EH 2 Heptode

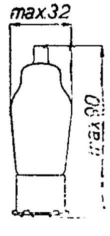

Fig. 1
Dimensions in mm

This pentagrid valve can be employed very successfully on very short wavelengths as a controlled modulator in conjunction with a separate oscillator, and also as R.F. or I.F. amplifier with limited control range.

The action of this valve is similar to that of a hexode in that, when used as modulator, the input signal is applied to the first grid and the oscillator signal to the third. The 2nd and 4th grids are screen grids having their own separate contacts on the base of the valve. The fifth grid which, regarded superficially, constitutes the main point of difference with the earlier type of hexode, is a suppressor grid, whose purpose is to improve the internal resistance and to ensure satisfactory performance when the valve is used in A.C./D.C. receivers with 100 V on the anode.

When the EH 2 is employed as frequency-changer a separate oscillator has many advantages; a triode such as the EBC 3 has an initial mutual conductance (at $Vg = 0$, $S = 3.0$ mA/V) that will guarantee stability of oscillation also in the short-wave range. A variable-mu modulator valve should meet the following requirements:

1) Conversion conductance should be sufficiently high.
2) Required oscillator voltage should be as low as possible.
3) Currents due to transit-time must not occur.

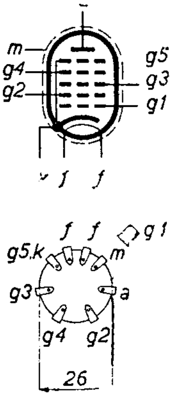

Fig. 2
Arrangement of electrodes and base connections.

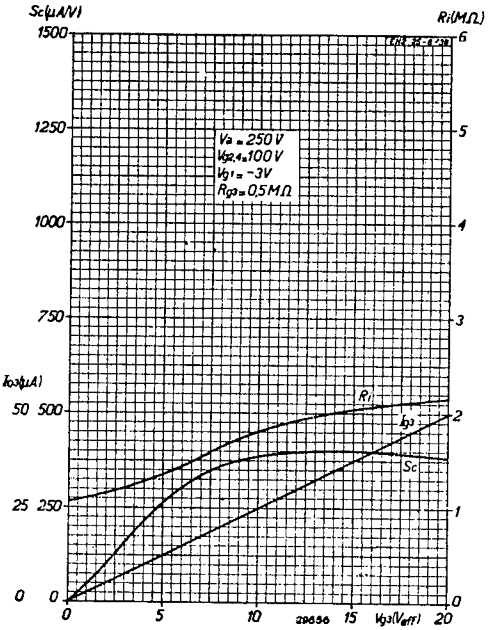

Fig. 3
Conversion conductance, internal resistance and oscillator-grid current as a function of the oscillator voltage on grid 3, at 250 V anode, 100 V screen and -3 V bias on grid 1.

4) Parallel input impedance should remain as high as possible, down to the very shortest wavelengths.
5) A satisfactory compromise between the least possible background noise, narrow range of bias for full control of the valve and also least possible cross-modulation.
6) Negligible frequency drift arising from the automatic gain control or from mains voltage variations.
7) Least possible coupling between input and oscillator circuits (inductive effect).

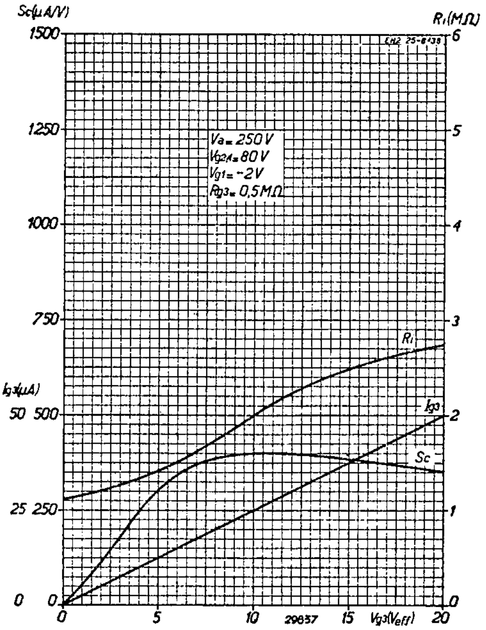

Fig. 4
Conversion conductance, internal resistance and oscillator current as a function of the oscillator voltage on grid 3, with 250 V anode, 80 V screen and –2 V bias on grid 2.

1) In the EH 2 the required conversion conductance is ensured by the high conductance of the 1st grid with respect to the anode current (when using this valve as a straight amplifier and at $V_{g3} = 0$). This conductance is 1.8 mA/V.

2) With regard to the required oscillator voltage, the characteristic of the conductance of the first grid in relation to the anode current, as a function of the voltage on the 3rd grid, is the deciding factor. The more steeply this characteristic drops when the bias on the 3rd grid (V_{g3}) is increased, the lower the peak oscillator voltage on the grid. Due to the particular construction of the first grid, this conductance is so high that when grids 2 and 4 are given a potential of 100 V the oscillator voltage necessary for the normal conversion conductance is approximately 14 V_{eff}, which can be supplied by any ordinary oscillator. Figs 3 and 4 reproduce the conversion conductance as a function of the oscillator voltage and these figures show that the values at very much lower oscillator voltages are still quite reasonable. This is important for short-wave reception.

3) The question of transit time current has also been satisfactorily dealt with. The electrons encounter a certain amount of delay in the field between grids 2 and 3, but at very high frequencies some of them, as a result of the alternating field produced by the oscillator voltage on grid 3, acquire so much kinetic energy that, despite the negative bias on grid 1,

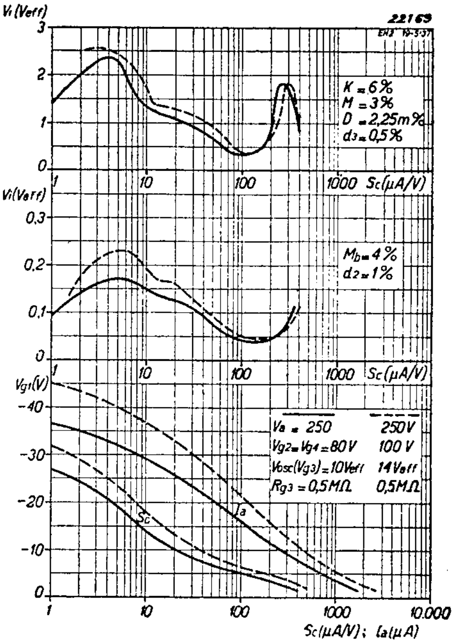

Fig. 5
Upper diagram. EH 2 used as a frequency changer. Alternating input voltage as a function of the conversion conductance as controlled by the bias on grid 1, with 6 % cross-modulation.
Centre diagram. Alternating input voltage as a function of the conversion conductance as controlled by the bias on grid 1, with 4 % modulation hum.
Lower diagram. Conversion conductance and anode current as a function of the bias on grid 1

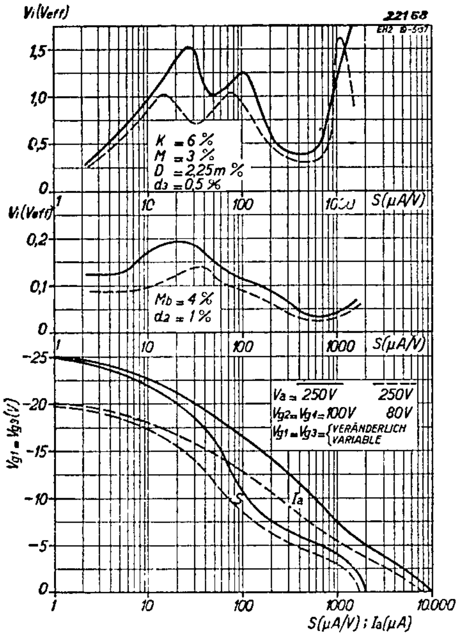

Fig. 6
EH 2 used as an R.F. or I.F. amplifier.
Upper diagram. Alternating input voltage as a function of the mutual conductance when controlled by a similar bias on grids 1 and 3, with 6 % cross-modulation.
Centre diagram. Alternating input voltage as a function of the mutual conductance when controlled by the bias on grids 1 and 3, with 4 % modulation hum.
Lower diagram. Mutual conductance and anode current as a function of the bias on grids 1 and 3.

they return in the direction of this grid: this will take place when the period of the alternating field corresponds in order of size to that of the transit time required by the electron between these grids. This transit time is reduced by making the space between grids 3 and 2 small, but normally this procedure has an adverse effect on other properties of a heptode and in this respect the EH 2 represents the best possible compromise.

4) The parallel input impedance in the short-wave range shows a considerable improvement over other types, by reason of the very small spacing of $g_1 - k$ and $g_2 - g_1$. At 15 metres and on a signal frequency of 500 kc/s above the oscillator frequency ($f_{osc} = f_i + 500$ kc/s) the following values of input impedance and capacitance were obtained by actual measurement:

R_{input} = 30,000 ohms
C_{input} = 6.3 $\mu\mu$F

5) In the development of the EH 2 every effort has been made to keep the noise factor as low as possible, whether the valve be used as frequency-changer or as R.F. amplifier. As will be seen from Figs 5 and 6, the alternating input voltage with 6 % cross-modulation, when under the effect of control, is in either case less than 0.3 V_{eff}.

6) When used with a separate oscillator valve, the valve has a frequency drift due to mains voltage flectuations that may be regarded as extremely slight. The drift arising from variations in the mutual conductance is also very small, since this is caused by differences in the capacitance of grid 3 which in themselves are negligible.

7) The heptode EH 2 will not produce any electrical coupling effects between oscillator and input grids, because grid 3 in no way influences the electrons in the neighbourhood of grid 1 ;

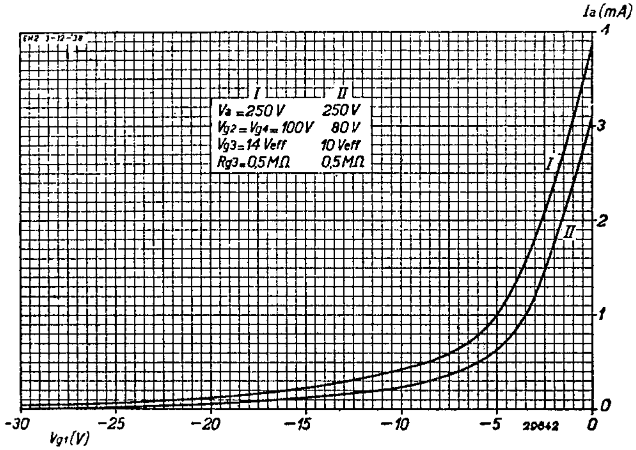

Fig. 7
Anode current as a function of the voltage on grid 1. EH 2 used as a frequency-changer.

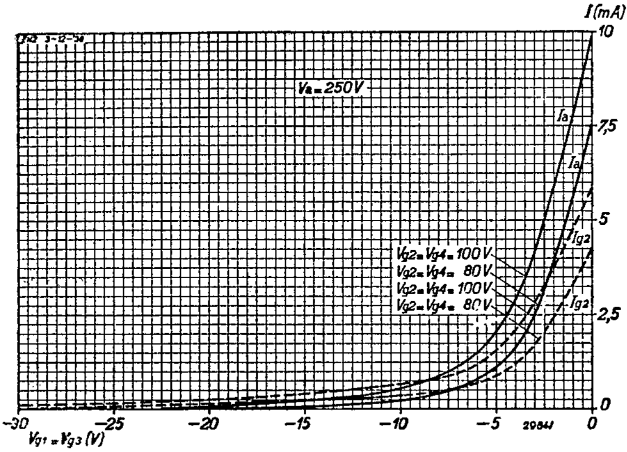

Fig. 8
Anode and screen-grid current as a function of the voltage on grids 1 and 3 when using the EH 2 as R.F. or I.F. amplifier.

there is therefore no negative capacitance between grids 1 and 3. The normal capacitance exists between the electrodes mutually, this being about 0.2 $\mu\mu$F, which on very short waves does result in retroaction from the oscillator voltage to the input circuit, although if the oscillator frequency is taken higher than the input frequency this will not affect the performance of the valve.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.200$ A.

CAPACITANCES

$C_{ag_1} < 0.0015$ $\mu\mu$F
$C_{g_1} = 5$ $\mu\mu$F
$C_a = 11$ $\mu\mu$F
$C_{g_1g_3} = 0.2$ $\mu\mu$F

OPERATING DATA: EH 2 used as frequency-changer

Anode voltage	V_a	=	250		250 V	
Screen-grid voltage	V_{g2+4}	=	100		80 V	
Grid leak, oscillator	R_{g3}	=	0.5		0.5 M ohm	
Oscillator voltage, grid 3	V_{osc}	=	14		10 V_{eff}	
Cathode resistor	R_k	=	530		380 ohms	
Grid bias.	V_{g1}	=	—3	—25	—2	—20 V
Anode current	I_a	=	1.85	—	1.8	— mA
Screen current	$I_{g2} + I_{g4}$	=	3.8	—	3.5	— mA
Conversion conductance	S_c	=	400	< 10	400	< 10 μA/V
Internal resistance	R_i	=	2	> 10	2	> 10 M ohms

OPERATING DATA: EH 2 used as R.F. or I.F. amplifier

Anode voltage	V_a	=	250		250 V	
Screen-grid voltage	$V_{g2} = V_{g4}$	=	100		80 V	
Cathode resistor	R_k	=	430		310 ohms	
Grid bias.	$V_{g1} = V_{g3}$	=	—3	—25	—2	— 20 V
Anode current	I_a	=	4.2	—	4	— mA
Screen current	$I_{g2} + I_{g4}$	=	2.8	—	2.5	— mA
Mutual conductance	S	=	1400	< 2	1400	< 2 μA/V
Internal resistance	R_i	=	1	> 10	1	> 10 M ohms

MAXIMUM RATINGS

V_{ao} = max. 550 V
V_{a} = max. 250 V
W_{a} = max. 1.5 W
$V_{g2o} = V_{g4o}$ = max. 400 V
$V_{g2} = V_{g4}$ = max. 125 V
$W_{g2} = W_{g4}$ = max. 0.5 W

V_{g1} ($I_{g1} = + 0.3\ \mu A$) = max. —1.3 V
V_{g3} ($I_{g3} = + 0.3\ \mu A$) = max. —1.3 V
$R_{g1} = R_{g3}$ = max. 2.5 M ohms
I_k = max. 10 mA
R_{fk} = max. 5,000 ohms
V_{fk} = max. 100 V [1]

APPLICATIONS

A) R.F. OR I.F. AMPLIFIER WITH VARIABLE SLOPE

A potential divider should be given preference for feeding the screen grids (grids 2 and 4) and the slope is best controlled by applying the same control voltage to both grids 1 and 3; if the latter grid is controlled by an attenuator (potential divider) giving a lower voltage, the control range is increased, but as the cross-modulation characteristic is identical in both instances this arrangement offers no advantages.

The metallizing of the envelope is connected to a separate contact on the base of the valve and, generally speaking, this should be earthed. The usual care must be taken with respect to the screening of the leads and the arrangement of the wiring, and the supply lines should be decoupled by means of filters. Fig. 9 shows the circuit diagram of this valve employed as a variable-mu I.F. amplifier.

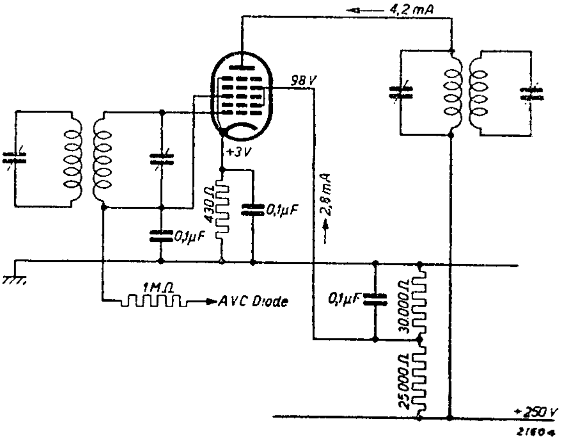

Fig. 9
Circuit diagram of the EH 2 used as an I.F. amplifier, with the same control voltage applied to grids 1 and 3.

B) VARIABLE-MU MODULATOR

Fig. 10 shows the circuit of the EH 2 used as a modulator, with the EBC 3 as oscillator, although the EF 6, connected as a triode, can also be employed for this purpose. This circuit will give satisfactory results at wavelengths of 5 m; it is preferable to couple the tuned oscillator circuit to the anode of the oscillator valve. The oscillator is coupled to grid 3 of the heptode EH 2 through a capasitor of 20 to 50 $\mu\mu F$, the latter being the best value for "all-wave" reception.

For wavelengths of 5 to 12 metres the oscillator coil may be made from about $4^1/_2$ turns of wire on an inside diameter of approximately 10 mm, not too closely wound and without an iron core. Tinned copper wire must not be used for this purpose and the leads from the coils to the tuning capacitor should be as short as possible. The coupling coil may also consist of $4^1/_2$ turns of silk-covered wire about 0.1 mm in diameter, wound directly on the anode-circuit coil. A resistor of 40 ohms in series with the grid of the oscillator will prevent over-oscillation at the lower end of the wave-range.

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[1]) direct voltage or effective value of the alternating voltage.

When the EF 6 is used as oscillator the oscillator voltage will be somewhat higher and, in the short-wave range, in contrast with octodes such as the EK 2, the oscillator frequency should be higher than the input frequency, as is usual on the medium and long waves. The other coupling, established by the capacitance between g_1 and g_3, then provides a voltage across the input circuit of the same frequency as the oscillator, and the phase of this voltage is such that it tends to augment the conversion amplification. In the uncontrolled condition the bias on grid 1 should be —2 V with 80 V on screens 2 and 4, or —3 V with 100 V on the screens. The control voltage from the A.G.C. is in this case applied only to the first grid. The two screens (2 and 4) should be fed from a generously proportioned potential divider.

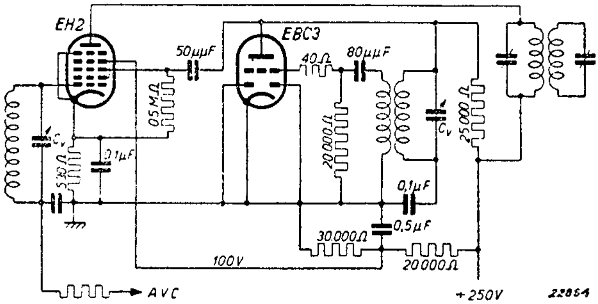

Fig. 10
Circuit diagram of the EH 2 used as frequency-changer with the EBC 3 as oscillator