BRIMAR

RECEIVING VALVE

12AT7
EEC81

APPLICATION REPORT VAD/513.3

Standard Telephones and Cables Limited

FOOTSCRAY, KENT, ENGLAND

1.0 INTRODUCTION: The Brimar type 12AT7 is an 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 or AC/DC equipment.

This report contains characteristics of the valve and details of its use as a normal amplifier, resistance capacity coupled amplifier, a frequency changer for ultra-short waves, oscillator, grounded grid amplifier and as a frequency multiplier.

2.0 DESCRIPTION: The valve comprises two triode units mounted side by side having separate heaters but common heater pin connections. The units are mounted in a standard T6½ bulb and based with a B.V.A. Standard base type B9A.

3.0 CHARACTERISTICS:

3.1 Cathode:

		Series	Parallel	
Indirectly heated				
Voltage		12·6	6·3	volts
Nominal Current		0·15	0·3	ampere
Max. Heater-Cathode potential (DC)			250 volts	

3.2 Dimensions:

Max. Overall Length   2-3/16 ins.
Max. Diameter   7/8 in.
Max. Seated Height   1-15/16 ins.

3.3 Base: Noval Type B9A

3.4 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′.

3.5 Ratings (Design centre):

EACH TRIODE UNIT:

Max. Anode Voltage	300 volts
Max. Anode Dissipation	2·5 watts
Max. Cathode Current	20 mA
Max. Negative Control Grid Voltage	50 volts
Max. Average Grid Current	1 mA

3.6 Capacities (approx.):*

GROUNDED CATHODE OPERATION:	Triode Unit′	Triode Unit″	
$c_{g,\,a}$	1·45	1·45	pF
$c_{g,\,kh}$	2·5	2·5	pF
$c_{a,\,kh}$	0·45	0·35	pF
$c_{h,\,k}$	2·5	2·5	pF
$c_{g}{}',\,a''$	0·20		pF
$c_{g}{}'',\,a'$	0·20		pF
$c_{a}{}',\,a''$	0·40		pF max.
$c_{g}{}',\,g''$	0·005		pF max.

* Measured with no external shield

GROUNDED GRID OPERATION:

$c_{a, k}$	0·15	0·15	pF
$c_{k, gh}$	5	5	pF
$c_{a, gh}$	1·6	1·5	pF

3.7 Characteristic Curves: Curves are attached to this report which show:

Anode current plotted against anode volts for various values of grid voltage (I_a/V_a) (Curve No. 313·13).

Anode current plotted against grid volts for various anode voltages (I_a/V_g) (Curve No. 313·14).

Mutual conductance, amplification factor and anode impedance plotted against anode current (g_m/I_a) (Curve No. 313·15).

4.0 Typical Operation:

4.1 Class AI Amplifier:

Anode	100	180	250	volts
Grid	—1	—1	—2	volts
Amplification Factor (μ)	54	62	55	
Anode Impedance (r_a)	13500	9400	10000	ohms
Mutual Conductance	4·0	6·6	5·5	mA/V
Anode Current	3·7	11	10	mA
Grid Volts for I_a 10μA	—6	—8	—12	volts

4.2 Resistance Coupled Amplifier: The valve may be used as a resistance coupled amplifier, and a graph is attached to this report which shows the relation between the various valve parameters under conditions of resistance capacity coupling. This graph, No. 313·16, is measured at an anode supply voltage $V_{a(b)}$ of 250 volts with three values of anode load resistance, viz.: 47,000, 100,000, 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 resistance) 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 the 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 —1·0 to —5·0 volts, the mid point being —3 volts. At this point the anode current is 1 mA, hence the cathode resistance should be 3,300 ohms. The peak input voltage is, say, 2 volts and the R.M.S. input 1·4 volts. Following the grid bias voltage upward it is evident that, with an anode load of 100,000 ohms, the amplification factor (μ) is 37 and the anode impedance is 33,000 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:

$$\frac{37 \times 82,000}{82,000 + 33,000} = 26·5.$$

The peak input voltage above was 2 volts, hence the peak output voltage will be this figure multiplied by the stage gain or 53 volts or 37·5 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 —1·0 volts is 38 and at —5·0 volts is 18·6, hence the positive peaks of the signal output will be less than the negative and the distortion at this input will be 17%.

4.3 Frequency Changer:

4.31 The valve is designed to perform efficiently as a frequency changer in receivers for short or ultra-short waves. It has the advantages of a low noise factor and a high conversion gain, this is particularly so when high intermediate frequencies are used in order to achieve wide band width or good second channel ratio. It is not suitable for this application when the signal frequency is of the same order as the intermediate frequency, as on medium or long waves with an IF of 465 Kc/s.

4.32 A curve of conversion conductance and anode current, plotted against peak heterodyne voltage, is shown on VAD/313·17. This indicates optimum conversion with a peak oscillator voltage of 4·5 volts. Under these conditions the equivalent noise resistance referred to the mixer grid is approximately 1000 ohms.

When used at frequencies above 30 Mc/s, the impedance in the mixer anode to signal frequency can have a considerable effect on the performance. If a small inductance is included in the anode lead this is reflected as a negative resistance in the input circuit, and tends to offset the normal low input resistance of a triode mixer. The inductance is obtainable from the length of lead between the anode tag on the valve holder and the IF transformer tuning condenser. This condenser forms an effective earth return to signal frequency when the latter is considerably higher than the IF. At 100 Mc/s, about 1 in. of lead is sufficient; at 400 Mc/s the condenser should be attached to the anode tag itself. Too much inductance in the anode circuit will lead to oscillation of the mixer.

Typical circuits for frequency changer service are given on VAD/313·67. Information is given on the circuit on tuning constants for operation at 100 Mc/s and 430 Mc/s.

It is not desirable to inject heterodyne volts of such value that mixer grid current flows, as this only serves to damp the input circuit and further lower its impedance. At frequencies up to 200 Mc/s a small coupling condenser from oscillator grid to mixer grid supplies adequate heterodyne voltage. At higher frequencies, stray capacities within the valve and across the holder are of sufficient magnitude to render unnecessary any additional capacity.

The condenser C on the circuits is the normal IF tuning condenser to which reference was made in the remarks on by-passing of mixer anode to signal frequency.

4.33 Measurements taken on the mixer at 430 Mc/s indicate a noise factor of about 10 and a conversion gain of the order of 5 db. At 45 Mc/s a noise factor of the order of 8 is obtainable. Experience indicates that the 12AT7 as a mixer offers distinct advantages over a diode up to at least 450 Mc/s. Above this frequency the valve will still give useful service, but it is to be expected that a rapid falling off in efficiency occurs.

4.4 Oscillator: The valve may be used as an oscillator either single ended or in push-pull. A typical circuit is given on No. 313·68, and a curve showing the performance obtainable at frequencies up to 500 Mc/s is given on No. 313·18. Using lines for the tuned circuit one 12AT7 with the two halves in push-pull will deliver about 2 watts output at 400 Mc/s.

Under single ended conditions rather under half this power is developed, as the efficiency is not so high as with a symmetrical circuit. When used at V.H.F. either single ended or in push-pull it may be found advantageous to insert a choke in series with the cathode lead.

4.5 RF Amplifier: The 12AT7 may be used either as a grounded cathode or grounded grid amplifier. Grounded cathode operation is not normally suitable for high frequency applications as, due to the anode/grid capacity, neutralisation is needed to prevent self oscillation, and such neutralisation is difficult to maintain when wide band operation is required.

4.51 Grounded Grid Operation: A typical circuit showing the 12AT7 used either single ended or push-pull as a grounded grid amplifier is shown on No. 313·69. The input impedance single ended is:

$$R_{in} = \frac{r_a + R_a}{\mu + 1}$$

where r_a is the valve impedance and R_a the anode load. If, as is usually the case at high frequencies, the effective anode load is low compared with the anode impedance the expression reduces to $R_{in} = \dfrac{1}{g_m}$ which is equal to 180 ohms for the 12AT7 at V_a 250 volts and V_g —2 volts, or 150 ohms with V_a 180 volts and V_g —1 volt.

When used in push-pull the overall input impedance is approximately 360 ohms and 300 ohms respectively, which facilitates matching to a 300Ω balanced transmission line.

Normally neutralisation is not required with a grounded grid amplifier, as the earthed grid forms an effective screen between cathode and anode, reducing the feed-back in the valve to a sufficiently low level. At high frequencies, however, it is not easy to hold the grid completely at ground due to the inductance of the earthing lead. Furthermore, the effect of the internal valve feed-back becomes greater at high frequencies. Above 350 Mc/s it is very often necessary to resort to neutralisation, but it is not critical to adjust and the required amount can often be obtained by dressing the wiring.

A single ended grounded grid amplifier using half a 12AT7 will give a gain of about 10 db at 200 Mc/s and about 6 db at 400 Mc/s. The noise factor is of the order of 8 at 200 Mc/s. Push-pull operation gives slightly better performance as the lower capacity across the tuned circuits allows a higher L/C ratio. The improvement in gain is of the order of 2 to 3 db. At 40 Mc/s the input impedance is approximately 40 kΩ in the single ended condition.
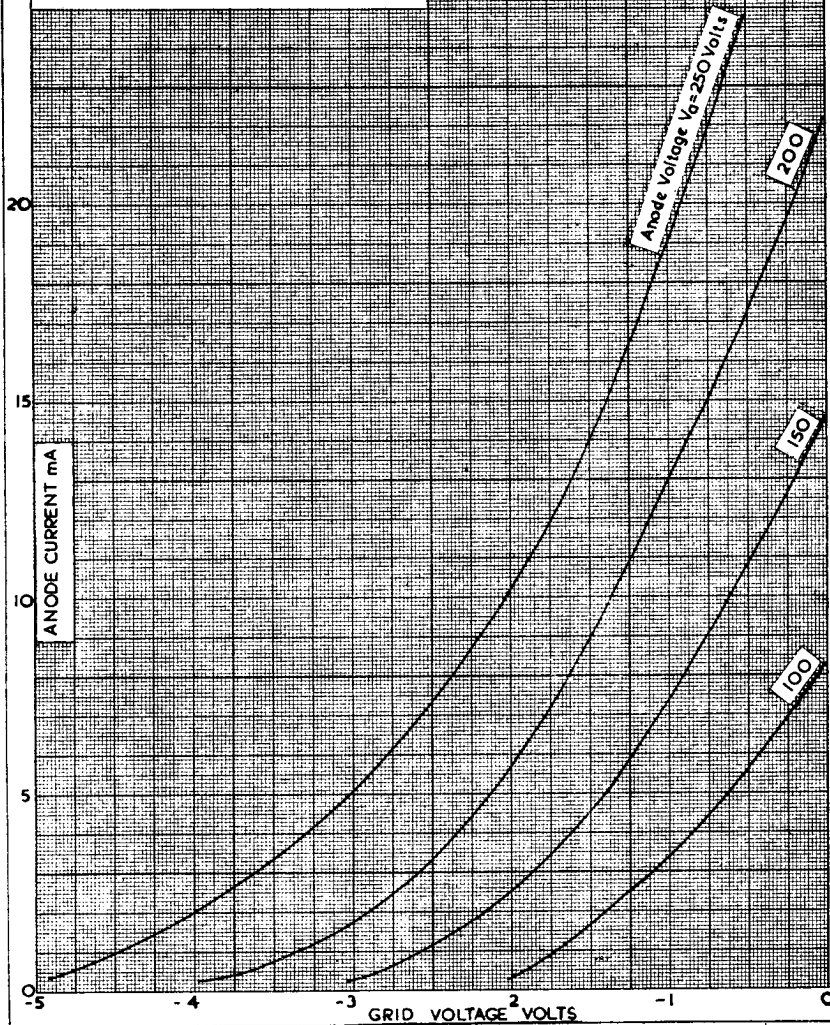
4.52 Grounded Cathode: Normally this method is not suitable at high frequencies as neutralisation is critical and difficult to maintain over a wide bandwidth. If, however, the grounded cathode amplifier is arranged to feed into a grounded grid amplifier the gain of the first stage looking into an impedance of approximately $\dfrac{1}{g_m}$ is unity, so that the circuit is stable. The output current of the grounded cathode stage flows in the anode circuit of the grounded grid stage so that the gain of the two stages is $g_m R_a$, where R_a is the anode load of the grounded grid stage.

A typical circuit is shown on 313·69. Neutralisation is necessary on the first stage solely to obtain minimum noise, but this is non-critical, as its application does not involve difficulties over stability. At 200 Mc/s a typical gain is 14 db with a noise factor of 7. This circuit is also useful for the first stage in a high gain IF amplifier at about 40 Mc/s.
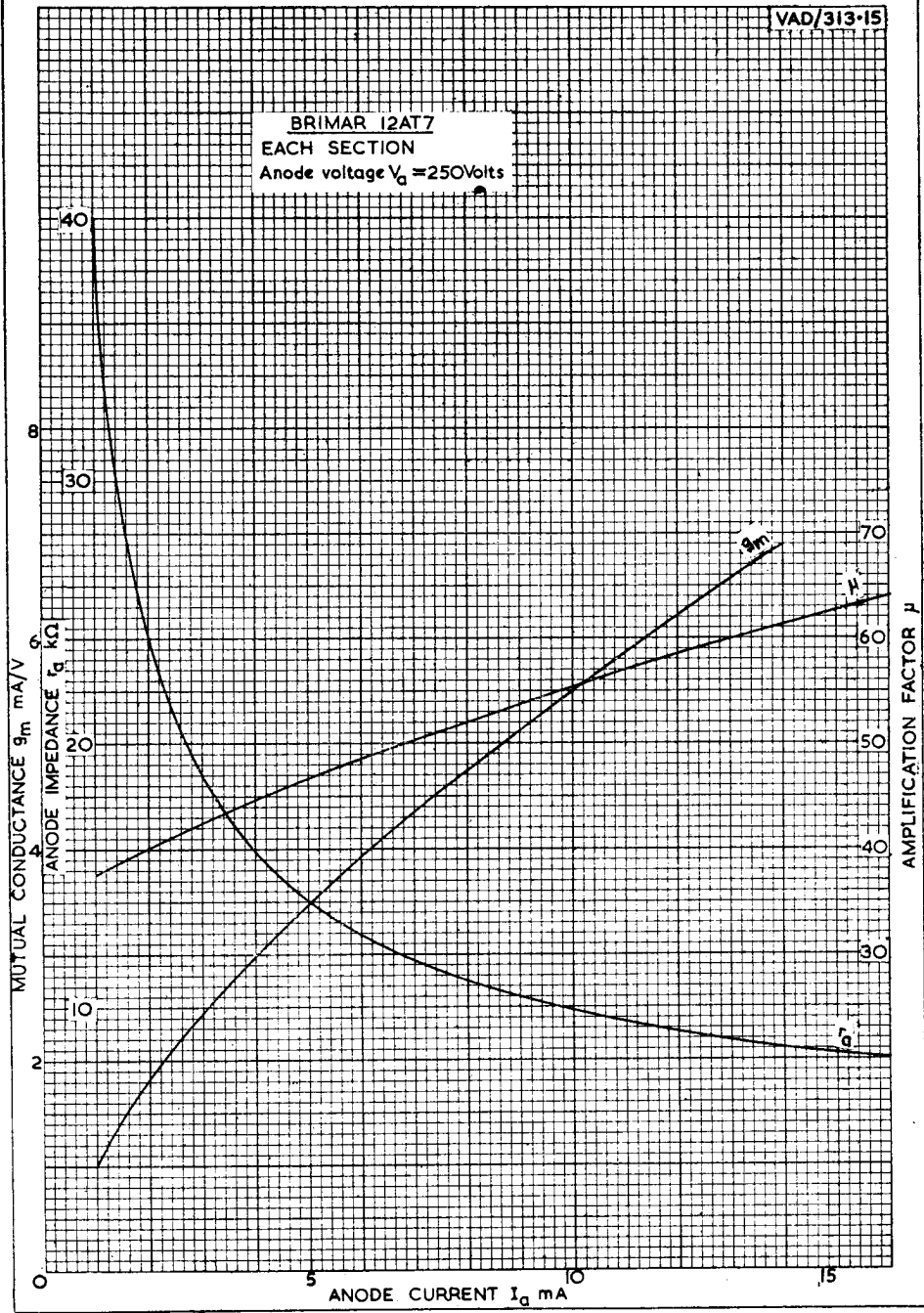
BRIMAR 12AT7
ANODE CURRENT versus ANODE VOLTAGE
Each Section

VAD/313 13

GRID VOLTAGE Vg 0·0

ANODE CURRENT mA

ANODE VOLTAGE VOLTS

VAD/313 14
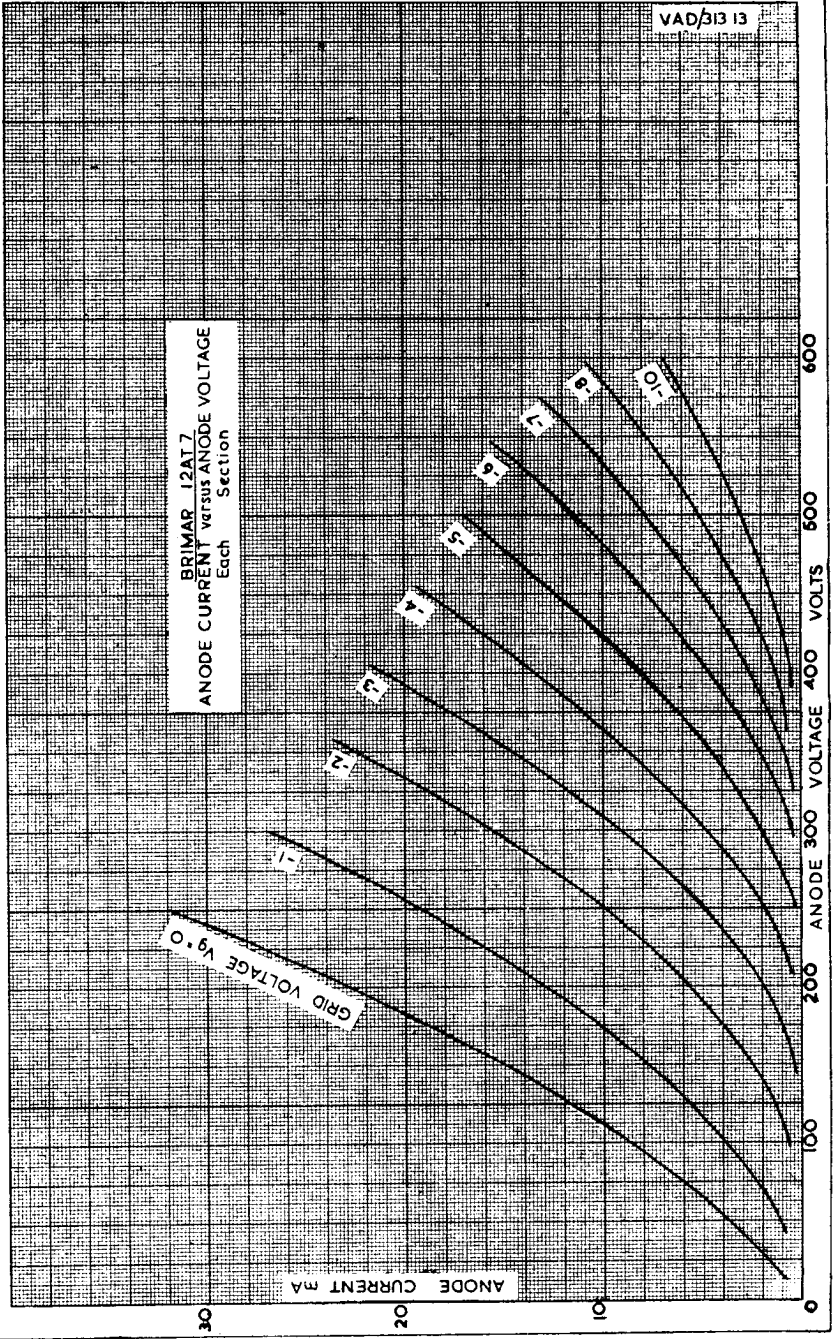
BRIMAR 12AT7
ANODE CURRENT versus GRID VOLTAGE
Each   Section

Anode Voltage Va=250 Volts

200

150

100

ANODE CURRENT mA

20

15

10

5

0

GRID VOLTAGE VOLTS
-5   -4   -3   -2   -1   0

VAD/313·15

BRIMAR 12AT7
EACH SECTION
Anode voltage V_a = 250 Volts

MUTUAL CONDUCTANCE g_m mA/V

ANODE IMPEDANCE r_a kΩ

AMPLIFICATION FACTOR μ

g_m

μ

r_a

ANODE CURRENT I_a mA

VAD/313·16

BRIMAR 12AT7
EACH SECTION
Anode supply voltage $V_{a(b)}$=250Volts
Anode loads:- 1-R_a= 47kΩ
2-R_a=100kΩ
3-R_a=220kΩ

ANODE IMPEDANCE r_a kΩ

GRID VOLTAGE VOLTS

AMPLIFICATION FACTOR μ

MUTUAL CONDUCTANCE gm mA/V

ANODE CURRENT I_a mA

1-μ
2-μ
3-μ

1-g_m
1-I_a
2-g_m
2-I_a
3-g_m
3-I_a
3-r_a
2-r_a
1-r_a

250
200
150
100
50
O

-10
-7.5
-5
-2.5

60
40
20

4
3
2
1
O

VAD/313·17
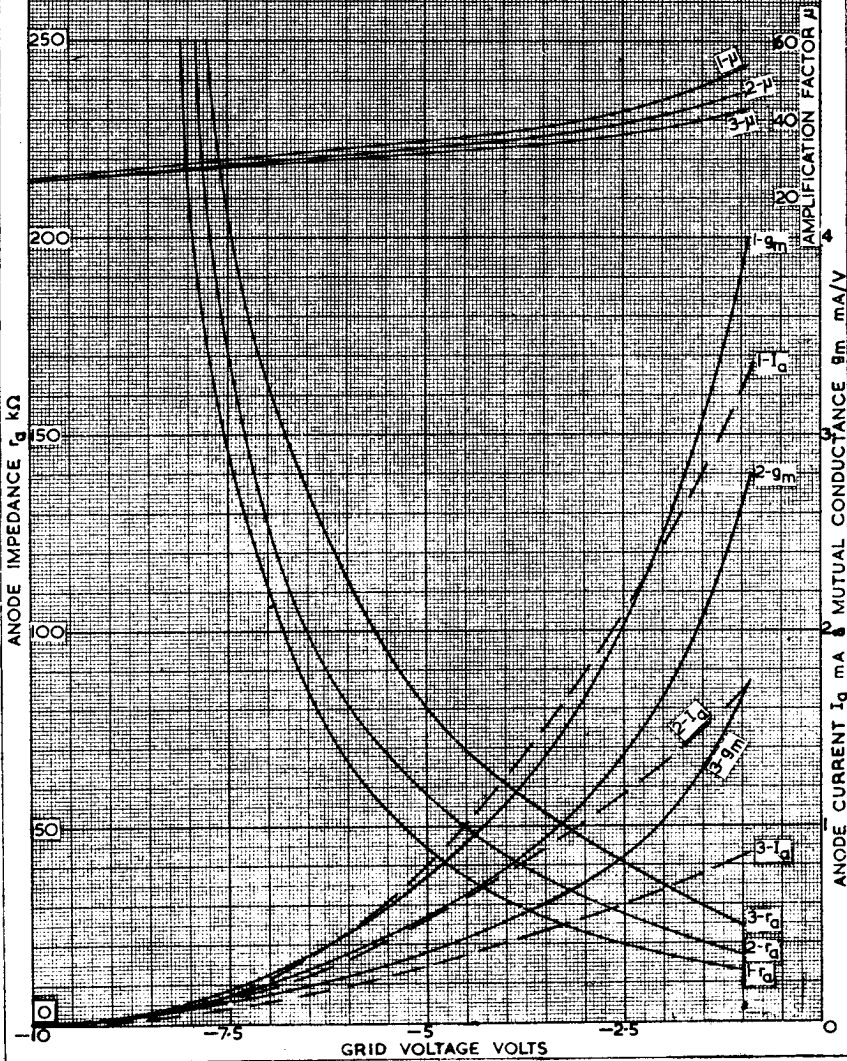
BRIMAR 12AT7
ONE TRIODE AS A FREQUENCY
CHANGER.
Anode voltage = 250Volts
Cathode bias = 680Ω
Grid injection of heterodyne
volts.

I_a

g_c

CONVERSION CONDUCTANCE g_c mA/v

MIXER ANODE CURRENT I_a mA

PEAK OSCILLATOR VOLTS ON MIXER GRID
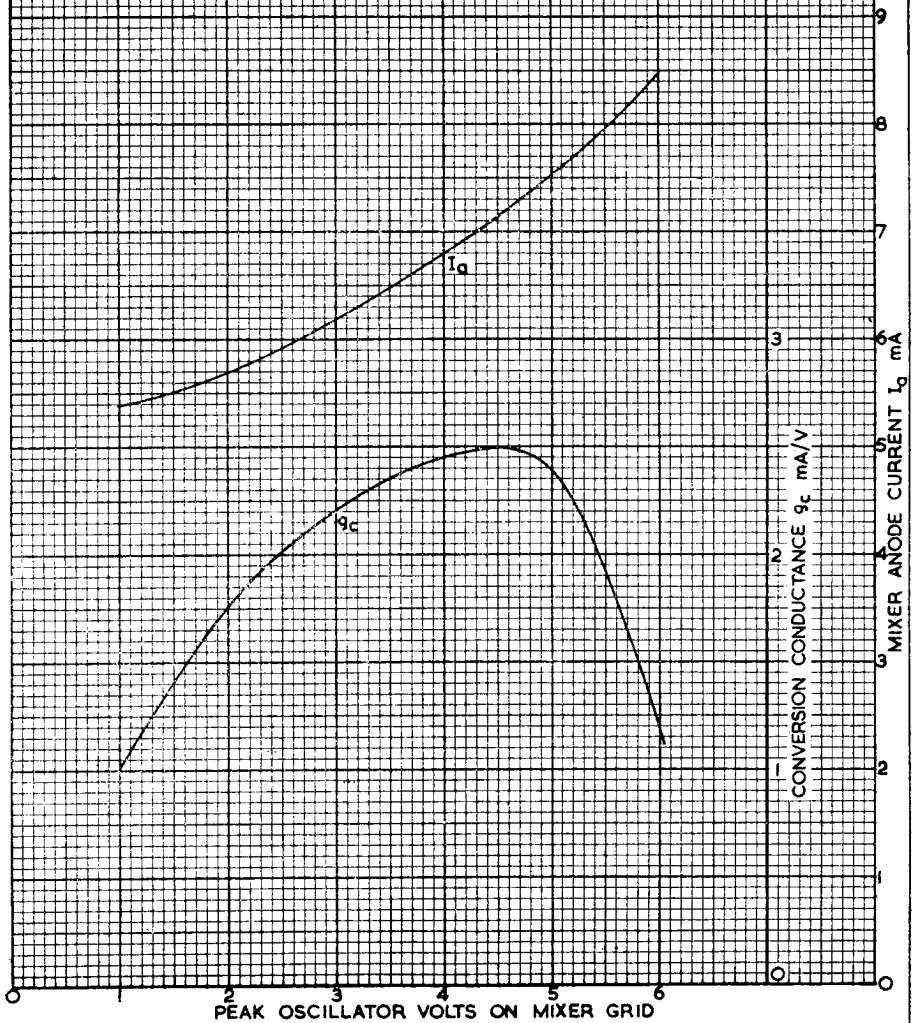
BRIMAR 12 AT7   420 Mc/s Frequency changer.
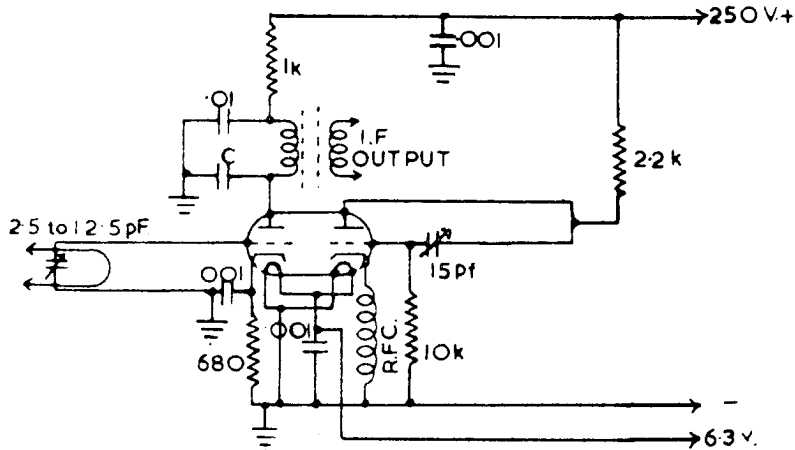
TUNED CIRCUITS PARALLEL LINES 14 S.W.G. COPPER WIRE,
APPROX 2 to 2 1/2 INCHES LONG, SPACED 1/2 INCH.
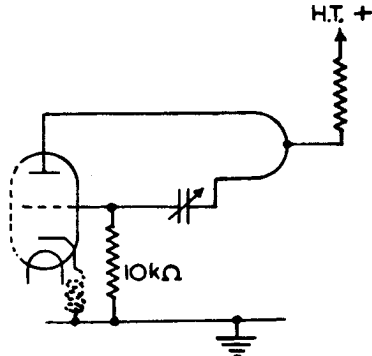
Frequency changer for F.M. band 88 to 108 Mc/s.
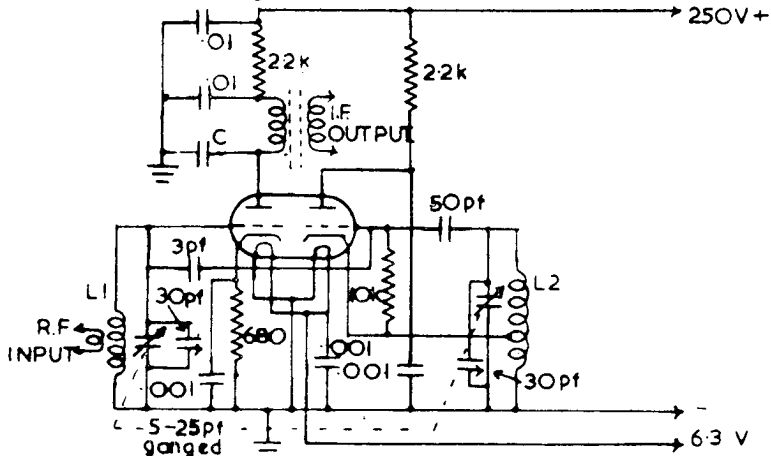
LI 2 1/4 TURNS 22 S.W.G. I.D. 3/8 in. 1/2 in. LONG. WIRE LENGTH,
INCLUDING LEADS 4 3/8 in.
L2. 1 3/4 TURNS 22 S.W.G I.D. 1/4 in. 3/16 in. LONG. WIRE LENGTH,
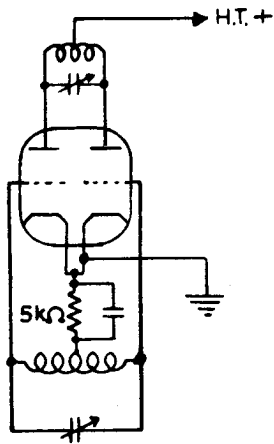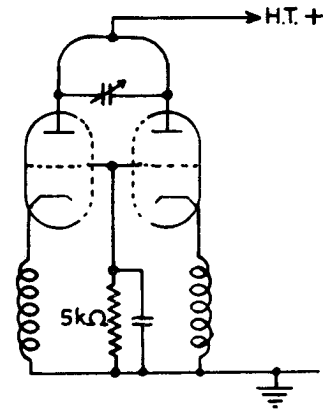INCLUDING LEADS, 3 3/4 in. TAP 1 TURN FROM EARTHY END.

BRIMAR 12AT7

POWER OUTPUT versus FREQUENCY
Two sections as push-pull oscillator
Anode voltage V_a = 250Volts
Grid bias resistor R_g = 4·7kΩ

LINES

COILS

FREQUENCY Mc/s

POWER OUTPUT WATTS

VAD/313·18

H.T. +
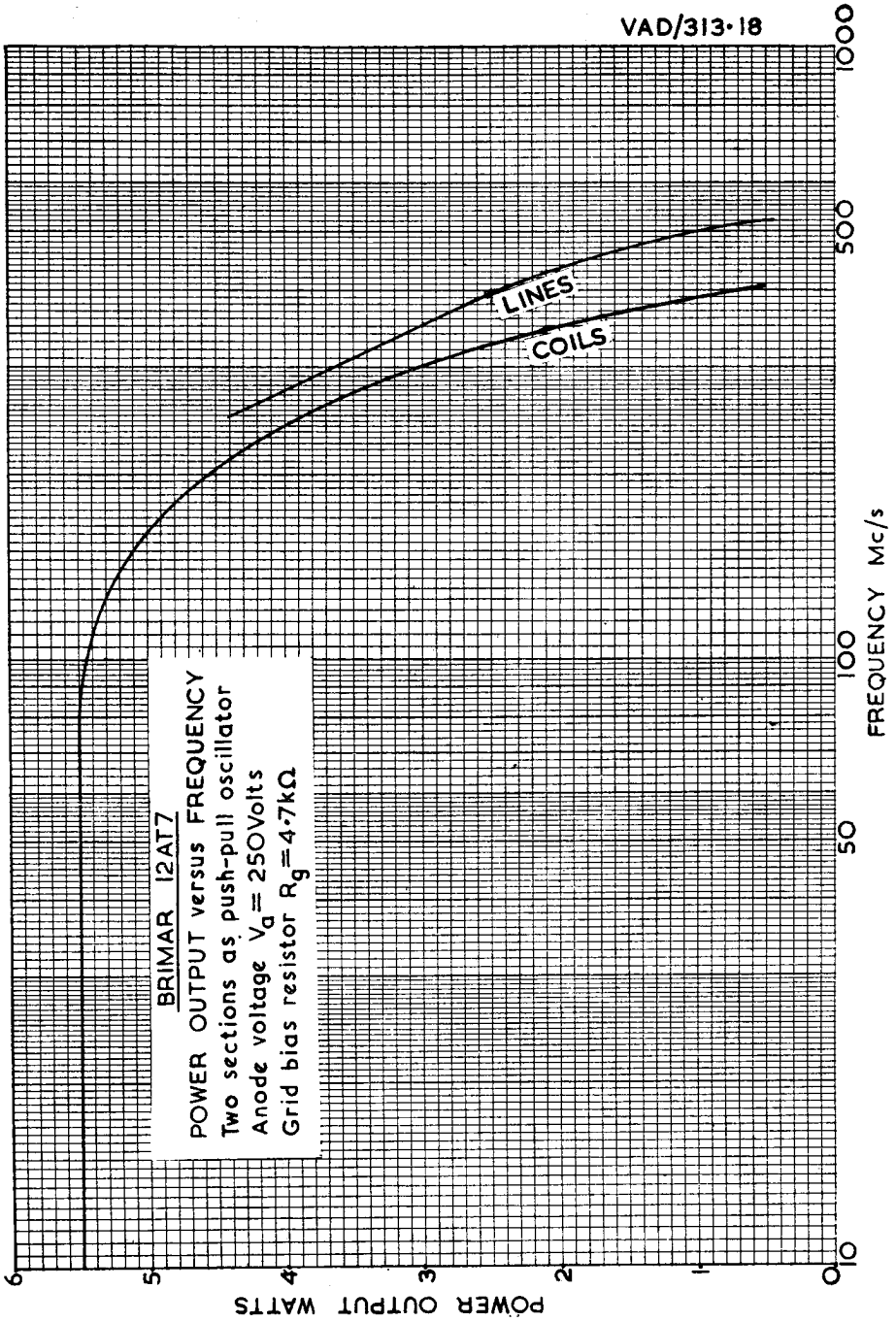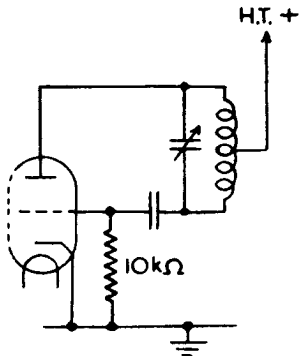
$\frac{1}{2}$ 12AT7 as a H.F.
   Oscillator

10kΩ

H.T. +

$\frac{1}{2}$ 12AT7 as a V.H.F.
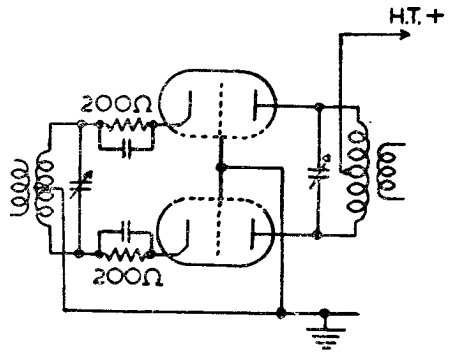   Oscillator

10kΩ

H.T. +

12AT7 as a push-pull
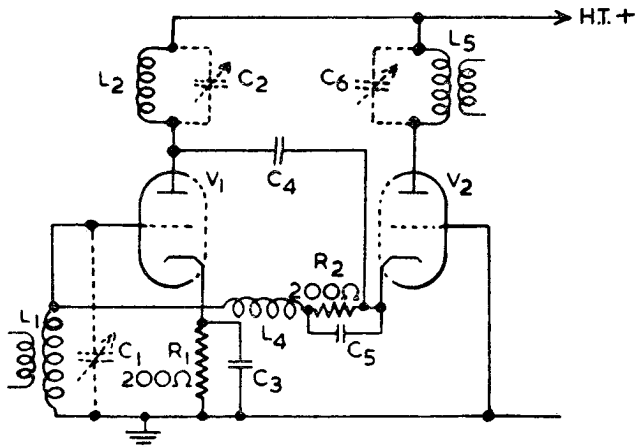   H.F. Oscillator

5kΩ

H.T. +

12AT7 as a push-pull V.H.F.
   Oscillator

5kΩ
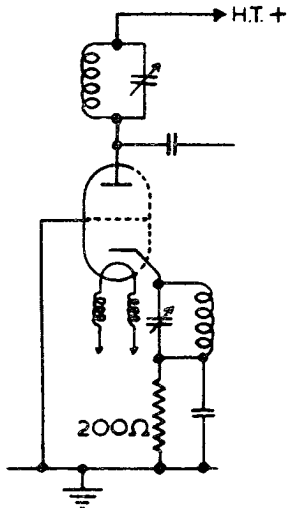
$\frac{1}{2}$ 12AT7 as a grounded
grid amplifier

12AT7 as a push pull grounded
grid amplifier

12AT7 as a grounded cathode, grounded grid amplifier