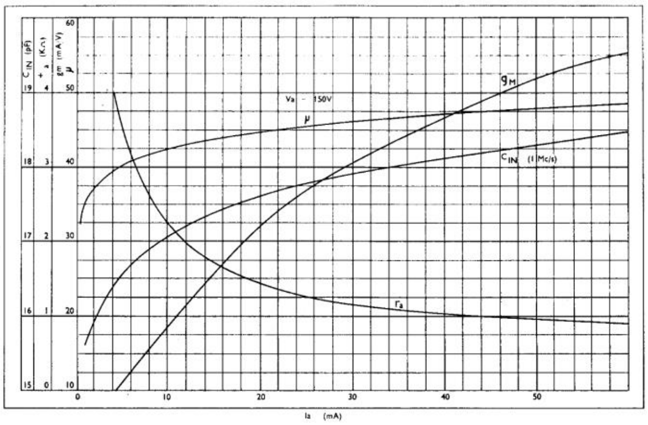


Fig. 3 Mutual conductance, amplification factor, anode impedance and input capacitance versus anode current.

4. APPLICATION NOTES

4·1 CATHODE BIAS

Normal automatic bias operation permits an undesirably large spread of operating anode current from valve to valve, a condition which should be avoided whenever possible.

The positive applied grid voltage condition of operation is recommended to ensure that, when a valve is changed, the replacement valve can be relied upon to give essentially the same performance as the valve it replaces. This permits the use of a relatively high value of cathode resistor, which gives stabilisation against any drift of valve characteristics during life. The spread of anode current arises from the major problem with high mutual conductance valves, namely the maintenance of close enough tolerances on critical dimensions and processes during manufacture.

The anode current tolerance given in section 3·2 enables calculation of the grid to cathode bias voltage tolerance which, in turn, enables calculation of the range of anode current for any cathode resistor. The range of anode current quoted above, for $R_k = 270\Omega \pm 5\%$, does not take account of the specification limits.

4·2 CATHODE DECOUPLING

Cathode resistor decoupling is particularly important in video amplifiers using high mutual conductance valves. Various methods of decoupling are possible, but none has been found to excel the performance of miniature electrolytic and Stantelum capacitors for good wide-band decoupling. Some small reduction of gain results at frequencies approaching 100 Mc/s, because of an increasingly inductive capacitor characteristic. This does not occur when Hi-K ceramic capacitors are used, but sufficiently large capacitance values are not available for decoupling at the low frequency end of the video band. Parallel connection of ceramic and electrolytic capacitors should be avoided, as measurements have shown that an 8μF electrolytic can resonate, with a 470pF ceramic capacitor, at approximately 50 Mc/s. This undesirable effect produces a narrow bandwidth Q curve superimposed on the amplifier gain-frequency characteristic.

4·3 INPUT IMPEDANCE

The cathode circuit has considerable effect on the input impedance of a valve, since introduction of inductive reactance into the cathode lead will reduce the input resistance and produce a series resonance with the grid to cathode capacitance. For input impedance measurement purposes the cathode resistor has been removed in order to obtain a true picture of the valve input characteristic resulting from transit time and residual internal lead inductance effects (See Figs. 8 and 14, pages 17 and 23, respectively). The correct anode current has been obtained by the application of negative grid bias.

4·4 GRID LEAK RESISTANCE

The anode current of this valve is very susceptible to small changes of grid voltage, such as may occur during life, owing to small changes of grid current with a high value of grid leak resistance. The use of an excessively high value of grid leak resistor may result in premature termination of valve life and it is therefore desirable to place a maximum limit on the resistor value. The change of anode current resulting from a change of grid voltage will, however, depend upon the amount of d.c. feedback which exists in the valve circuit, usually a result of using a cathode resistor. A curve which relates maximum grid leak resistance to cathode resistor value is given in Fig. 4. It should be noted that there is no well-defined limit in practice and that where a valve is operated at very low dissipation the grid resistance may be increased considerably, but it is not easy to determine the functional relationship between these parameters.

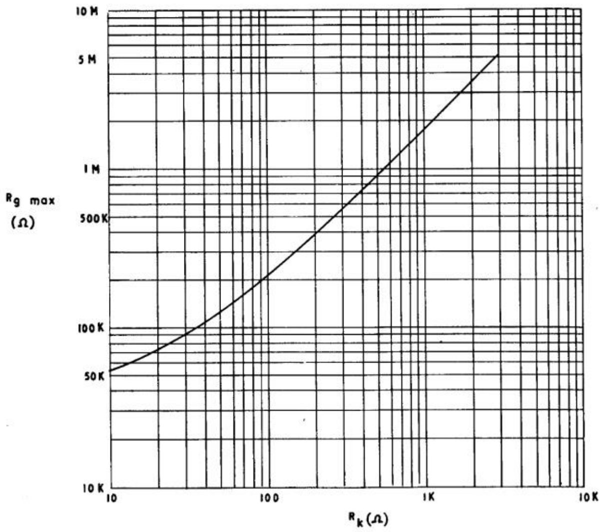


Fig. 4 Maximum grid leak resistance versus cathode resistance.
V_a = 160 volts I_a = 40mA

4·5 PARASITIC OSCILLATIONS

High mutual conductance increases circuit tendencies to parasitic oscillations and normal precautions for their suppression must be observed. Decoupling of the heater circuit at the base pins, the earthing of grid and cathode circuits to a common point, and the use of short grid, anode and cathode leads, are precautions which are normally sufficient. Grid and anode stopper resistors may be introduced, but in low noise or high frequency amplifiers this will impair the performance. Sensitivity of anode current to hand capacity, in an amplifier circuit, usually indicates the presence of parasitic oscillations.

4·6 PULSE CIRCUIT APPLICATIONS

Pulse circuits normally require small anode loads in order to reduce the integrating effects which result from stray capacitances. This means that high slope valves are required in order to give reasonable gain, also that simple pentode formulae often suffice for triodes. To develop reasonable pulse voltages across small anode loads, the valves must be operated at high currents, consistent always with the rated mean power dissipation. It is quite clear that the characteristics of the 3A/167M fit most pulse circuit requirements perfectly, but the restriction of maximum positive going grid to cathode voltage excursion is a limitation in some types of circuit. In general the most fertile field of application for this valve is pulse amplification, but pulse generation, in such circuits as multi-vibrators, is permissible if it is accompanied by grid excursion limitation, either by careful design or diode clamping. Semi-conductor clamping diodes do not usually give satisfactory performance in applications where millimicrosecond pulse rise times are considered. Grid excursion of a few volts positive with respect to cathode is likely to damage this valve.

In order to demonstrate the performance which can be achieved, some common pulse circuit designs and measured characteristics are given under sections 10, 12 and 13. A description of these circuits is given by Farley, (Ref. 6.) Since fast rise time is synonymous with good frequency response, these circuits may be advantageously applied in other fields.

4·7 BULB TEMPERATURE

The maximum bulb temperature given in the ratings (see 3.3, page 6), must not be exceeded if the long life characteristics of the valve are not to be impaired. The relationship between bulb temperature and anode dissipation is given in Fig. 5, which shows the bulb hot-spot temperature to be 100°C above the ambient temperature, with normal anode dissipation. Consequently, the maximum ambient temperature at which this valve may be used with the recommended operating conditions is 35°C (95°F). Above this ambient temperature the anode dissipation must be reduced, or some bulb cooling arrangement used, such as a heat conducting shield. When mounted in an equipment, heat radiation from adjacent valves or components must be considered in the determination of the effective ambient temperature. It is advisable to determine the effective ambient temperature, rather than attempt to measure the bulb temperature, because the latter varies a few degrees from valve to valve and measurement requires considerable care with carefully designed thermocouples.

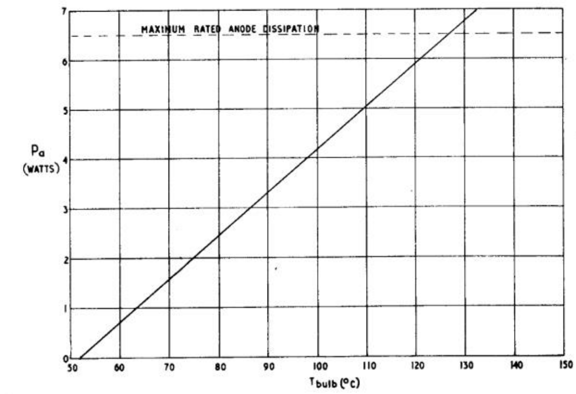


Fig. 5 Bulb temperature (hot spot) versus anode dissipation. Ambient temperature 21°C.

5. TRIODE AMPLIFIER

The following characteristics are typical of the performance of the 3A/167M as a triode amplifier.

5·1 CHARACTERISTICS

	Mutual conductance	g_m	47	mA/V
	Anode impedance	r_a	1.0	kΩ
	Equivalent noise resistance	Req	65	Ω
	Figure of merit, hot valve, $g_m/[2\pi (c_{in} + c_{out})]$	M	370	Mc/s
*	Input resistance at 100 Mc/s	R_{in}	130	Ω
*	Input capacitance at 100 Mc/s	C_{in}	25	pF
**	Harmonic distortion, 2nd (for i_a=1mA r.m.s.)	D_2	—50	dB
	Harmonic distortion, 3rd (for i_a=1mA r.m.s.)	D_3	—70	dB
***	Equivalent hum voltage, 50 c/s	Vg,hum	180	μV r.m.s.
***	Equivalent hum voltage, 100c/s		80	μV r.m.s.
	Mutual conductance change during life		—2.5	%/10^3 hrs.
	Cathode to grid electron transit time		100	μμs

* For frequency curves of these parameters, see Fig. 8.

** —60 dB/mA. r.m.s. corresponds to 0·1%/mA. r.m.s.

*** Alternating heater supply voltage, 50 c/s, Ck = 0μF, R_g = 0·5MΩ2 V_{hk} = 0V(d.c.), R_k = 262Ω

The figure of merit is given according to the definition: "*The frequency at which unity gain results, from interstage output and input capacity loading of the first stage, in a two stage amplifier*".

Harmonic distortion is expressed in decibels referred to one milliampere (r.m.s.) of anode signal current. For an anode signal current i_a other than 1 mA, the resulting second harmonic distortion D'_2 is

$$D'_2 = (20 \log_{10} i_a - 50) \text{ dB with respect to } i_a$$

For the triode amplifier, curves are given in percentage harmonic distortion versus signal input voltage (see Figure 10, page 19).

5·2 TRIODE AMPLIFIER CIRCUIT

A basic amplifier circuit, with grid biasing, and heater decoupling arrangement, is given in Fig. 6. The performance of this circuit is given below, and low frequency response curves are given in Fig. 9.

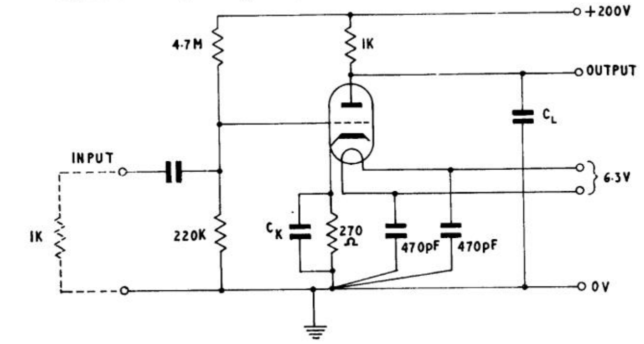


Fig. 6 Triode amplifier circuit.

Anode load resistance	R_L	1·0	k Ω
Voltage amplification	A	24	
Maximum output voltage	V_{out},r.m.s.	28	V
Input capacitance	C_{in}	117	pF
Load capacitance	C_L	117	pF
High frequency cut-off (– 3dB)		500	kc/s
Low frequency cut-off (– 3dB)		See Fig. 9	

5·3 EQUIVALENT CIRCUIT

High frequency circuit design requires adequate knowledge of valve parameters which are likely to influence circuit performance. The equivalent circuit of Fig. 7 contains hot-valve capacitances, and is applicable up to frequencies where input resistance effects become appreciable (see Fig. 8). The high input and output capacitances, which are given above in 5·2, result from the Miller effect, and can be derived from Fig. 7. Neutralisation of the anode to grid capacitance is necessary at radio frequencies.

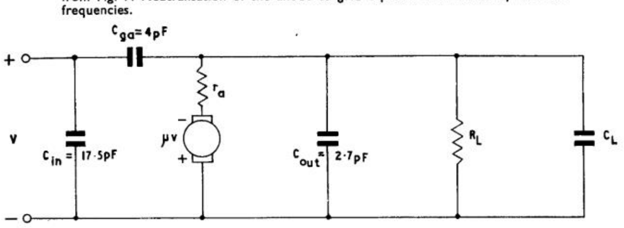


Fig. 7 Triode equivalent circuit.

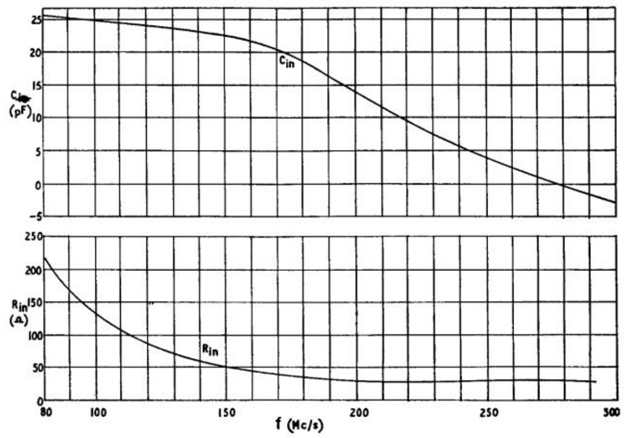


Fig. 8 Triode input resistance and capacitance.

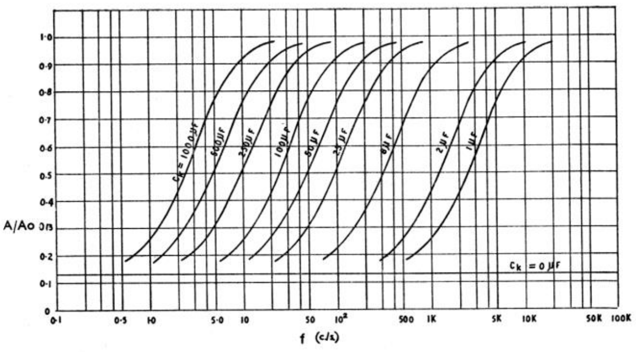


Fig. 9 Triode amplifier, low frequency gain characteristics.

Normalised voltage gain A/Ao, versus frequency, cathode bypass capacitor as parameter.

Operating conditions, as recommended, with Rk = 270Ω, R_L = 1kΩ, A = 24.

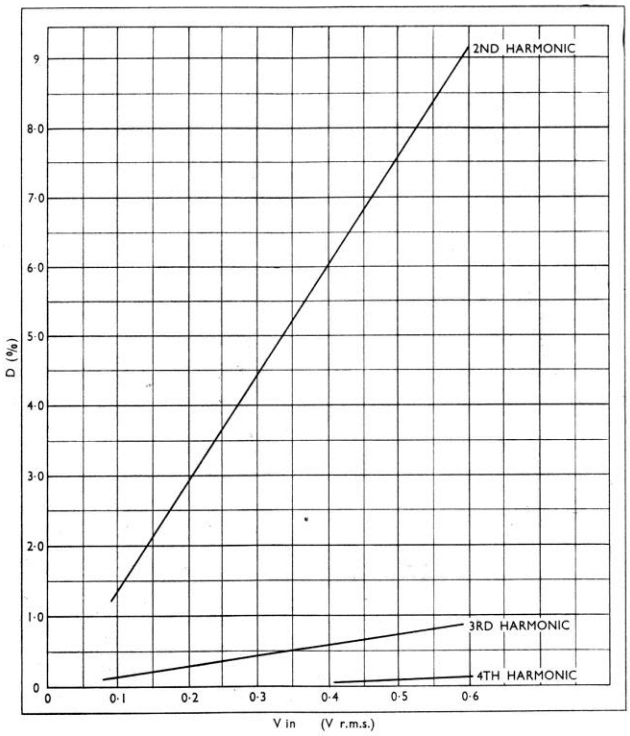


Fig. 10 Triode amplifier, percentage harmonic distortion versus r.m.s. input voltage.

V_a = 150V
I_a = 40mA
R_L = 500 Ω
Voltage gain = 16

6. CATHODE FOLLOWER

Low output resistance and high load currents are possible when the 3A/167M is used as a cathode follower.

6·1 TYPICAL OPERATING CONDITIONS

Direct anode voltage	V_a	190	190	160	V
Direct grid voltage	V_g	+38.5	+38·5	+9	V
Cathode resistor	R_k	1,000	1,000	270	Ω

6·2 CHARACTERISTICS

Anode current	I_a	40	40	39	mA
Load resistance (capacitively coupled)	R_L	⩾ 1,000	75	⩾ 1,000	Ω
Voltage gain	A	0.96	0.75	0·91	
Output resistance	R_{out}	20	20	19	Ω
Output current (sinusoidal)	$i_{k,pk}$	40	40	40	mA max.
Output voltage (sinusoidal)	$v_{k,pk}$	40	2·8	11	V max.
Hot input capacitance	C_{in}	5·7	9·0	6·5	pF
Hot output capacitance	C_{out}	22	22	22	pF

The maximum permissible grid leak resistance with reference to R_k, may be determined from Fig. 4. The voltage gain of a cathode follower is always less than one, therefore the rise of grid voltage when a positive going signal is applied is always greater than the rise of cathode voltage. When the difference between these voltage rises equals the zero signal grid-cathode bias, the maximum permissible positive going applied voltage has been reached, since further increase of the input signal will produce a positive grid to cathode voltage.

6·3 CATHODE FOLLOWER CIRCUIT

The following simple circuit shows a commonly used arrangement.

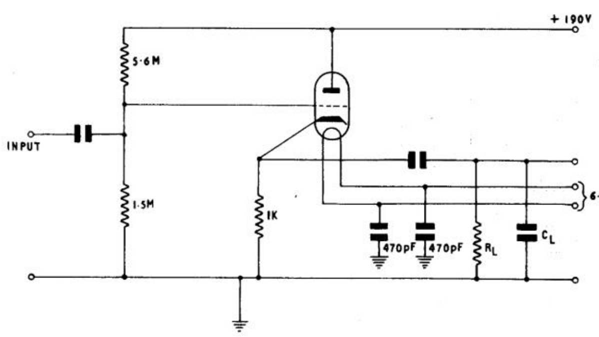


Fig. 11 Cathode follower circuit.

6·4 EQUIVALENT CIRCUIT

The equivalence shown in Fig. 12 is important for calculation of the input and output parameters, but it is confined to small signal working. The functional relationship between output resistance and signal amplitude, shown in Fig. 13, illustrates the departure from small signal equivalence. However, if the curves of Fig. 3 are utilised, this circuit may be used to derive parameters for all operating conditions.

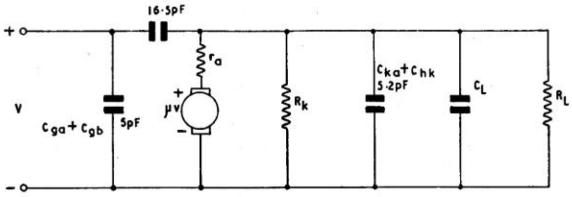
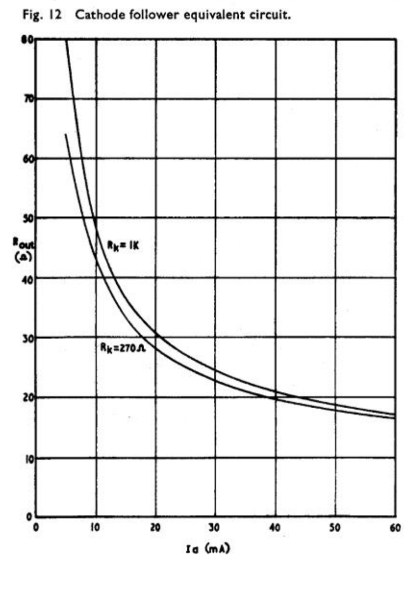


Fig. 12 Cathode follower equivalent circuit.

Fig. 13 Cathode follower output resistance.



7. CASCODE AMPLIFIER

The cascode circuit Fig. 15, has characteristics resembling those of the pentode and can in many respects replace it. No screen current is required and partition noise is consequently absent. The overall mutual conductance is the same as for a single valve and the amplification factor is increased to μ (μ+ 1). The grounded grid stage V_2 (Fig. 15) drastically reduces capacitive feedback from output to input, while its shot noise contribution to overall noise is negligible, due to the highly degenerative effect of r_{a1} in series with the cathode. The noise figure thus approaches the theoretical value for V_1 used as a triode. The very high mutual conductance of the 3A/167M permits the use of low impedance loads, giving wide frequency bands of stable amplification extending to V.H.F.; useful gains are obtainable with standard coaxial line impedances. The cascode circuit can be recommended for all wide-band amplifiers.

7·1 TYPICAL OPERATING CONDITIONS (D.C. COUPLED AMPLIFIER)

Direct anode voltage	V_{2a}	300	V
Direct grid voltage	V_{2g}	159	V
Direct grid voltage	V_{1g}	+9	V
Cathode resistor	R_{1k}	270	Ω

7·2 CHARACTERISTICS

Direct anode current	I_a	39	mA
Mutual conductance	g_m'	45	mA/V
Anode impedance	r_a'	49	kΩ
Equivalent noise resistance	R_{eq}	65	Ω
Harmonic distortion, (2nd) (for i_a = 1mA r.m.s.)	D_2	−45	dB
Harmonic distortion, (3rd) (for i_a = 1mA r.m.s.)	D_3	−88	dB
Hot input capacitance, 1Mc/s	C_{in}	25·4 nom.	pF
Hot output capacitance, 1Mc/s	C_{out}	6·4 nom.	pF
Hot figure of merit, gm/2π (C_{in} + C_{out})	M	225	Mc/s
*Hot input capacitance, 100 Mc/s	C_{in}	35	pF
*Input resistance, 100 Mc/s	R_{in}	70	Ω

*For frequency curves of these parameters, see Fig. 14.

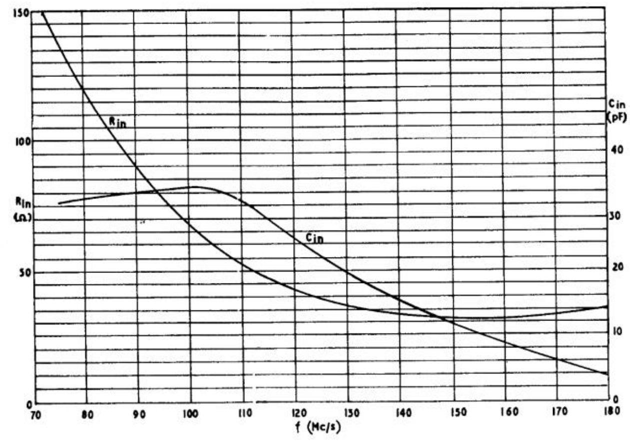


Fig. 14 Cascode input resistance and capacitance.

7·3 A.F. TO V.H.F. CASCODE CIRCUIT, D.C. COUPLED

The d.c. cascode circuit is widely used because of its economy of current drain when compared with the a.c. coupled circuit. A typical circuit of this class is shown in Fig. 15. Particular note should be made of the increased bandwidth which results from reduced capacitance loading, as is the case when the next stage is a cathode follower.

Separate heater supplies for V1 and V2 should be used with this circuit, to avoid excessive heater to cathode voltage.

Anode load resistance	R_L	600	600	Ω
Voltage amplification	A	22	22	
Anode load capacitance	C_L	19	4	pF
High frequency cut-off (−3dB)		12	33	Mc/s
Cathode bypass capacitor	C_k	8	8	μF
Low frequency cut-off (−3dB)		580	580	c/s

Uncompensated amplifier H.F. characteristics are given in Fig. 17 for various anode load resistances and capacitances. Compensated amplifier H.F. characteristics are given in Fig. 22, using one terminal pair, Wheeler compensating networks (Ref. 4). Low frequency gain characteristics for various values of cathode bypass capacitance are given approximately in Fig. 9. V.H.F. input resistance and capacitance curves are given in Fig. 14.

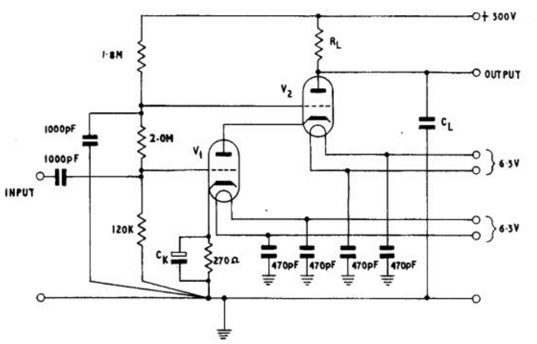


Fig. 15 A.F. to V.H.F. cascode circuit, d.c. coupled.

7·4 EQUIVALENT CIRCUIT

This is derived from the triode characteristics, considering a grounded cathode stage driving a grounded grid stage, with heaters earthed in the a.c. sense.

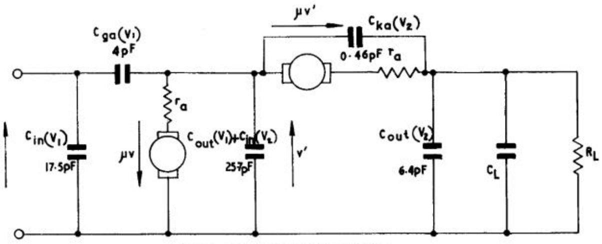


Fig. 16 Cascode equivalent circuit.

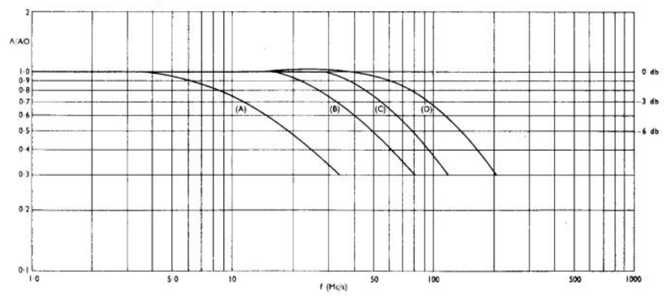


Fig. 17 Cascode amplifier, high frequency characteristics.

Voltage gain A, normalised to mid-band value A_o, versus frequency F.

Curve (A)	A_o = 22, R_L = 600Ω	C_L = 19pF
Curve (B)	A_o = 22, R_L = 600Ω	C_L = 4pF
Curve (C)	A_o = 5·5, R_L = 120Ω	C_L = 19pF
Curve (D)	A_o = 5·5, R_L = 120Ω	C_L = 4pF

C_k = 8μF miniature electrolytic.

7·5 R.F. TO V.H.F. CASCODE CIRCUIT, A.C. COUPLED, HEATER EARTHED

This form of the cascode circuit is useful when a low supply voltage is more important than low current drain. It also has the advantage of requiring only one heater supply for the two valves.

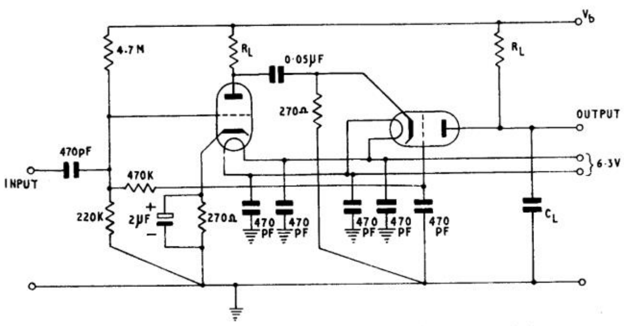


Fig. 18 R.F. to V.H.F. cascode circuit, a.c. coupled, heater earthed.

Anode supply voltage	V_b	180	V
Anode load resistance	R_L	600	Ω
Voltage amplification	A	20	
High frequency characteristic as for a d.c. coupled amplifier.			
Low frequency cut-off (−3dB)		25	kc/s

7·6 CATHODE DECOUPLING

Cathode resistor decoupling is particularly important in video amplifiers using high mutual conductance valves. Various methods of decoupling are possible, but none has been found to excel the performance of miniature electrolytic and Stantelum capacitors for good wide-band decoupling. Some small reduction of gain results at frequencies approaching 100 Mc/s, because of an increasingly inductive capacitor characteristic. This does not occur when Hi-K ceramic capacitors are used, but sufficiently large capacitance values are not available for decoupling at the low frequency end of the video band. Parallel connection of ceramic and electrolytic capacitors should be avoided, as measurements have shown that an 8μF electrolytic can resonate, with a 470pF ceramic capacitor, at approximately 50 Mc/s. This undesirable effect produces a narrow bandwidth Q curve superimposed on the amplifier gain-frequency characteristic.

8. WIDE-BAND, LOW NOISE AMPLIFIER

SPECIFICATION:

Bandwidth at − 3dB points, 5·5 kc/s to 37·5 Mc/s	
Bandwidth at − 1·0 dB points, 15 kc/s to 36 Mc/s	
Voltage gain (output open circuit)	200
Output resistance	21Ω
Equivalent noise resistance at input	100Ω

The above characteristics are those measured on an amplifier unit using 3A/167M triodes throughout. The circuit diagram is given in Fig. 19, showing the use of two cascode amplifiers with an interstage cathode follower and a cathode follower output stage. This use of cathode followers reduces the load capacitances of the cascodes and thereby gives increased bandwidth. Inductors have been used in series with the anode load resistors, to give a simple form of compensation and to improve the high frequency cut-off characteristic as shown in Fig. 20. Complex compensating networks of the Wheeler type (Ref. 4), as used in obtaining Fig. 22 and given in Fig. 23, will give much greater bandwidth.

This amplifier has been used as a pre-amplifier for noise spectrum measurements, with a superheterodyne receiver connected to the output. The equivalent noise resistance of approximately 100 ohms at the input, see Fig. 21, applies to the amplifier when connected to a 50 ohms source and consists of valve noise plus source noise. It corresponds to a noise figure of 3dB with a 50 ohms source and a noise voltage of 80mμV in a 4 kc/s band.

COMPONENT VALUES

Resistors	Value	Type	Watts
R1	1K Ω	WW	2
R2	330 Ω	C	0·5
R3	100K Ω	C	0·25
R4	100K Ω	C	0·5
R5	270 Ω	C	0·5
R6	470 Ω	C	0·25
R7	100K Ω	C	0·25
R8	91K Ω	C	0·5
R9	62K Ω	C	0·25
R10	15K Ω	C	0·25
R11	4·7K Ω	C	0·25
R12	3·9K Ω	WW	10
R13	100 Ω	C	0·5
R14	1K Ω	C	2
R15	100K Ω	C	0·25
R16	100K Ω	C	0·25
R17	330 Ω	C	0·5
R18	1K Ω	C	2
R19	270 Ω	C	0·25
R20	3·9K Ω	WW	10
R21	100 Ω	C	0·25
R22	10K Ω	C	0·25
R23	1K Ω	C	2
R24	470 Ω	C	0·25
R25	100K Ω	C	0·25

C = Carbon WW = Wire Wound.

Capacitor	Value	Type	Volts
C1	0·5μF	P	350
C2	0·1μF	P	200
C3	2μF	E	25
C4	0·1μF	P	200
C5	0·1μF	P	200
C6	0·1μF	P	350
C7	0·1μF	P	250
C8	0·1μF	P	200
C9	0·1μF	P	200
C10	2μF	E	25
C11	1μF	P	350
C12	1μF	P	350
C13	0·01μF	P	250
C14	1μF	P	250
C15	0·01μF	P	350
C16	0·01μF	P	250
C17	0·01μF	P	250
C18	0·01μF	P	250
C19	0·01μF	P	250
C20	0·01μF	P	250
C21	0·01μF	P	250

E = Electrolytic P = Paper

Valves	Type
V1	3A/167M
V2	,,
V3	,,
V4	,,
V5	,,
V6	,,

	Inductance
L1	0·77μH
L2	,,
5¾ turns of 20 SWG. on ½″ Former.	

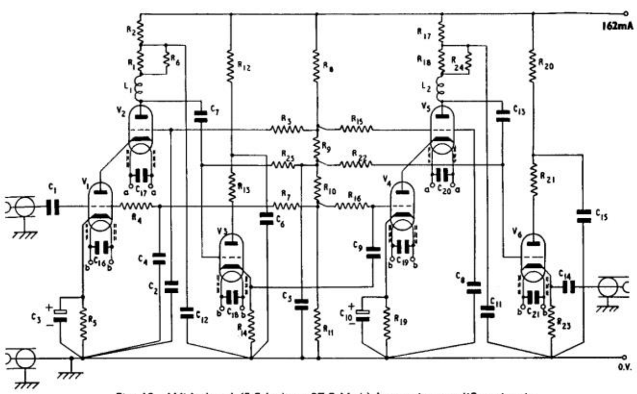


Fig. 19 Wide-band (5·5 kc/s to 37·5 Mc/s) low noise amplifier circuit.

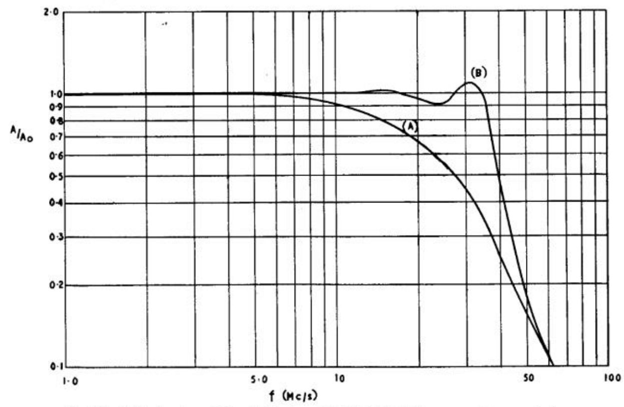


Fig. 20 Wide-band amplifier (5·5 kc/s to 37·5 Mc/s) high frequency characteristics. Voltage gain A, normalised to mid-band value A_o, versus frequency f.
A_o = 200
Low frequency cut-off 5·5 kc/s.
Uncompensated amplifier, curve (A).
Compensated amplifier, curve (B).

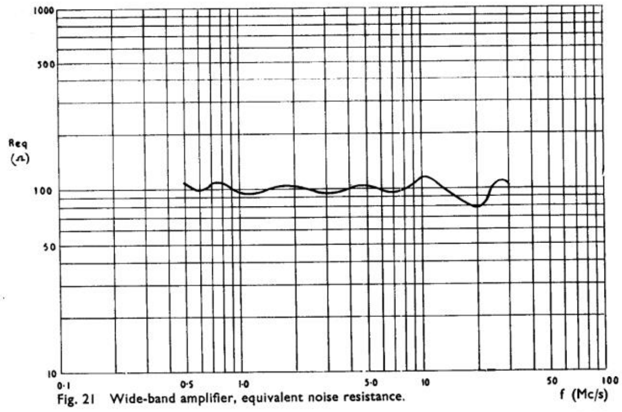


Fig. 21 Wide-band amplifier, equivalent noise resistance. f (Mc/s)

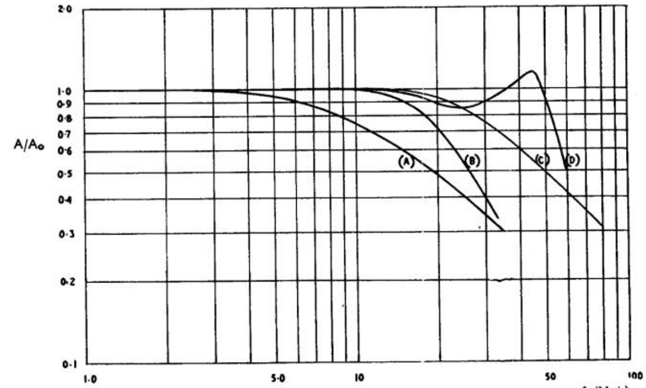


Fig. 22 Cascode amplifier, high frequency characteristics. f (Mc/s)

Voltage gain A normalised to mid-band value A_o:— $A_o = 18$
Curve (A): Uncompensated amplifier H.F. characteristic, $R_L = 600\Omega$, $C_L = 19$ pF.
Curve (B): Compensated amplifier H.F. characteristic, $R_L = 600\Omega$, $C_L = 19$ pF, $L_1 = 4{\cdot}5\ \mu H$; $L_2 = 7{\cdot}2\ \mu H$; $C_1 = 7{\cdot}5$ pF.
Curve (C): Uncompensated amplifier H.F. characteristic. $R_L = 600\Omega$; $C_L = 4$ pF.
Curve (D): Compensated amplifier H.F. characteristic. $R_L = 600\Omega$; $C_L = 4$ pF; $L_1 = 1{\cdot}6\ \mu H$; $C_1 = 2{\cdot}5$ pF; $L_2 = 2{\cdot}4\ \mu H$.

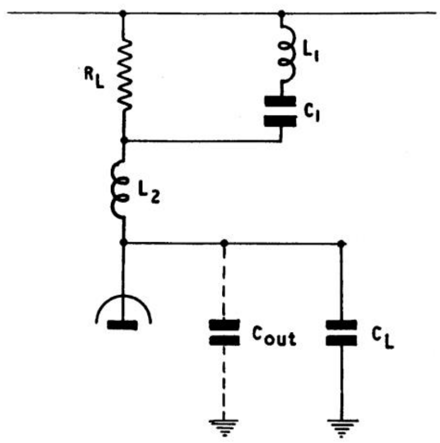


Fig. 23 Compensating Circuit.

This circuit is composed of a constant **k** half section, low pass filter, followed by an **m** derived half section. The component values for $m = 0{\cdot}6$ may be estimated from the following equations:

(1) $$\frac{(C_L + C_{out})}{2} = \frac{L_1}{(0{\cdot}66\ R_L^2)}$$

(2) $$\frac{L_1}{L_2} = \frac{0{\cdot}53}{0{\cdot}8}$$

(3) $$\frac{C_1}{(C_L + C_{out})} = 0{\cdot}3$$

In the pass band the filter will present a resistive load, R_L, to the amplifier and the amplifier will possess a bandwidth nearly twice that obtainable without compensation.

9. TRIODE MIXER

The performance of the 3A/167M as a triode mixer is characterised by very high conversion conductance and very low equivalent noise resistance.

9·1 TYPICAL OPERATING CONDITIONS

The grid is biased almost to cut-off when there is no oscillator or signal injection voltage. When oscillator and signal voltages are present it is necessary to limit the peak positive excursion from the bias point, to avoid driving the grid positive with respect to the cathode since grid current should not be drawn.

Direct anode voltage	V_a	160	V
Direct grid voltage	V_g	0	V
Cathode resistor	R_k	270	Ω
Oscillator voltage	$V_{osc.r.m.s.}$	3	V

9·2 CHARACTERISTICS (See Fig. 25)

Direct anode current	I_a	16	mA
Conversion conductance	g_c	10	mA/V
Equivalent noise resistance	R_{eq}	400	Ω

The effective anode impedance to intermediate frequency voltages is approximately three times the anode impedance of the valve when operating as an amplifier drawing the same anode current.

9·3 TRIODE MIXER CIRCUIT

The circuit of Fig. 24 is identical with that used for measurement of the valve characteristics. A number of variations of this basic circuit may be used, such as the use of capacitance coupling of the oscillator signal.

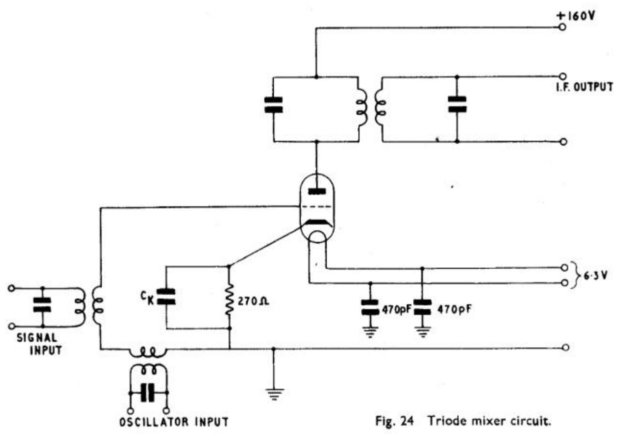


Fig. 24 Triode mixer circuit.

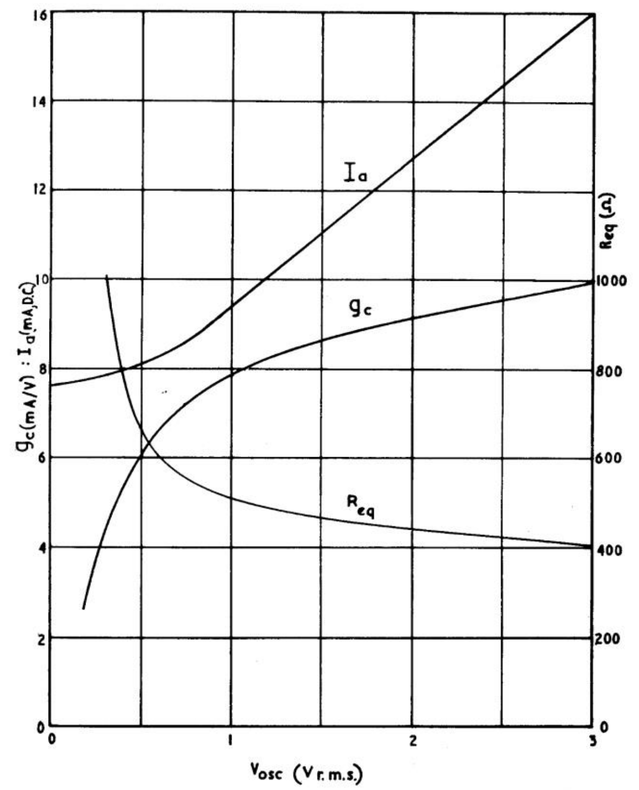


Fig. 25 Triode mixer conversion conductance, anode current and equivalent noise resistance, versus applied oscillator voltage.

10. WHITE CATHODE FOLLOWER

With a voltage gain near unity and very low output resistance, this circuit will develop almost undistorted positive or negative signals across a substantial load capacitance. The output voltage may be direct coupled, positive or negative output, but for a stable d.c. output level near zero voltage, on no signal, a low load impedance must be used. Choke loading shunted by a low resistance load may be necessary.

Separate heater supplies are required for V_1 and V_2.

The characteristics of the circuit of Fig. 26 are:—

Anode current	I_a	40	mA
Output current (sinusoidal)	$i_{out, pk}$	±40	mA max.
Output resistance	R_{out}	1·0	Ω

The low output resistance is retained over the frequency band 200 c/s to 2·7 Mc/s; outside this band the resistance rises but unity gain will remain, providing the load resistance is much greater than the output resistance.

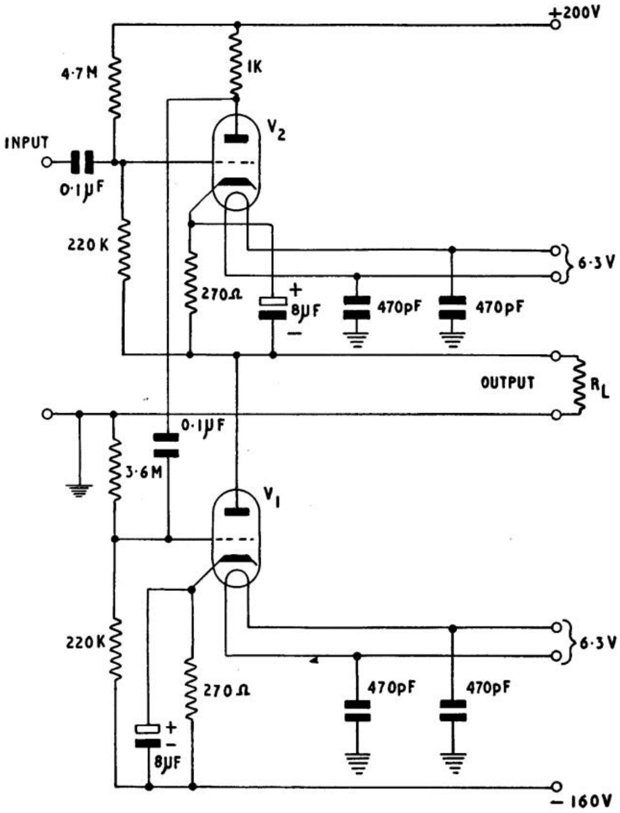


Fig. 26 White cathode follower circuit.

11. SINGLE-ENDED AUDIO OUTPUT STAGE

The White cathode follower circuit of Fig. 26 may be used as a single-ended, class A, audio output stage, directly coupled to a high impedance loudspeaker. The maximum output power into 250 ohms is 0·2 watt, with 10 volts r.m.s. drive. The output is virtually undistorted and the stage gives an excellent frequency response. The low output impedance results in very low efficiency, but good damping of speaker resonances results. The modification of Fig. 26, given in Fig. 27, gives a frequency response extending down to 15 c/s, but an increased, zero signal, out-of-balance load current is likely. Either circuit may be supplied from a 360 volt H.T. supply, with capacitance coupling to the loudspeaker. This circuit may be used where large output power is not required, such as in audio monitoring equipment.

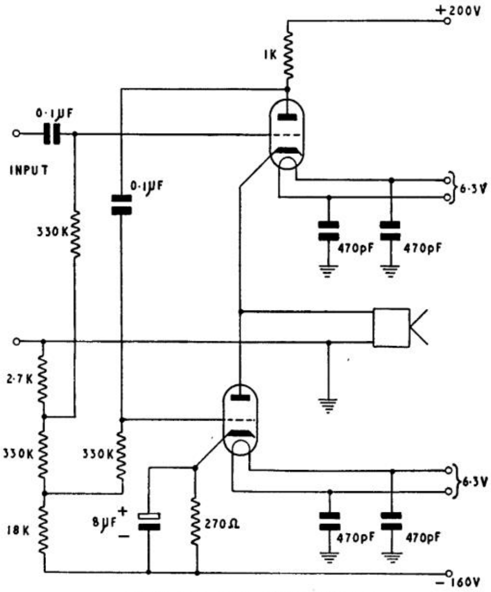


Fig. 27 Single-ended audio output stage.

12. BOOTSTRAP AMPLIFIER

The characteristics of this circuit combine the output impedance of a cathode follower with the voltage gain of an amplifier. It is thereby able to drive large currents into high load capacitances to produce fast rising output pulses.

The measured rise time is for a square, zero rise time, input pulse.

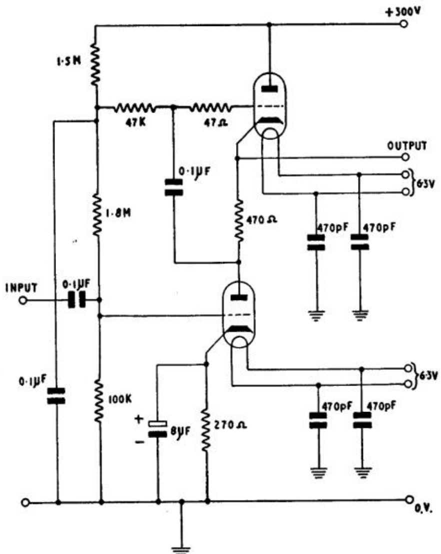


Fig. 28 Bootstrap amplifier circuit.

The circuit characteristics of Fig. 28 are:—

Anode current	I_a	40	mA
Voltage gain	A	48	
Output current (sinusoidal)	$i_{out, pk}$	40	mA max.
Output resistance	R_{out}	64	Ω
Output pulse rise time (measured)	t	45	mμs

13. ANODE FOLLOWER

Where fast falling negative pulses with moderately low output impedance are required, the anode follower can be applied.

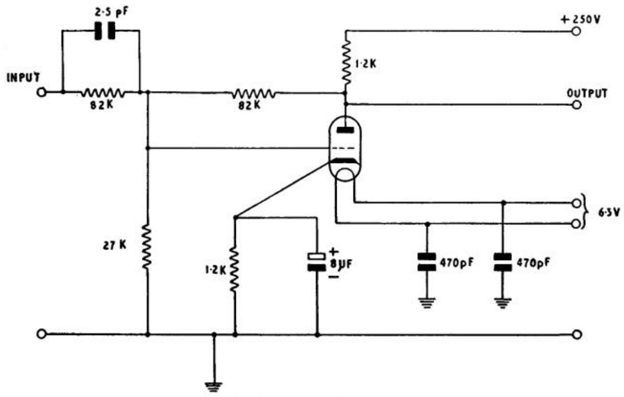


Fig. 29 Anode follower circuit.

The circuit characteristics of Fig. 29 are:—

Anode current	I_a	40	mA
Voltage gain	A	0·87	
Output voltage (sinusoidal)	$V_{out,pk}$	48	V. max
Output resistance	R_{out}	180	Ω
Output pulse fall time (measured)	t	<7	mµs

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