BRIMAR

RECEIVING VALVE

12AU7
ECC82

APPLICATION REPORT VAD/513.4

Standard Telephones and Cables Limited

FOOTSCRAY, KENT, ENGLAND

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INTRODUCTION: The Brimar type 12AU7 is a miniature indirectly heated twin triode. Each triode unit is a separate structure, the heater connections only being common with a result that it is possible to use each unit for different functions or in cascade.

The feature of a heater centre tap enables the valve to be used in both AC and AC/DC equipment.

This report contains characteristics of the valve and details of its use as a normal amplifier, resistance capacity coupled amplifier, paraphase amplifier, oscillator and as a frequency multiplier.

DESCRIPTION: The valve comprises two triode units mounted side by side having separate heaters, but common heater pin connections. Each triode unit has characteristics similar to a 6C4 and the units are mounted in a standard T6½ bulb, and based with a B.V.A. standard base type B9A.

CHARACTERISTICS:

Cathode:	Indirectly heated	*Series*	*Parallel*	
	Voltage	12·6	6·3	volts
	Nominal Current	0·15	0·3	ampere
	Max. Heater-Cathode potential (DC)	250		volts
Dimensions:	Max. Overall Length	2-3/16 ins.		
	Max. Diameter	7/8 in.		
	Max. Seated Height	1-15/16 ins.		
Base:	Noval type B9A			
Basing Connections:	Pin 1 Anode ″			
	Pin 2 Grid ″			
	Pin 3 Cathode ″			
	Pin 4 Heater			
	Pin 5 Heater			
	Pin 6 Anode ′			
	Pin 7 Grid ′			
	Pin 8 Cathode ′			
	Pin 9 Heater Tap			

Note.—The getter is attached to anode ′.

Ratings:

EACH TRIODE UNIT:

Max. Anode Voltage	300 volts
Max. Anode Dissipation	2·75 watts
Max. Anode Current	20 mA
Max. Negative Control Grid Voltage	150 volts
Max. Average Grid Current	5 mA
Max. Grid Circuit Resistance (autobias)	1 megohm
Max. Grid Circuit Resistance (fixed bias)	0·25 megohm

Capacities (approx.):*

	Triode Unit ′	*Triode Unit ″*	
$c_{g,a}$	1·5	1·5	pF
$c_{g,k}$	1·6	1·6	pF
$c_{a,k}$	0·5	0·35	pF
$c_{h,k}$	4·5		pF
$c_{a',a''}$	0·7		pF
$c_{g',g''}$	0·004		pF
$c_{g',a''}$	0·035		pF
$c_{g'',a'}$	0·02		pF

*** Measured without shield.**

CHARACTERISTIC CURVES: Curves are attached to this report which show:

Anode current plotted against anode voltage for various values of grid voltages (I_a/V_a) (Curve No. 313·20).

Anode Current plotted against grid voltage for various anode voltages (I_a/V_g) (Curve No. 313·21).

Mutual conductance, amplification factor and anode impedance plotted against anode current (g_m/I_a) (Curve No. 313·22).

TYPICAL OPERATION

Class AI Amplifier:

Heater	6·3	6·3	volts
Anode	100	250	volts
Grid	0	—8·5	volts
Amplification Factor (μ)	19·5	17	
Anode Impedance (r_a)	6250	7700	ohms
Mutual Conductance	3·1	2·2	mA/V
Anode Current	11·8	10·5	mA

Push-Pull Class AI Amplifier: The valve provides a very satisfactory push-pull stage for power outputs up to 1200 Milliwatts and is suitable for driving a Class "AB2" and Class "B" amplifier stage, such as a pair of 6BW6 valves or a 5763.

A curve, VAD/313·24, is attached to this report, which shows the harmonic distortion plotted against power output, for operating conditions of anode volts 300, grid volts —11·5, output load 10,000 ohms, and anode volts 250, grid volts —9·5, output load 15,000 ohms. The maximum outputs shown are those obtainable in Class AI, i.e. up to the point where grid current commences.

Resistance Coupled Amplifier: The valve is very suitable for use as a resistance coupled amplifier and below is a table giving a summary of useful values for three different supply voltages for one triode unit:

a. Anode Supply Voltage $V_{a(b)}$ 100 volts:

Anode Load (R_a megohms)	0·047		0·1		0·22	
Grid Leak (succeeding valve) (megohms)	0·1	0·22	0·22	0·47	0·47	1·0
Cathode Resistance (ohms)	1800	2000	3800	4700	9500	11500
Output Voltage (peak)	11	14	15	18	20	24
Voltage Gain	11	11	11	11	11	11

b. Anode Supply Voltage $V_{a(b)}$ 200 volts:

Anode Load (R_a megohms)	0·047		0·1		0·22	
Grid Leak (succeeding valve) (megohms)	0·1	0·22	0·22	0·47	0·47	1·0
Cathode Resistance (ohms)	1200	1400	2800	3600	8300	10000
Output Voltage (peak)	26	29	33	40	44	54
Voltage Gain	12	12	12	12	12	12

c. Anode Supply Voltage $V_{a(b)}$ 300 volts:

Anode Load (R_a megohms)	0·047		0·1		0·22	
Grid Leak (succeeding valve) (megohms)	0·1	0·22	0·22	0·47	0·47	1·0
Cathode Resistance (ohms)	1200	1500	3000	4000	8800	11000
Output Voltage Peak	52	68	68	80	82	92
Voltage Gain	12	12	12	12	12	12

A graph is attached to this report which shows the relation of the various valve parameters under conditions of resistance capacity coupling. This graph (No. VAD/313·23) is taken at an anode supply voltage $V_{a(b)}$ of 250 volts, with three values of anode load resistance, viz. 47,000, 100,000 and 220,000 ohms and plots the anode current, amplification factor, mutual conductance and anode impedance against grid voltage. From this graph the correct grid bias (cathode resistor) can be obtained, also the stage gain can be calculated and an estimate made of the distortion. The graph is not drawn beyond the limits of start of grid current or around the grid cut-off region.

Below follows a description of the method of using the graph.

If, for example, it is desired to use a valve at a supply voltage of 250 volts, an anode load of 100,000 ohms, and a succeeding valve grid leak of 470,000 ohms, then to determine the grid bias an inspection of the graph indicates a relatively linear portion of the curve of anode current/grid volts over the range of —1 to —11 volts, the mid point being —6 volts. At this point the anode current is 1·4 mA hence the cathode resistance should be 4250 ohms. The peak input voltage is 5 volts and the R.M.S. input 3·5 volts. Following the grid bias voltage upward it is evident that with an anode load of 100,000 ohms, the amplification factor (μ) is 15·4, and the anode impedance is 19,000 ohms. The anode load is effectively in parallel with the succeeding valve grid leak as regards the signal, but not as regards the anode current, hence the effective signal value of the anode load is 100,000 ohms in parallel with 470,000 ohms, or is 82,000 ohms.

The stage gain is:

$$\frac{\mu R_a}{R_a + r_a}$$

or in the above case:

$$\frac{15{\cdot}4 \times 82{,}000}{82{,}000 + 19{,}000} = 12{\cdot}5.$$

The peak input/voltage above was 5 volts, hence the peak output voltage will be this figure multiplied by the stage gain or 62·5 volts R.M.S.

An estimate of the distortion may be made by calculating from the graph, as above, the stage gain at the extremes of grid bias; in the example the stage gain at 1 volt is 17 and at 11 volts is 10·5, hence the positive peaks of the signal output will be 37% less than the negative, and the distortion as this input is 12%.

Cascade Resistance Capacity Coupled Amplifier: The two triode units of the valve may be used in cascade if required, and no particular precautions are necessary to avoid instability. Grid and anode leads should not, however, be unduly long or close together and anode supply voltage decoupling requires to be similar to that used for the separate valves, such as the 6C4.

It is not recommended that a common cathode resistor be used for the two units when operated in cascade unless a condenser of very low reactance is employed.

A circuit is attached to this report (Ref. 313·60) which indicates two sets of typical values, together with the figures of output voltage, gain and frequency response. These figures indicate a peak output of approximately 55 volts, an overall voltage gain of 150 and a frequency response within 1 dB from 50 cycles to 30 Kc.

Paraphase Amplifier: For many applications a push-pull output is required from an input having one side earthed. Where it is not desired to use a transformer for obtaining the two phase output, such output can be conveniently obtained from a resistance capacity phase splitting circuit.

The valve is very suitable for this purpose and three circuits are described below.

a. Normal Paraphase: The circuit attached to this report (Ref. 313·61, shows a paraphase circuit in which one triode unit is fed from the output of the other unit. In order to reverse the phase, the input is so adjusted that the gain is the same. Two sets of typical values are given, together with figures of output voltage, gain and frequency response. These figures indicate a peak push-pull output of approximately 150 volts with an input for this output of 7 volts peak.

The condenser across the common cathode bias resistor may be omitted, but if so, the balance of the higher frequencies is not so good. In this circuit the potentiometer tapping down the grid of the second triode unit is critical, if an accurate balance of the push-pull output is essential and it should be made variable.

b. **Anode-Cathode Load Phase Inverter:** In this application the push-pull output is obtained by dividing the load into two equal parts, one half being in the anode and one half in the cathode of the same triode unit. In this case this triode unit gives no gain and the other unit is used as a straight amplifier before it. The circuit attached to this report (Ref. 313·62) gives two sets of typical values, together with figures of output voltage, gain and frequency response. These figures indicate a peak push-pull output of approximately 110 volts and an input for this output of 9 volts peak.

The condenser across the cathode resistor of the second unit may be omitted if desired, its removal results in about 0.5 dB loss of gain only and the frequency response is slightly improved. The balance in the bass is improved, the treble balance deteriorates, but the maximum undistorted output is unaffected.

In this circuit the accurate matching of R3 and R4 is essential, and to a lesser extent the matching of R6 and R7, if an accurate balance of the push-pull is required.

c. **Cathode and Anode Coupled Phase Inverter:** In this application the push-pull output is obtained by connecting the cathodes of the two units together, as shown in the circuit attached to this report (Ref. 313·63). The grid of the second unit is driven from part of the anode load of the first unit R3 which part is also common to the load in the anode of the second unit. Hence there is negative feed back present in both anode and cathode circuits. Two sets of typical values are given together with figures of output voltage, gain and frequency response. These figures indicate a peak push-pull output of approximately 90 volts and an input for this voltage of 8 volts peak. This phase splitter gives less output than the other types described above (**a** and **b**), but the values of the resistances R1 and R2 and the succeeding valve grid leaks are not at all critical and may be to 20% tolerance without affecting the balance of the push-pull output. The resistance R3 should be so chosen that balance is obtained and if R3 is made variable an adjustable balance is realised; the balance is also unaffected by frequency.

Cathode Follower: Either, or both triodes may be employed as required as a cathode follower, but care should be exercised not to exceed the ratings given on page 2.

Oscillator: The valve functions excellently as an oscillator either utilising one unit for such purpose or both units in push-pull or in parallel.

As an oscillator the anode voltage should not exceed 300 volts and the DC grid current in the grid of either unit should not exceed 5 mA. The power output from each unit in general will be of the order of 2·5 watts maximum depending upon the circuit and frequency. The curve (Ref. 313·25) shows the relation between the power output obtainable and the frequency for both units as a push-pull oscillator.

Driven Amplifier: If this valve is employed as a driven Class C amplifier the ratings on page 2 must not be exceeded. Neutralisation will normally be required.

Frequency Multiplier: When used in this application the ratings given on page 2 apply and within these ratings quite a useful output as drive to a succeeding stage is obtained. Below are typical operating conditions of one section as a frequency doubler, and as a frequency trebler, the fundamental input being obtained from the other unit as an oscillator or multiplier. When used for a low power transmitter or receiver frequency changer the output is defined as a grid drive in mA in a stated value of grid resistor of the succeeding stage.

a. RF Doubler: Continuous ratings as a doubler without modulation.

DC Anode Voltage	250 volts
DC Grid Voltage	—108 volts
DC Grid Resistor	47,000 ohms
Peak RF Grid Voltage	120 volts
DC Anode Current	16 mA
DC Grid Current	2·3 mA
Succeeding Valve Grid Resistor	22,000 ohms
Succeeding Valve Grid Drive	6 mA*

* Measured with typical coil doubling from 45 Mc/s.

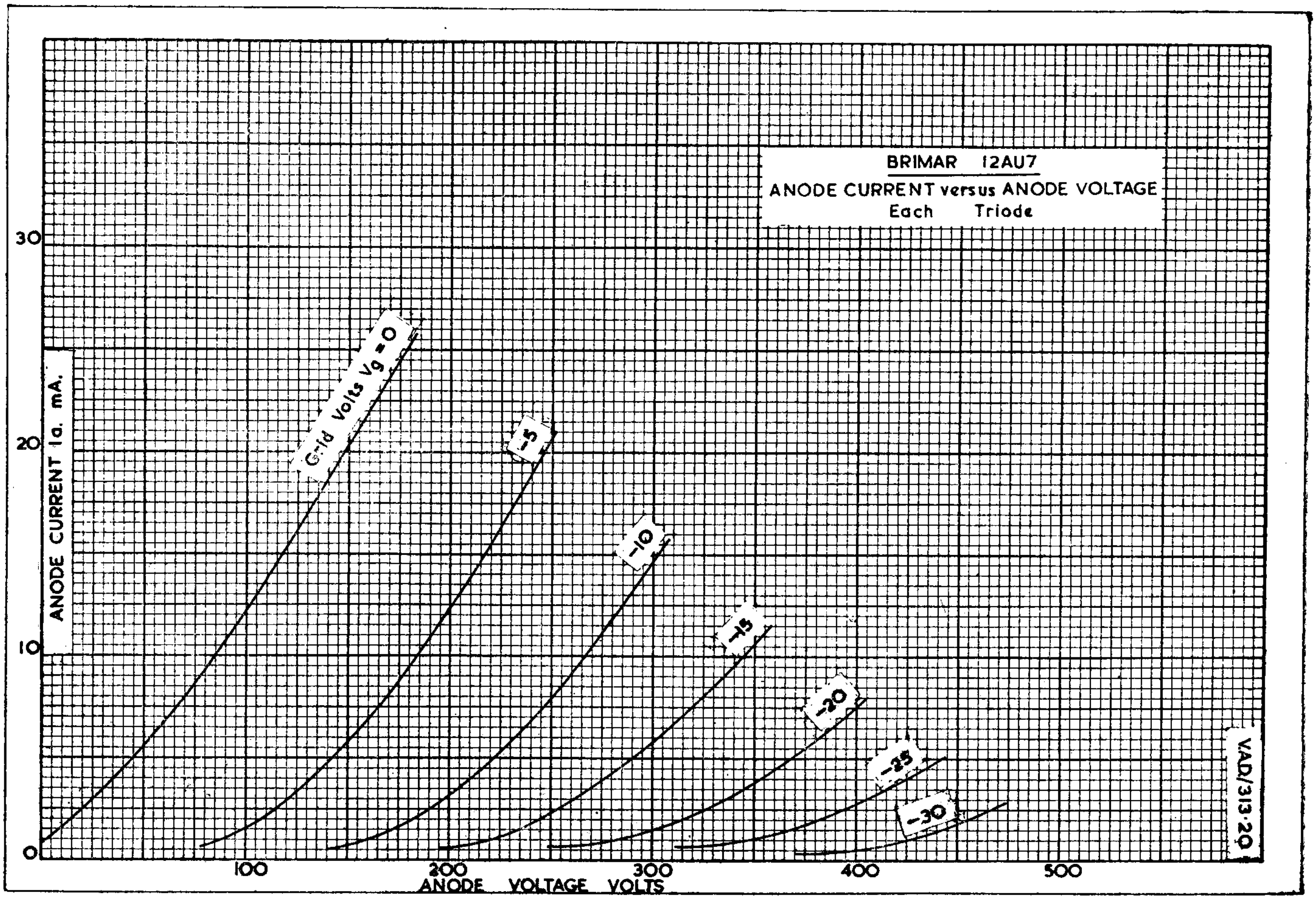
b. RF Trebler: Continuous ratings as an RF trebler without modulation.

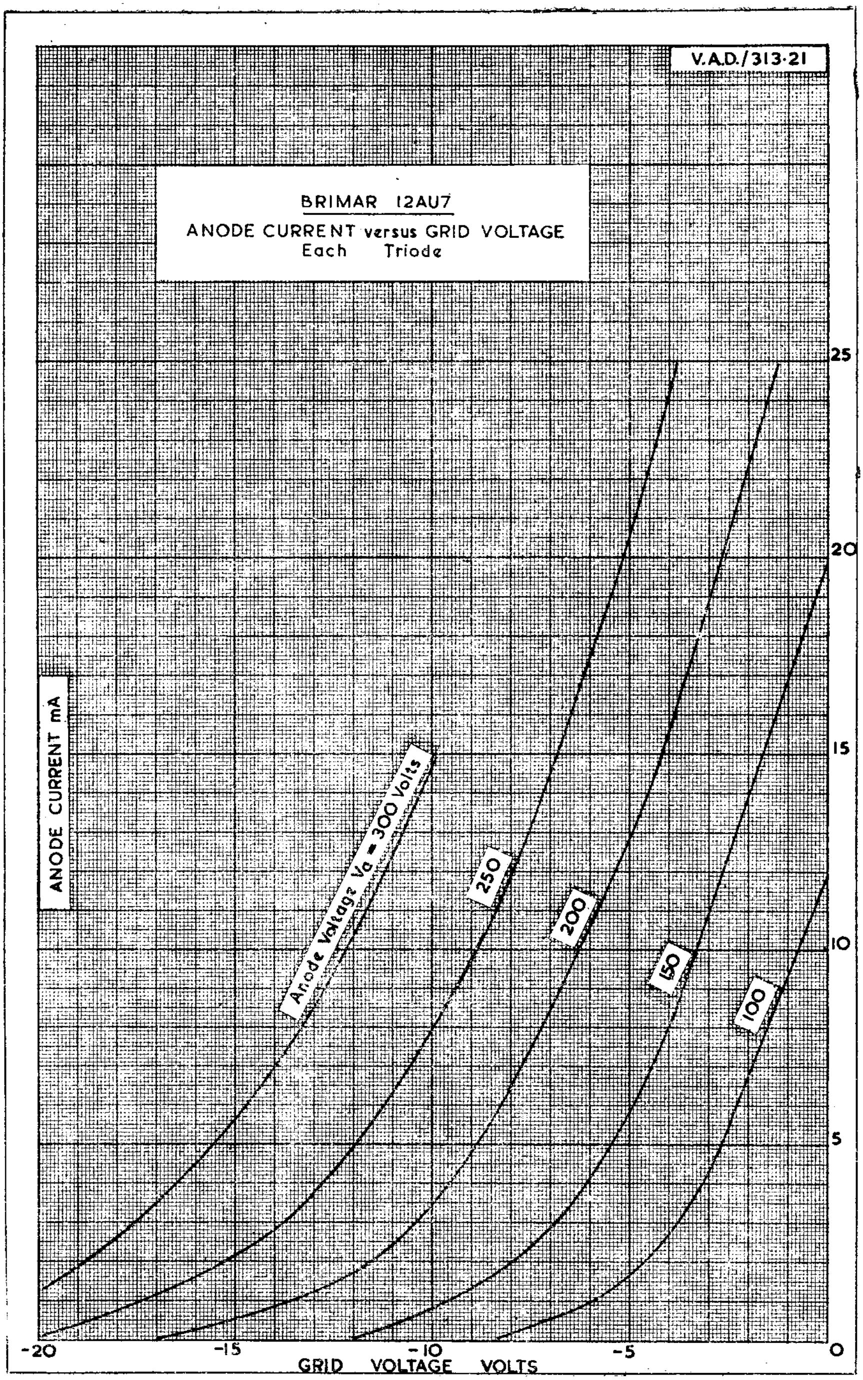
DC Anode Voltage	250 volts
DC Grid Voltage	—124 volts
DC Grid Resistor	62,000 ohms
Peak RF Grid Voltage	140 volts
DC Anode Current	16 mA
DC Grid Current	2·0 mA
Succeeding Valve Grid Resistor	22,000 ohms
Succeeding Valve Grid Drive	2·5 mA*

* Measured with typical coil trebling from 30 Mc/s.

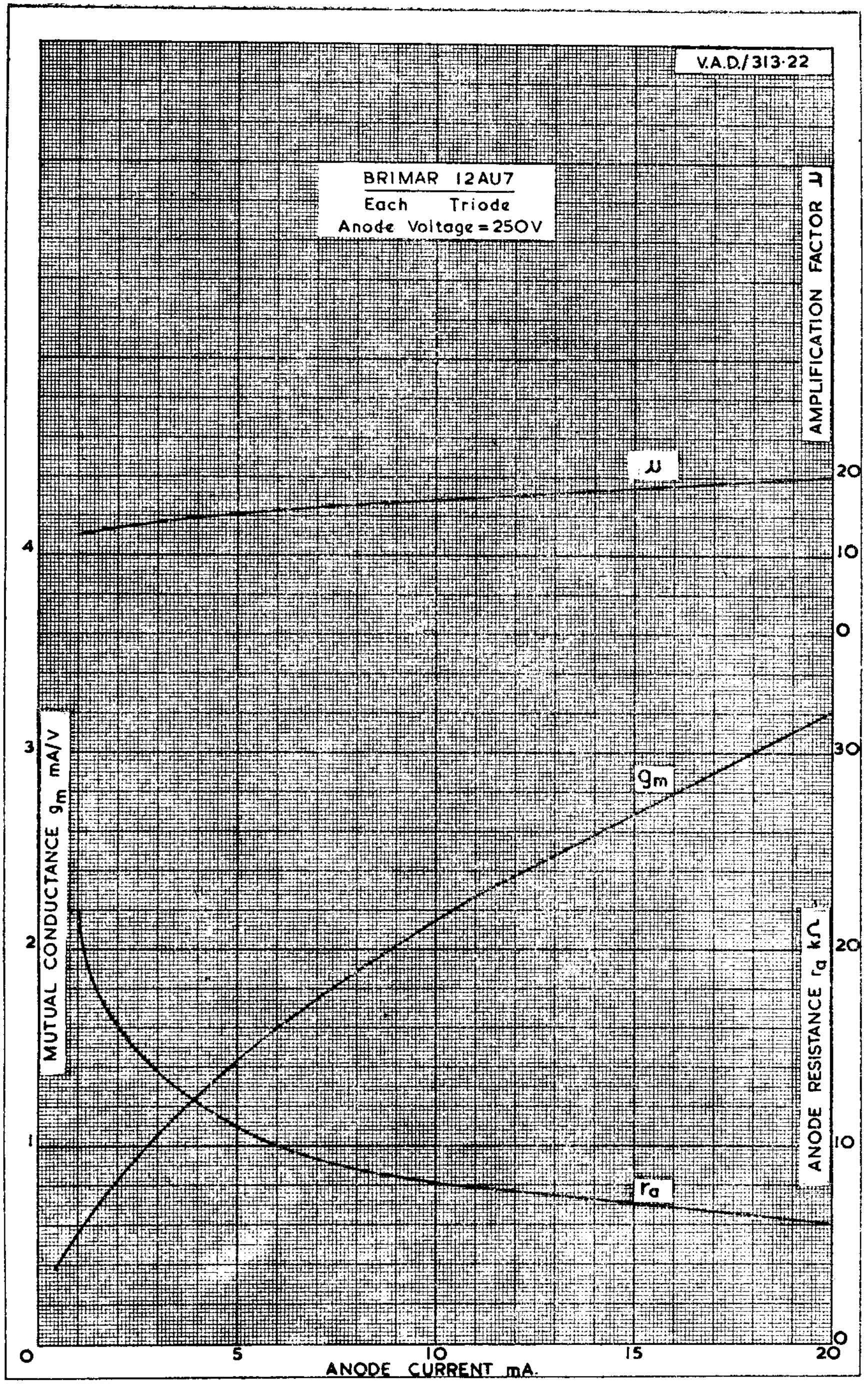
TELEVISION RECEIVERS

The valve may be usefully employed in television time base circuits as combined frame and line squegging oscillators or as a combined frame oscillator and output stage if suitable circuits and frame scanning coils are employed. If necessary the two sections may be used in parallel in frame scan circuits of lower efficiency, or where more power is essential.

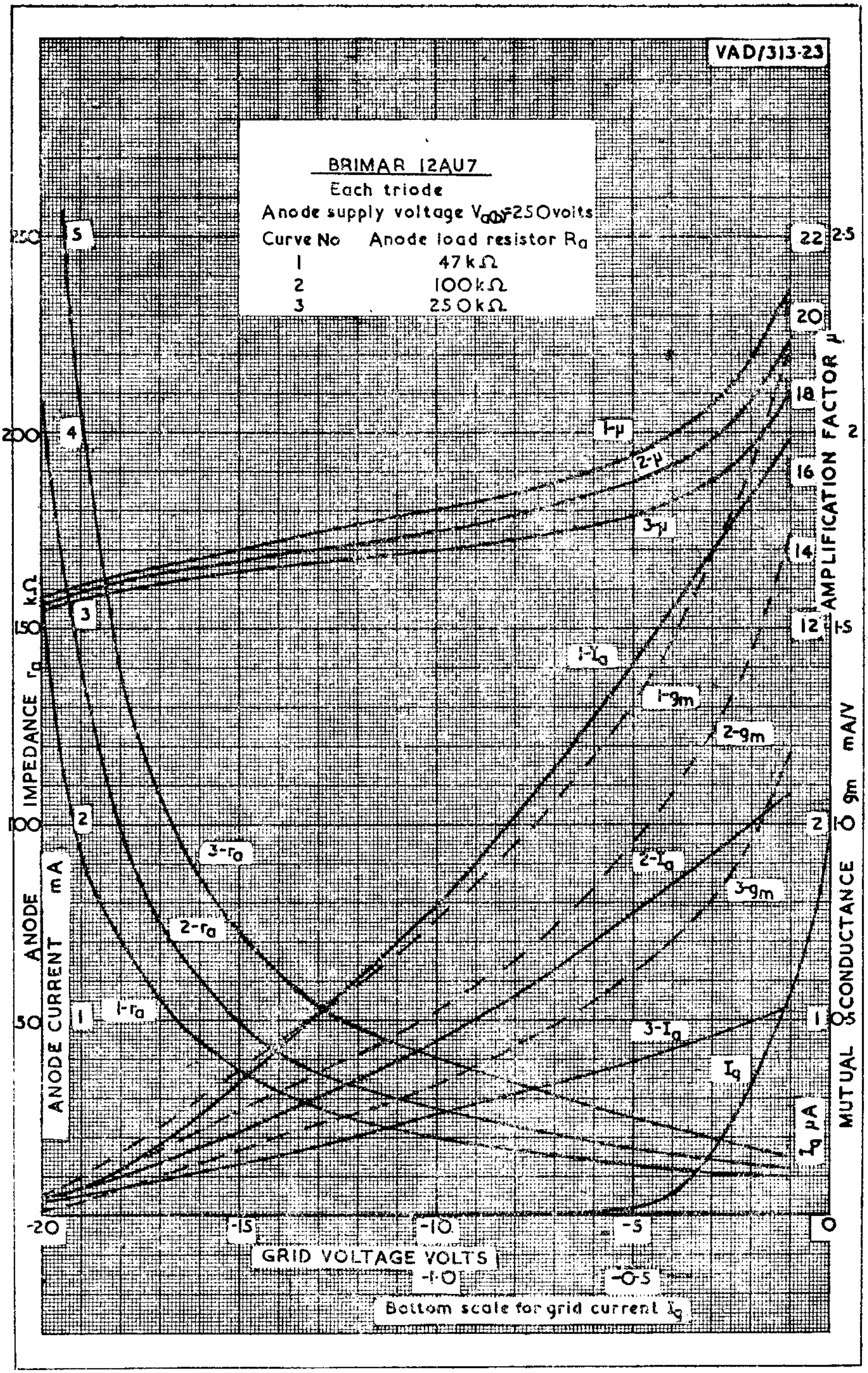

BRIMAR 12AU7
ANODE CURRENT versus ANODE VOLTAGE
Each Triode
ANODE CURRENT Ia. mA.
0
10
20
30
ANODE VOLTAGE VOLTS
100
200
300
400
500
Grid Volts Vg = 0
-5
-10
-15
-20
-25
-30
VAD/313·20

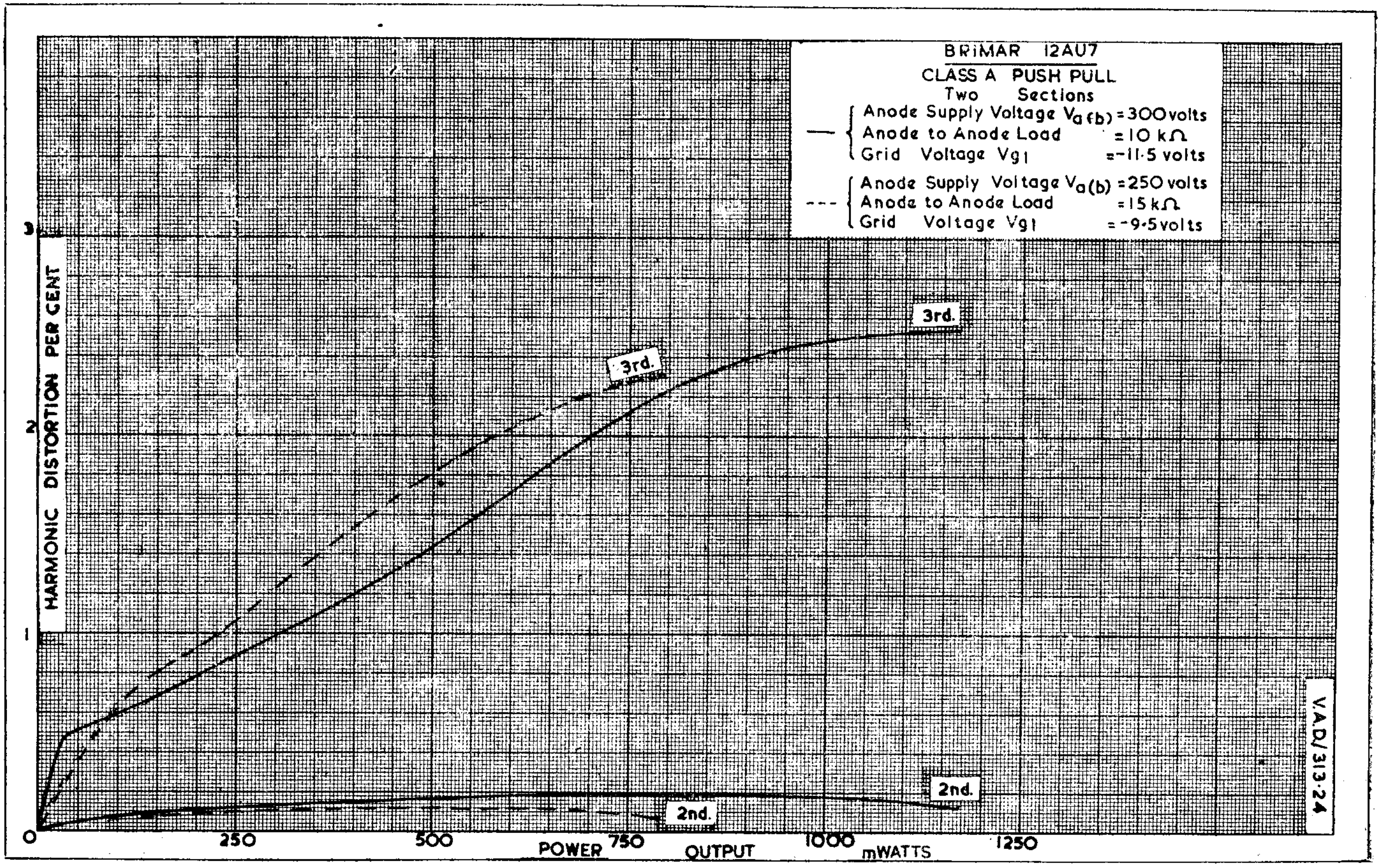


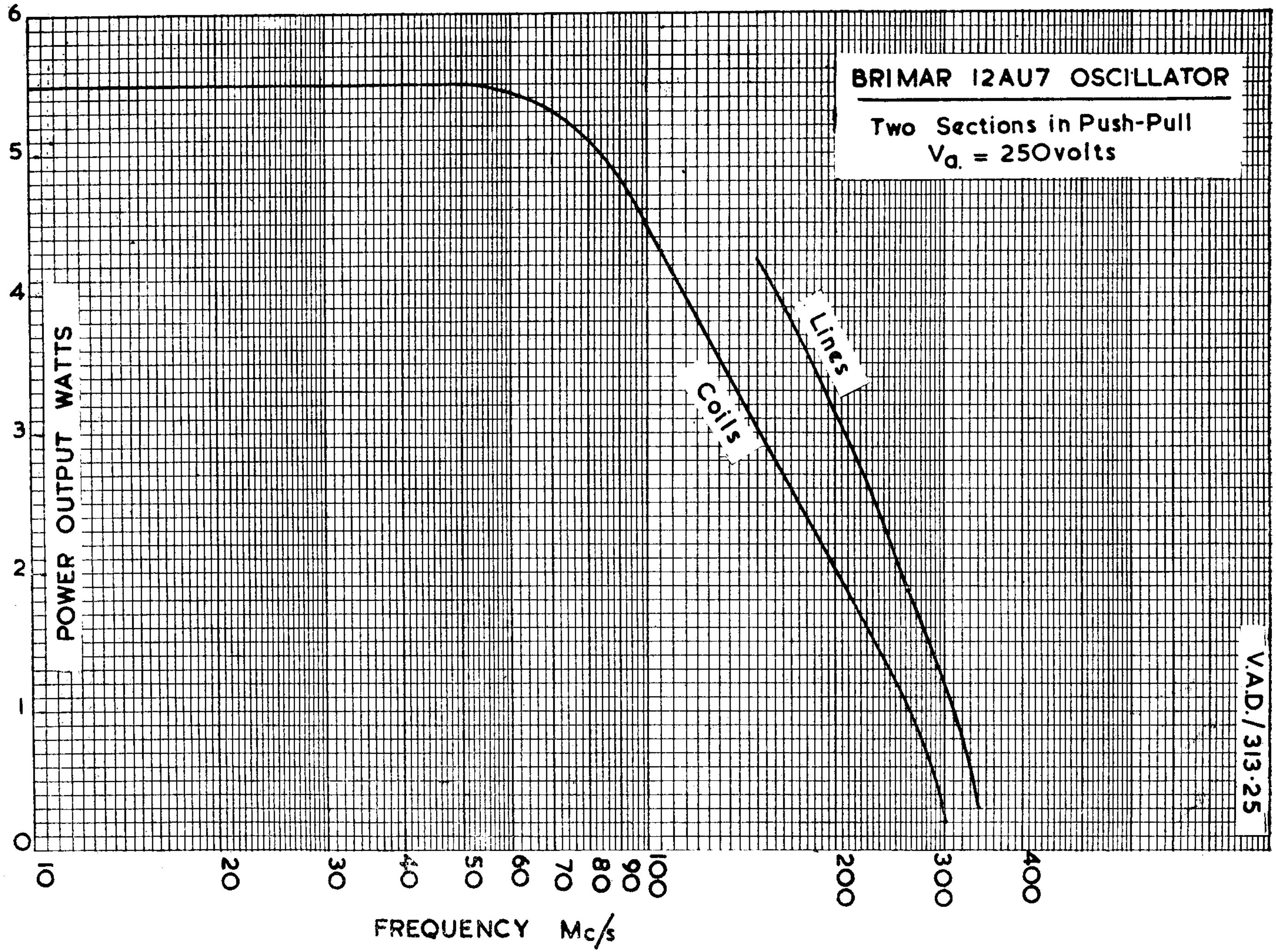
V.A.D./313·21
BRIMAR 12AU7
ANODE CURRENT versus GRID VOLTAGE
Each Triode
ANODE CURRENT mA
Anode Voltage Va = 300 Volts
250
200
150
100
25
20
15
10
5
-20
-15
-10
-5
0
GRID VOLTAGE VOLTS



V.A.D./313·22
BRIMAR 12AU7
Each Triode
Anode Voltage = 250V
AMPLIFICATION FACTOR µ
µ
g_m
r_a
MUTUAL CONDUCTANCE g_m mA/V
ANODE RESISTANCE r_a kΩ
ANODE CURRENT mA.
0
5
10
15
20
1
2
3
4
10
20
30
0

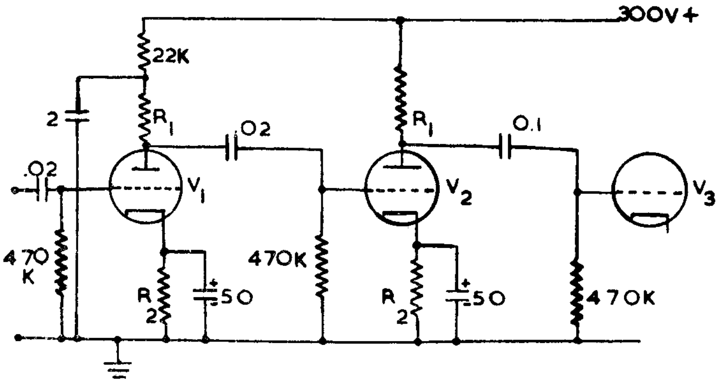

VAD/313-23
BRIMAR 12AU7
Each triode
Anode supply voltage $V_{a(b)}$=250volts
Curve No Anode load resistor R_a
1 47kΩ
2 100kΩ
3 250kΩ
1-μ
2-μ
3-μ
1-I_a
1-gm
2-gm
2-I_a
3-gm
3-I_a
I_g
3-r_a
2-r_a
1-r_a
AMPLIFICATION FACTOR μ
MUTUAL CONDUCTANCE gm mA/V
ANODE IMPEDANCE r_a kΩ
ANODE CURRENT mA
I_g μA
250
200
150
100
50
5
4
3
2
1
22
20
18
16
14
12
2·5
2
1·5
1·0
0·5
-20
-15
-10
-5
0
GRID VOLTAGE VOLTS
-1·0
-0·5
Bottom scale for grid current I_g


BRIMAR 12AU7
CLASS A PUSH PULL
Two Sections
Anode Supply Voltage Va(b) = 300 volts
Anode to Anode Load = 10 kΩ
Grid Voltage Vg1 = -11·5 volts
Anode Supply Voltage Va(b) = 250 volts
Anode to Anode Load = 15 kΩ
Grid Voltage Vg1 = -9·5 volts
3rd.
3rd.
2nd.
2nd.
HARMONIC DISTORTION PER CENT
0
1
2
3
250
500
750
1000
1250
POWER OUTPUT mWATTS
V.A.D./313·24


BRIMAR 12AU7 OSCILLATOR
Two Sections in Push-Pull
$V_{a.}$ = 250 volts
Lines
Coils
POWER OUTPUT WATTS
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
200
300
400
FREQUENCY Mc/s
V.A.D./313·25

BRIMAR 12AU7

CASCADE AMPLIFIER RESISTANCE-CAPACITY COUPLED



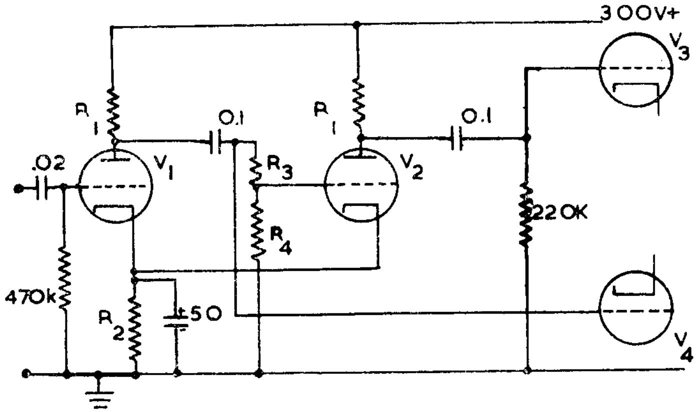
V_1 and V_2 are two units of 12AU7.

V_3 is succeeding stage or output valve.

	Condition 1	*Condition* 2	
R_1	100,000	220,000	ohms
R_2	2,200	6,800	ohms
Voltage Gain at 1 kc	174	155	
Max. R.M.S. Output Voltage for 5% Total Harmonic Distortion at 1 kc	40	40	volts
Gain at 50 c/s (compared with 1 kc)	—0·35	—0·35	dB
Gain at 30 kc (compared with 1 kc)	—0·35	—0·85	dB

BRIMAR 12AU7

PARAPHASE AMPLIFIER



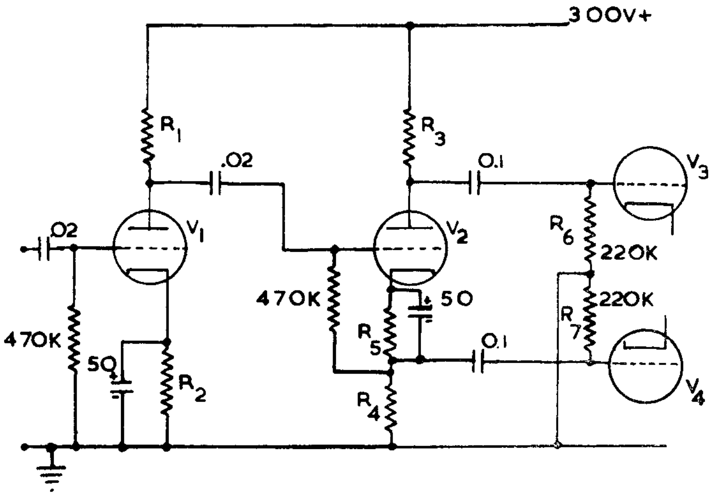
V_1 and V_2 are two units of 12AU7.

V_3 and V_4 are succeeding push-pull stage.

	Condition 1	*Condition 2*	
R_1	100,000	220,000	ohms
R_2	1,000	680	ohms
R_3	220,000	220,000	ohms
R_4	33,000	33,000	ohms
Voltage Gain at 1 kc	12·2	10·9	
Max. R.M.S. Output Voltage for 5% Total Harmonic Distortion at 1 kc (grid to grid)	110	120	volts
Gain at 30 kc/s (compared with 1 kc)	—0·66	—1·25	dB
Gain at 50 c/s (compared with 1 kc)	—0·33	—0·15	dB

BRIMAR 12AU7

VOLTAGE AMPLIFIER AND PHASE INVERTER



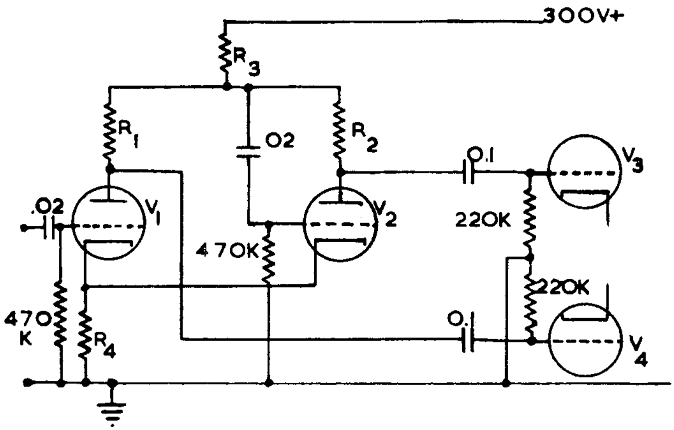
V_1 and V_2 are two units of 12AU7.

V_3 and V_4 are succeeding push-pull stage.

	Condition 1	*Condition* 2	
R_1	100,000	220,000	ohms
R_2 and R_5	2,200	6,800	ohms
R_3 and R_4	47,000	100,000	ohms
Voltage Gain at 1 kc	12·1	10·4	
Max. R.M.S. Output Voltage for 5% Total Harmonic Distortion at 1 kc (grid to grid)	80	75	volts
Gain at 50 c/s (compared with 1 kc)	—0·7	—0·25	dB
Gain at 30 kc (compared with 1 kc)	—0·85	—2·0	dB

BRIMAR 12AU7

PHASE INVERTER CATHODE AND ANODE COUPLED



V_1 and V_2 are two units of 12AU7.

V_3 and V_4 are succeeding push-pull stage.

	Condition 1	*Condition* 2	
R_1	47,000	100,000	ohms
R_2	70,000	150,000	ohms
R_3	10,000	22,000	ohms
R_4	680	1,500	ohms
Voltage Gain at 1 kc	11·4	11·0	
Max. R.M.S. Voltage for 5% Total Harmonic Distortion at 1 kc (grid to grid)	65	60	volts
Gain at 50 c/s (compared with 1 kc)	—0·55	—0·6	dB
Gain at 30 kc/s (compared with 1 kc)	0	0	dB