G.E.C. VALVES

LOW NOISE AF PENTODE 6·3V INDIRECTLY HEATED

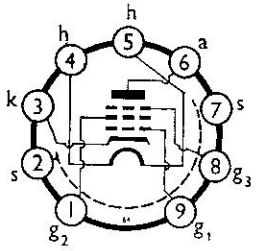
Z729/EF86

ISSUE 2

The Z729 is a commercial equivalent of CV2901.

An indirectly heated pentode with low hum and low microphony, suitable for use in low level low frequency amplifiers, measuring instruments, industrial control circuits, etc. Its low grid current makes it particularly useful in circuits requiring a high input impedance.

BASE CONNECTIONS AND VALVE DIMENSIONS



View from underside of base.

Base : B9A
Bulb : Tubular

Max. overall length :	56 mm.
Max. seated length :	49 mm.
Max. diameter :	22·2 mm.

HEATER

V_h	6·3	V
I_h	0·2 (approx)	A

MAXIMUM RATINGS

V_b	550	V
V_a	300	V
V_{g2}	250	V
*$V_{a,g2,g3}$	250	V
p_a	1	W
p_{g2}	0·2	W
*$p_{a+g2+g3}$	1·2	W
I_k	6	mA
V_{h-k}	150	V
†R_{g1-k} (fixed bias)	1	MΩ
†R_{g1-k} (cathode bias)	2	MΩ

*Triode connection.
†At $p_a+p_{g2}=1·2W$, $V_a=300V$.

CAPACITANCES (of cold externally unscreened valve)

c_{g1-a}	0·025 pF	c_{g1-h}	0·0025 pF
$c_{g1-\text{all less a}}$	4·0 pF	$c_{a-\text{all less g1}}$	5·5 pF

CHARACTERISTICS

Pentode Connection

V_a	250	V
V_{g2}	140	V
V_{g3}	0	V
V_{g1}	−2	V
I_a	3·0	mA
I_{g2}	0·55	mA
I_{g1}	0·05	μA
g_m	1·85	mA/V
r_a	2	MΩ
$\mu_{(g1-g2)}$	38	—

THE M-O VALVE CO. LTD. · BROOK GREEN · LONDON · W.6
a subsidiary of
THE GENERAL ELECTRIC CO. LTD. OF ENGLAND

JUNE, 1959

Triode Connection

$V_{a,g2,g3}$	250	V
V_{g1}	−5	V
I_k	4·0	mA
I_{g1}	0·06	μA
g_m	2·0	mA/V
r_a	16·5	kΩ
μ	33	—

TYPICAL OPERATION

AF Amplifier. Pentode Connection.

V_b (V)	R_a (kΩ)	I_k (mA)	R_{g2} (MΩ)	R_k (kΩ)	$R_{g1\ (max)}$ (MΩ)	Gain	V_{out}† (V)	D_{tot}† (%)	R_g* (kΩ)
400	100	3·3	0·39	1·0	22	124	87	5	330
300	100	2·45	0·39	1·0	36	116	64	5	330
200	100	1·65	0·39	1·0	80	106	40	5	330
400	220	1·55	1·0	2·2	44	200	73	5	680
300	220	1·1	1·0	2·2	80	188	54	5	680
200	220	0·75	1·0	2·2	100	170	36	5	680

AF Amplifier. Triode Connection.

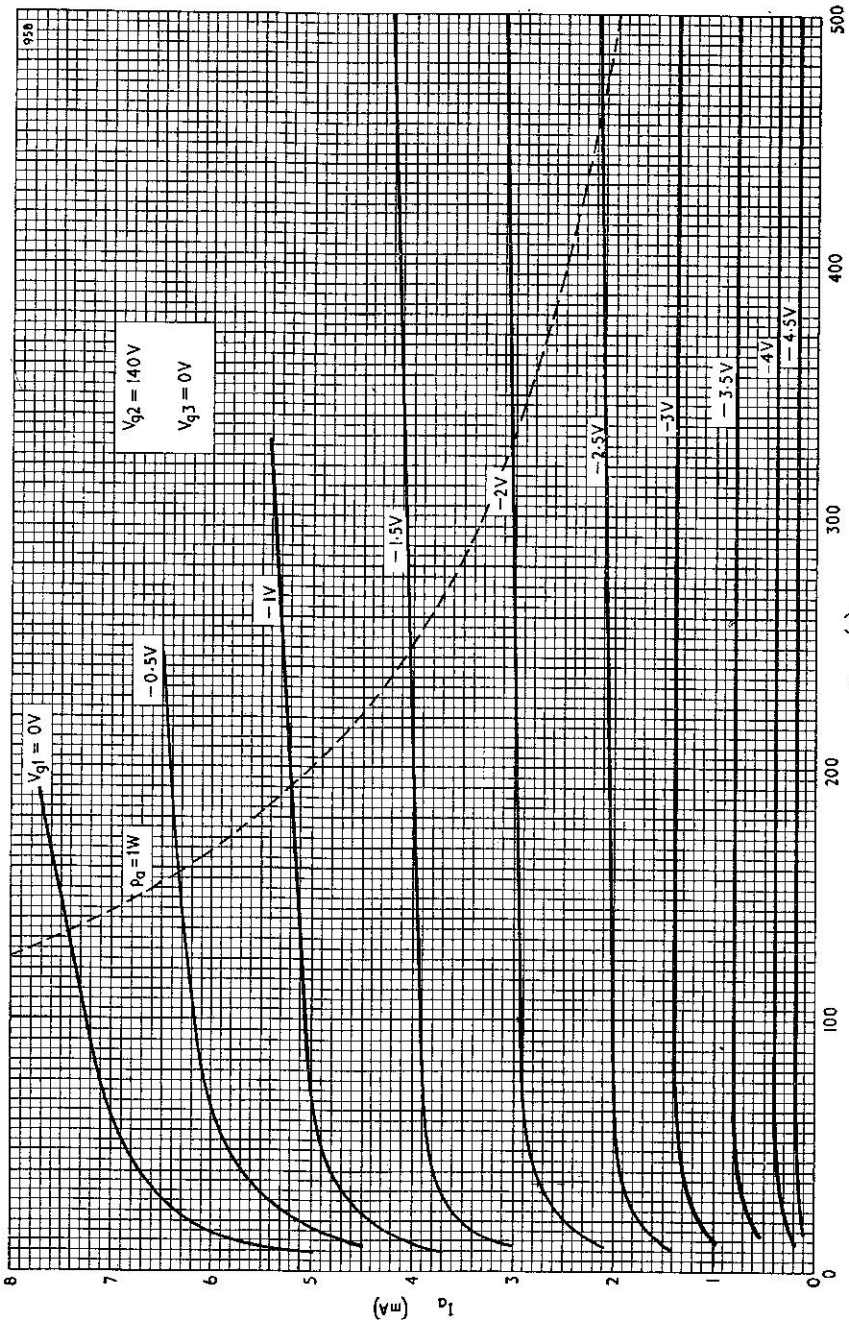
V_b (V)	R_A (kΩ)	I_a (mA)	R_k (kΩ)	$R_{g1\ (max)}$ (MΩ)	Gain	V_{out}† (V)	D_{tot}† (%)	R_g* (kΩ)
400	47	3·7	1·2	3·9	24·5	64	4·5	150
300	47	2·7	1·2	9	24	43	3·8	150
200	47	1·85	1·2	33	23·5	22	3·1	150
400	100	2	2·2	9	28·5	73	4·0	330
300	100	1·5	2·2	21	28·5	50	3·8	330
200	100	1·0	2·2	72	27·5	27·5	3·3	330
400	220	1·05	3·9	24	32	74	3·8	680
300	220	0·8	3·9	60	31	51	3·7	680
200	220	0·5	3·9	100	30·5	28	3·1	680

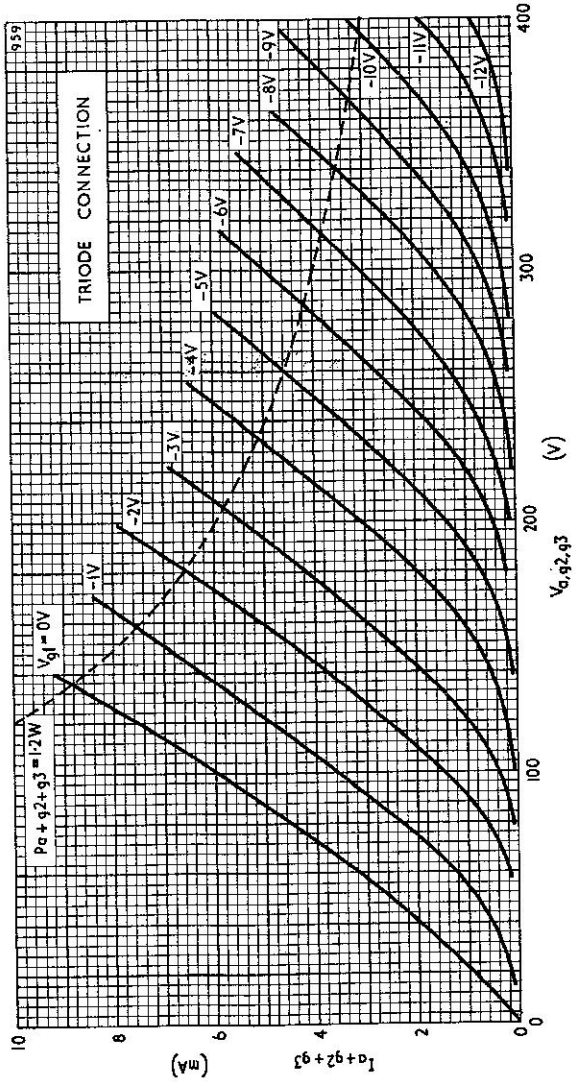
*Following valve grid resistor.

†V_{out} and distortion at the start of positive grid current. At lower output values, the distortion is approximately proportional to the input voltage.

INSTALLATION

The valve may be mounted in any position. The use of a retaining device is recommended. The valve is internally screened.


958
V_{g2} = 140 V
V_{g3} = 0V
V_{g1} = 0V
P_a = 1W
-0.5V
-1V
-1.5V
-2V
-2.5V
-3V
-3.5V
-4V
-4.5V
I_a (mA)
V_a (V)
0
100
200
300
400
500
1
2
3
4
5
6
7
8



Printed in England. C.

The Z729/EF86 may be classed as intermediate between an electrometer valve and one of normal design because of the small grid current to be expected.

In all applications where low grid current is important it is essential to ensure that the grid is always negative with respect to cathode by at least 1·7V in order to avoid positive grid current due to the interception of electrons by the grid. The magnitude of the negative grid current depends upon operating conditions and limits the value of maximum external resistance between grid and cathode. Under d.c. conditions the grid current varies roughly as $(V_a \times p_a + V_{g2} \times p_{g2})$. Under the conditions shown in the data sheet under "Characteristics," the grid current does not normally exceed 0·2μA and is usually less than 0·05μA. A valve that has been stored for some time may have a higher grid current initially but will settle to a satisfactorily low value if operated for a few minutes under normal conditions with a low value of grid resistor.

If the valve is used under conditions of maximum voltage and dissipation, the external grid to cathode resistance should not exceed 1MΩ with fixed bias or 2MΩ with cathode bias in order to obtain satisfactory operation with all valves. Permissible grid to cathode resistance values at reduced voltages and dissipations are given below and apply to both triode and pentode operation.

The majority of valves will operate satisfactorily with resistance values up to four times those shown and advantage may be taken of this when selection is possible. However, it is advisable not to exceed 100MΩ.

Maximum External Grid to Cathode Resistance with Fixed Bias

V_a	$R_{g-k(max)}$ at $p_{a+g2(max)}$ =			
	1·2W	0·5W	0·2W	0·1W
300V	1MΩ	2·5MΩ	6MΩ	12MΩ
200V	1·5MΩ	3·75MΩ	9MΩ	18MΩ
100V	3MΩ	7·5MΩ	18MΩ	36MΩ

These values may be doubled for cathode bias.

The above table values applies to applications in which the operating point is determined by a specified grid bias with respect to cathode. On the other hand, any valve may be operated with the grid left floating and the grid will then adjust itself to the crossover potential at which the grid current curve passes through zero. In the Z729/EF86 this occurs normally at about $V_g = -1{\cdot}3V$. Although this method is useful for certain special applications, the incremental input impedance is extremely variable, ranging typically between 1MΩ and 50MΩ because of the rapid rise of positive grid current.

AF AMPLIFIER OPERATION AND HUM

The Z729/EF86 is normally used as an RC coupled pentode amplifier as shown in fig. 1. For exceptionally low noise applications, the valve may be used as a triode by connecting the anode, suppressor and screen together, and fig. 2 gives the performance to be expected. When high impedance circuits are possible, very high gain is obtainable as shown by the curve of fig. 4.

To obtain minimum hum pickup, the heater connections should be twisted together for three or four inches and kept as far as possible from the grid contact. A valve socket having low leakage and low capacitance between contacts is required, preferably of porcelain or PTFE with a central screening boss, this being earthed together with contacts 2 and 7 which connect to the valve internal screening system. The suppressor (pin 8) is normally earthed but it may be connected to the cathode. Special precautions have been taken to reduce to a minimum the grid/heater capacitance in order to render

the valve relatively insensitive to an unbalanced heater supply. Similar precautions must be taken with external components. Normally a centre-tapped 6·3V supply will be used with the tap earthed. The hum pickup with a 470kΩ grid resistor will then be less than 1·5μV referred to the grid. The use of a higher or lower grid resistance will modify the hum pickup proportionally. A balancing resistor may be used if desired and in some cases this will reduce the hum by approximately 1-2dB. If even this hum level is still too high, a d.c. heater supply must be used.

As the total anode and screen current is very low in most applications, it is sometimes convenient to obtain a very smooth, stable, hum-free and low noise h.t. supply from a standard 120V battery.

To avoid hum pickup, etc., in the input circuit, care must be taken to avoid coupling with higher signal level circuits, bearing in mind the possibility that the chassis itself can be responsible for such coupling.

In order to maintain a low hum level it is essential to bypass any cathode bias resistor with a suitably large capacitor of at least 500μF. At higher signal levels part of the cathode resistance may be left unbypassed when negative feedback is necessary, or for tone control purposes.

At audio frequencies the screen in the pentode circuit should be bypassed to earth with a paper capacitor of at least 0·1μF.

Acoustic feedback is not normally encountered in the Z729/EF86 as it is especially anti-microphonic and it is not usually necessary to use special techniques such as a separate flexibly mounted and weighted sub-chassis, except in extreme cases as when the valve is close to a loudspeaker or when considerable vibration is present. The internal screening renders an external screening can unnecessary but one may be used as a retainer when necessary.

The Z729/EF86 may be used in a 0·3A series heater chain if the heater is shunted by a 63Ω resistor. This resistor should be rated at 5W since it will carry 0·3A if the valve is removed. The heater should be connected into the earthy end of the chain.

INDUSTRIAL APPLICATIONS

The Z729/EF86 has many applications in the industrial field because of its high order of stability and its freedom from unwanted effects. A high value grid resistor may be used when required because of the low grid current. The valve is ideal for photocell circuits and will show a considerable increase in sensitivity over valves normally used hitherto.

Many requirements in test equipment can be fulfilled by the Z729/EF86 ; a valve voltmeter, for example, needs a very stable valve characteristic and a suitable circuit is given in fig. 3. Certain component values are not given since they depend upon the ranges required but the resistors associated with the range switch may total 10-20MΩ.

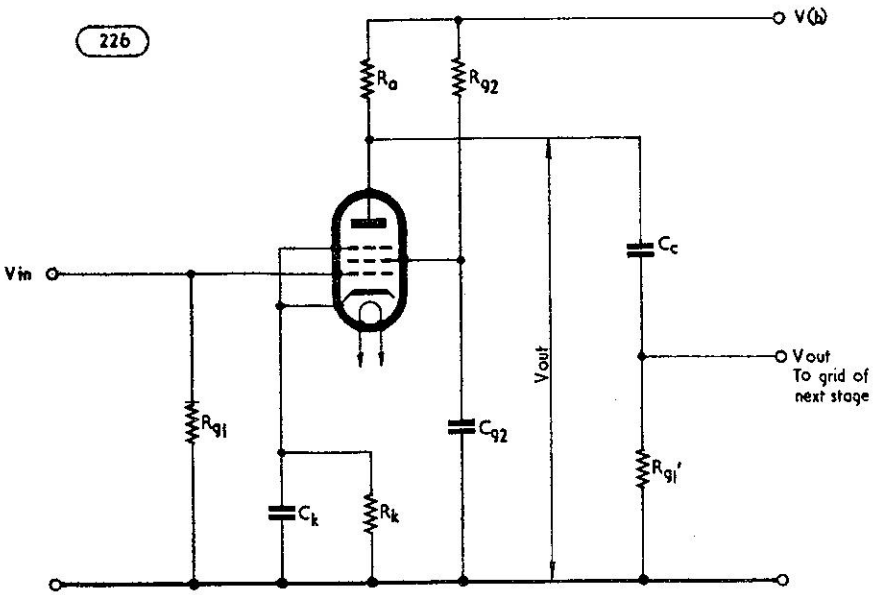


Fig. 1. Recommended circuit for a pentode-connected a.f. amplifier. Component values for various conditions of operation are given below.

V_b (V)	R_a (kΩ)	I_k (mA)	R_{g2} (MΩ)	R_k (kΩ)	$R_{g1\ (max)}$ (MΩ)	Gain	V_{out}† (V)	D_{tot}† (%)	R_{g1}'* (kΩ)
400	100	3·3	0·39	1·0	22	124	87	5	330
300	100	2·45	0·39	1·0	36	116	64	5	330
200	100	1·65	0·39	1·0	80	106	40	5	330
400	220	1·55	1·0	2·2	44	200	73	5	680
300	220	1·1	1·0	2·2	80	188	54	5	680
200	220	0·75	1·0	2·2	100	170	36	5	680

*Following valve grid resistor.

†V_{out} and distortion at the start of positive grid cnrrent. At lower output values, the distortion is approximately proportional to the input voltage.

Capacitor valves : The reactance of C_k should normally be less than one tenth of R_k at the lowest frequency ; the reactance of C_{g2} should normally be less than one tenth of R_{g2} and that of C_c should normally be less than one tenth of R_{g1}'.

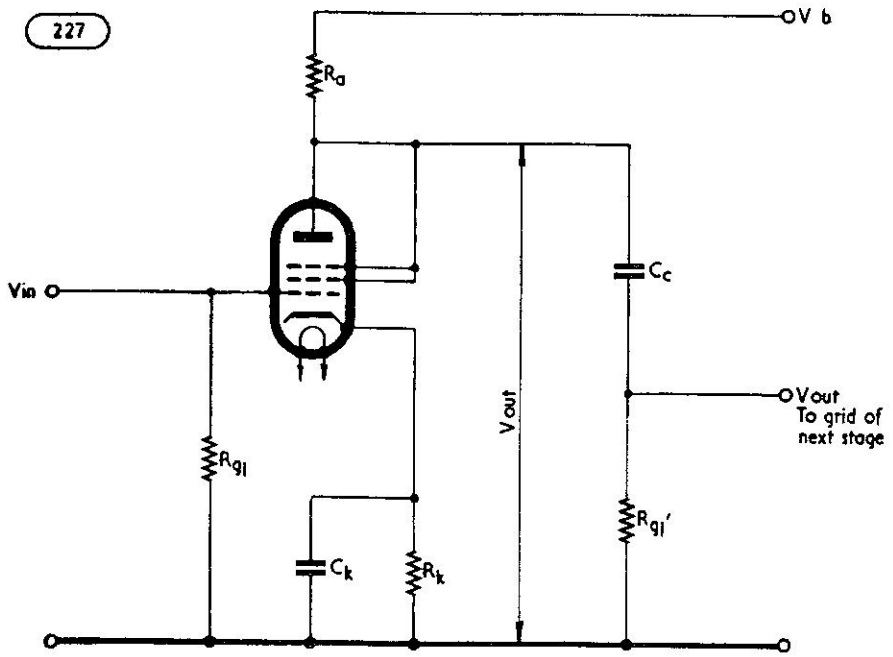


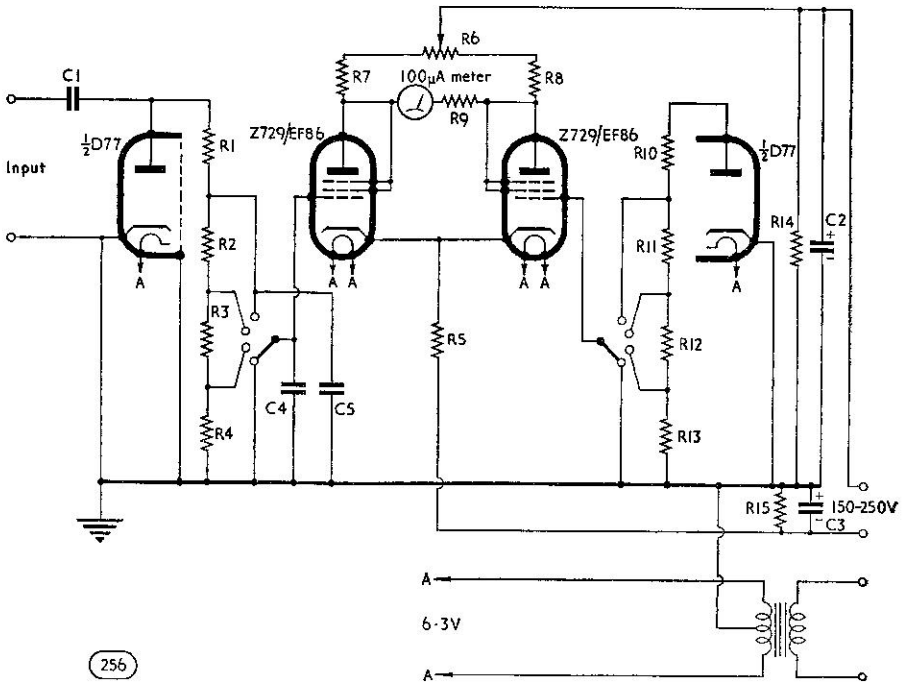
Fig. 2. Recommended circuit for a triode-connected a.f. amplifier. Component values for various conditions of operation are given below.

V_b (V)	R_a (kΩ)	I_a (mA)	R_k (kΩ)	R_{g1} (max) (MΩ)	Gain	V_{out}† (V)	D_{tot}† (%)	$R_{g1'}$* (kΩ)
400	47	3·7	1·2	3·9	24·5	64	4·5	150
300	47	2·7	1·2	9	24	43	3·8	150
200	47	1·85	1·2	33	23·5	22	3·1	150
400	100	2	2·2	9	28·5	73	4·0	330
300	100	1·5	2·2	21	28·5	50	3·8	330
200	100	1·0	2·2	72	27·5	27·5	3·3	330
400	220	1·05	3·9	24	32	74	3·8	680
300	220	0·8	3·9	60	31	51	3·7	680
200	220	0·5	3·9	100	30·5	28	3·1	680

*Following valve grid resistor.

†V_{out} and distortion at the start of positive grid current. At lower output values, the distortion is approximately proportional to the input voltage.

Capacitor values : The reactance of C_k should normally be less than one tenth of R_k at the lowest frequency and the reactance of C_c should normally be less than one tenth of $R_{g1'}$ at the lowest frequency.



Component values :

R1		
R2		Range switch resistors
R3		
R4		
R5	33kΩ 10% 1W	
R6	500Ω wirewound variable (zero set)	
R7	1kΩ wirewound	
R8	1kΩ wirewound	
R9	Meter resistance	
R10		
R11		Range switch resistors
R12		
R13		
R14	47kΩ 10% 1W	
R15	47kΩ 10% 1W	
C1	0·1μF	
C2	8μF Electrolytic	
C3	8μF Electrolytic	
C4	0·1μF	
C5	0·1μF	

Fig. 3. Valve voltmeter circuit.

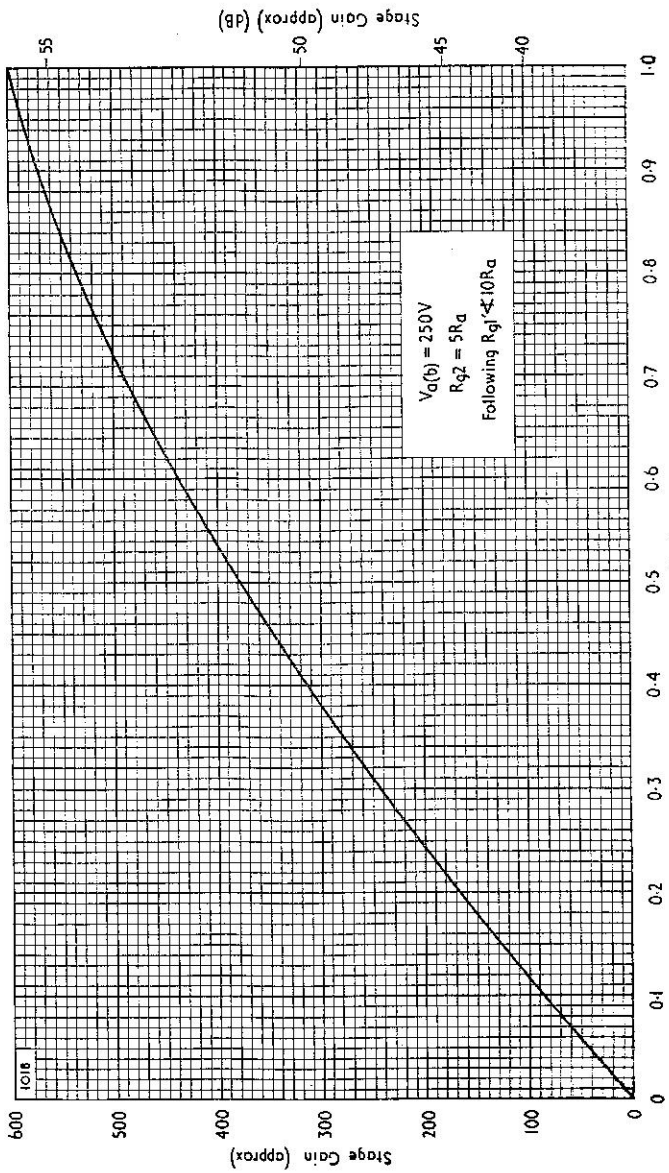

Stage Gain (approx)
600
500
400
300
200
100
0
Stage Gain (approx) (dB)
55
50
45
40
$V_{a(b)}$ = 250V
R_{g2} = 5R_a
Following R_{g1} ≪ 10R_a
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
R_a (MΩ)
6016

Fig. 4.