EK 3 Octode

The EK 3 is an octode frequency-changer the characteristics of which show a considerable improvement over those of the EK 2; certain forms of interference are here reduced to a minimum by means of electronic bunching.

This valve gives an equally high conversion amplification in the short-wave band and in the ordinary broadcast ranges. In comparison with other frequency-changers the EK 3 offers many advantages. The principle of electronic bunching makes it possible to separate the oscillator unit from the mixing section as completely as though two separate valves were involved. Four electron bunches are formed, two for generating the oscillation and two for the mixing, and the two functions are to such an extent independent of each other that interaction is practically impossible. Fig. 3 shows a cross-section through the system of electrodes, together with the different electron streams. The advantages of this 4-channel system are as follows:

1) Frequency drift caused by mains voltage fluctuations, or variation of the bias on grid 4, is extremely slight.

2) Constant oscillator slope on very short wavelengths.

The almost perfect screening of the oscillator section of the EK 3 means that electrons returned to the 4th grid as a result of the control have no effect whatever on the space charge and slope of the oscillator unit; frequency drift arising from control on the valve is thus avoided and the EK 3 can therefore be included in the A.G.C., even on the short-wave range.

This screening of the oscillator unit is accompanied by the following advantages:

a) the space charge between grid 1 and the cathode, and between grids 2 and 1, does not vary when the bias on grid 4 is altered.

b) The mutual conductance of grid 1 with respect to grid 2 is not affected by the bias on grid 4.

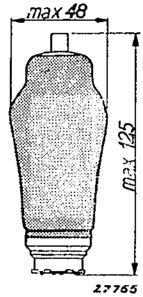

Fig. 1
Dimensions in mm.

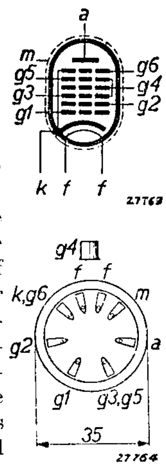

Fig. 2
Arrangement of electrodes and base connections.

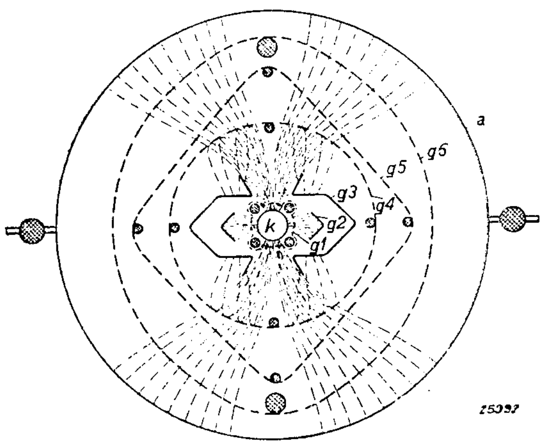

Fig. 3
Cross-section of the system of electrodes in the EK 3, showing the electron streams. The two bunches to left and right serve to generate the oscillation. The oscillator voltage thus occurs on grid 1 and the two streams flowing upwards and downwards are modulated by this voltage. The oscillator section is surrounded by a screen having in it two slots through which the bunches of electrons are directed; this screen is maintained at a positive potential and functions as a third octode grid. Electrons leaving the oscillator section are deflected to a certain extent before they reach the 4th grid. Any electrons that may be repelled back cannot re-enter the oscillator section but return to the screen surrounding the oscillator.

c) The mutual conductance of grid 4 with respect to grid 2 may be entirely ignored. Interference due to undesired coupling between the input circuit and the oscillator is thus avoided; coupling of this kind will often set up an oscillation in the input circuit of the valve as well as relaxation oscillations caused by frequency drift.

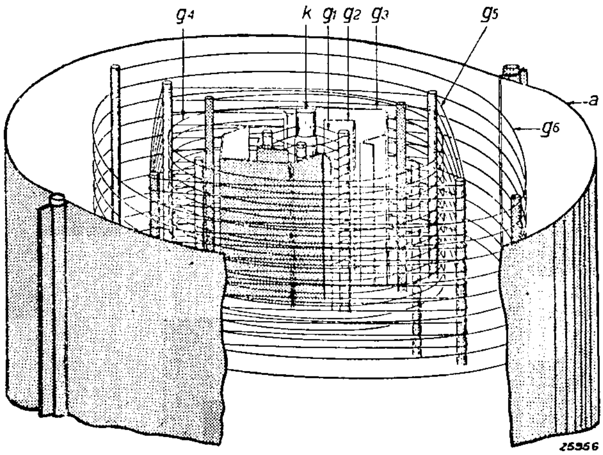

Fig. 4
Details of construction of the 4-channel octode.

The oscillator anode consists of two V-shaped plates and the electron streams directed towards these are held by them, variations in the direct voltage on grid g_3 being prevented from influencing the oscillator unit in any way. The short path of the electrons from the cathode to the auxiliary anode plates ensures very short transit-times in the oscillator section; this effect is so pronounced that the oscillator conductance corresponds to the statically measured slope, even at very short wavelengths.

The static conductance of grid 1 with respect to grid 2 is extremely high, being 4 mA/V at the threshold of oscillation, for which reason the coupling of the components in the oscillatory circuit may be fairly loose; the valve capacitances then only play a very small part in the detuning of the oscillator frequency. Measures have been taken in the design of the valve to reduce the inductive effect (electronic coupling between grids 1 and 4) and the amount of interference met with under this head is extremely small. A capacitor in series with a resistor is connected between grids 1 and 4, the function of the resistor being to make the phase angle of the alternating voltage, as applied to grid 4 through the capacitor, exactly equal to that of the induced voltage arising from the transit time of the electrons passing from grid 1 to grid 4; the conversion amplification at the lower end of the different wave-

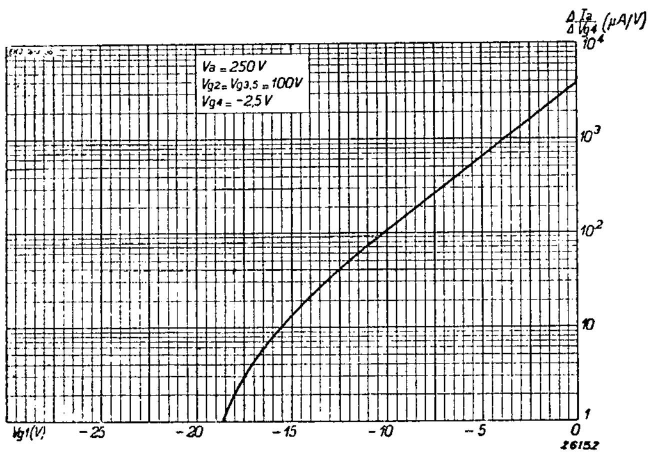

Fig. 5
Conversion of the 4th grid as a function of the direct voltage on grid 1

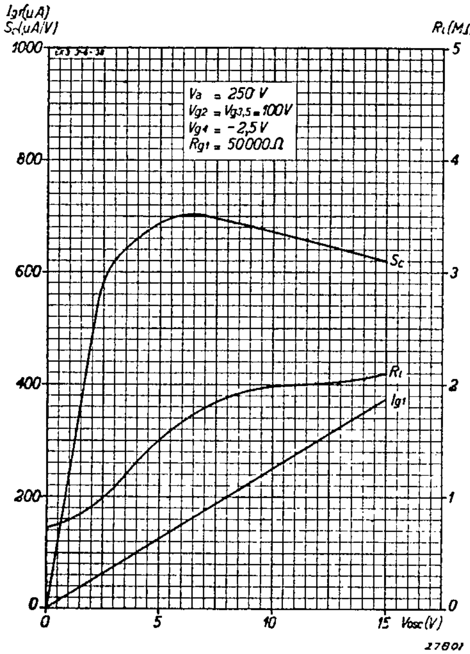

Fig. 6
Internal resistance, conversion conductance and oscillator-grid current as a function of the oscillator voltage when a grid leak of 50,000 ohms is used.

ranges is hardly influenced at all by the effect in question.

The input impedance of the EK 3 in the short-wave bands is very high in comparison with the impedance of the normal receiver circuit, and its effect on the amplification may therefore be ignored. At a wavelength of 14 metres the impedance is about 60,000 ohms. The input capacitance is different for every value of control voltage applied to the grid, because variations are produced in the density of the space charge in front of the grid and these variations tend to detune the circuit coupled to the grid and reduce the sensitivity of the receiver. Furthermore, the R.F. signal in this case does not occur at the centre of the resonance curve and the amplification of the sidebands is not uniform; the resultant asymmetry tends to cause considerable distortion in the detector.

In the EK 3 such capacitive variations are very small, namely only 0.2 μμF, and the consequent detuning effect is only slight, in any case within the limits for the normal broadcast bands.

If a better cross-modulation characteristic is required it should be noted that the conductance of the EK 3 drops less sharply when a control voltage is applied to the 4th grid.

The high conductance of the oscillator unit and increased conversion conductance necessitate a high power cathode and the heater current is accordingly well above 200 mA, being actually 0.6 A; this valve cannot therefore be used in A.C./D.C. receivers, for which purpose a special valve with a 200 mA filament for series operation has been developed.

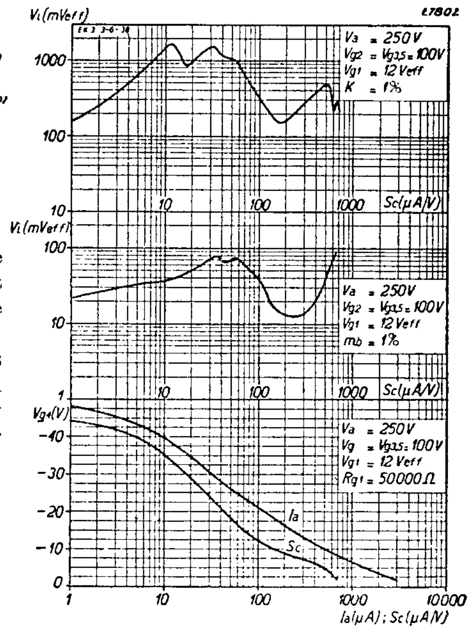

Fig. 7
Upper diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % cross-modulation.
Centre diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % modulation hum.
Lower diagram. Anode current and conversion conductance as a function of the bias on grid 4.

HEATER RATINGS

Heating: indirect, A.C., parallel supply.

Heater voltage	V_f = 6.3 V
Heater current	I_f = 0.6 A

CAPACITANCES

C_{ag4}	< 0.07 μμF	C_{g1g4}	= 1.1 μμF
C_a	= 16.5 μμF	C_{g2}	= 8.6 μμF
C_{g1}	= 14 μμF	C_{g4}	= 15.2 μμF

OPERATING DATA: EK 3 employed as a frequency-changer for "all-wave" reception

Anode voltage	V_a	= 250 V		
Screen-grid voltage	$V_{g3,5}$	= 100 V		
Oscillator-anode voltage	V_{g2}	= 100 V		
Oscillator grid leak	R_{g1}	= 50,000 ohms		
Oscillatory voltage, grid 1	V_{osc}	= 12 V_{eff}		
Oscillator-grid current	I_{g1}	= 300 μA		
Cathode resistor	R_k	= 190 ohms		
Bias, grid 4	V_{g4}	= —2.5 V [1]	—38 V [2]	—42 V [3]
Anode current	I_a	= 2.5 mA	—	—
Screen-grid current	$I_{g3,5}$	= 5.5 mA	—	—
Oscillator-anode current	I_{g2}	= 5 mA	—	—
Conversion conductance	S_c	= 650	6.5	3 μA/V
Internal resistance	R_i	= 2	> 10	> 10 M ohms
Mutual conductance, grid 1 with respect to grid 2 (V_{osc} = 0)	S_{g1g2}	= 4 mA/V	—	—
Direct current, oscillator anode at threshold of oscillation (V_{osc} = 0)	I_{g2}	= 18 mA	—	—

[1]) Without control
[2]) Conversion conductance reduced to one-hundredth of uncontrolled value
[3]) Extreme limit of control

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V
Anode dissipation	W_a	= max. 1 W
Screen voltage in cold condition	$V_{g3,5o}$	= max. 550 V
Screen voltage	$V_{g3,5}$	= max. 150 V
Screen dissipation	$W_{g3,5}$	= max. 1 W
Oscill. anode voltage in cold condition	V_{g2o}	= max. 550 V
Oscill. anode voltage	V_{g2}	= max. 150 V
Oscill. anode dissipation	W_{g2}	= max. 1 W
Cathode current	I_k	= max. 23 mA
Grid voltage at grid current start (I_{g4} = + 0.3 μA)	V_{g4}	= max. —1.3 V
Resistance in circuit of grid 4	R_{g4k}	= max. 3 M ohms
Resistance in circuit of grid 1	R_{g1k}	= max. 100,000 ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	max. 50 V

Because of the steep slope of the oscillator section it is not a difficult matter to establish and maintain the oscillation; the grid leak can therefore be connected to the cathode. The triode unit also oscillates readily and the reaction may with advantage be fairly loose; over-oscillation or squegging will then not occur. A grid leak of 50,000 ohms with a grid capacitor of 50 μμF is recommended and will serve for all wavelengths.

In the EK 3 the inductive effect is counteracted by a form of compensation between grids 1 and 4, to which end it is necessary for the oscillator voltage at the lower end of the short-wave range to be 12 V (effective), (300 μA grid current passes through the 50,000 ohm grid leak). On other wavelengths the oscillator voltage will, of course, be different and the compensation not quite so complete, but outside the short-wave range the inductive effect is so slight that it may otherwise be ignored.

The principle of electron bunching ensures that frequency drift is kept as low as possible; only the potential of the 3rd grid has any effect on the capacitance of the first, but this is to be expected, as the former surrounds the latter. If frequency drift is to be minimized the voltage on the screen ($V_{g3,5}$) must be stabilized by means of a potential divider passing a fairly considerable current; for practical purposes, however, there is a limit to this stabilization of the screen voltage. A useful method of eliminating any residual frequency drift consists in coupling the oscillator circuit to the anode circuit of the triode. Capacitive variations in the 1st grid then have less effect upon the tuning, provided that the reaction is not too tight, since the grid capacitance is induced in the oscillator circuit by way of this coil. This demonstrates clearly the importance of the high mutual conductance of this valve, since the coupling may be made extremely loose.

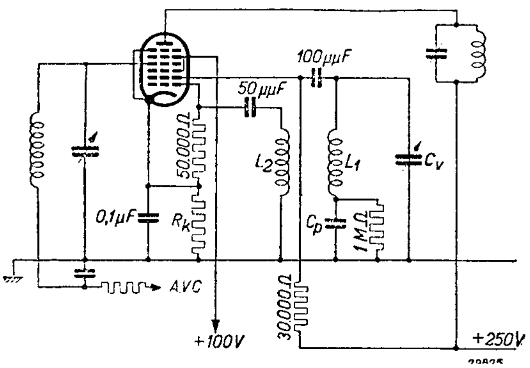

Fig. 8
Circuit diagram showing the oscillatory circuit in the oscillator-anode circuit of the EK3, with the anode fed through a resistor of 30,000 ohms. The oscillator circuit is not accessible to the direct voltage.

The circuit to be recommended from the point of view of frequency drift is that shown in Fig. 8, in which the oscillator circuit is not coupled directly to the anode circuit but by means of a capacitor of 100 μμF. In this way the direct voltage of 100 V does not reach the plates of the tuning capacitor. The circuit is a simple one, but it has the drawback that it is damped by the feed resistor of 30,000 ohms, whereas damping of this circuit is the very thing to be avoided, since:

1) the coupling in the short-wave range should preferably be as loose as possible to avoid frequency drift;

2) on long waves extra damping is often provided in series with the padding capacitor on medium waves, expressly to prevent parasitic oscillation. In the great majority of cases the circuit depicted in Fig. 8 will present no difficulties.

If a padding capacitor C_p is connected in series with the oscillator coil (on the medium and long wave ranges), this should actually be bye-passed by a high value resistor, to prevent a direct voltage from occurring across the tuning capacitor C_v.

Another method of feeding the oscillator anode is shown in Fig. 9, where the voltage is applied through the oscillator coil; the padding capacitor then serves simultaneously to block the voltage from the variable capacitor C_v. This circuit also has a disadvantage, in that extra contacts are required on the wave-change switch for connection to the padding capacitor C_p; on the other hand, the damping of the oscillator circuit is not so heavy as in the circuit in Fig. 8. The latter, in which 5 turns of wire are used for the reaction coil, grids 3 and 5 being fed through a resistor, has given an actual measured frequency-drift value of only 4.5 kc/s at 15 m, this measurement being taken with control applied to the 4th grid, of from —2 to —20 V, in other words, under extremely adverse conditions. When the voltage for the screen $V_{g3,5}$ is taken from a potential divider the frequency drift is even less.

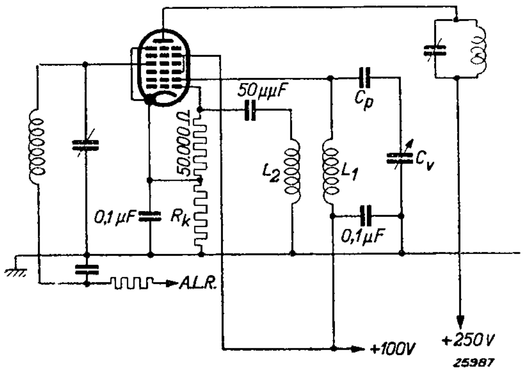

Fig. 9
Circuit diagram of oscillatory circuit in the oscillator-anode circuit, this anode being fed through the coil. The padding capacitor also serves to isolate the variable capacitor C_v from the direct voltage.