ECH 21 triode heptode

The ECH 21 is a variable-mu triode-heptode intended for A.C. supply. The two electrode systems employ a common cathode, consuming approximately 2.1 W.

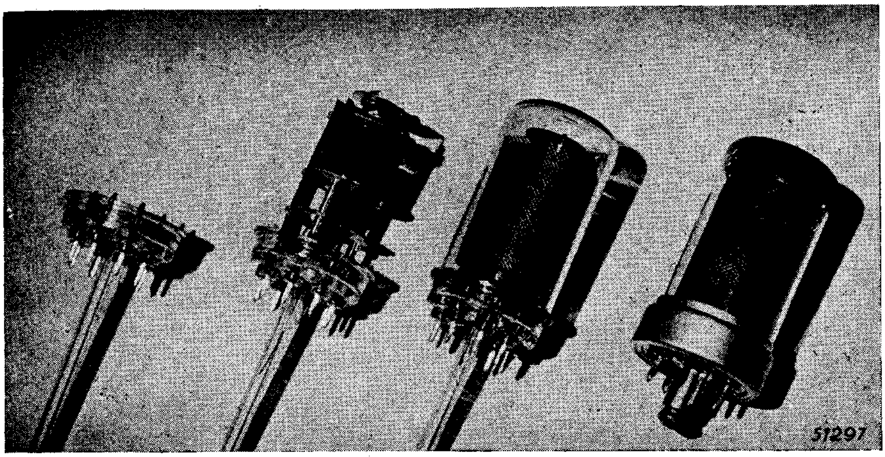

Fig. 1
Four stages in assembly of the triode-heptode all-glass valve ECH 21.

The ECH 21 is recommended primarily as a frequency changer and as such has the following advantages:

a) *Mixer section constructed as heptode*
The fifth grid of the heptode section is a suppressor grid, to neutralize any adverse effects of secondary emission from the screen and anode. It is therefore possible to apply sliding screen grid voltage, without affecting the internal resistance of the valve; in other words, the screens may be fed from the source of anode voltage through a series-resistance. This not only saves the use of another resistance, but also saves current, in that no potentiometer network is required. The suppressor also ensures a low noise level, since the 4th grid emits no secondary electrons.

b) *High mutual conductance.*
750 μA/V at low anode current (3 mA).
This relation between the slope and the anode current is again an advantage from the aspect of noise.

c) *Low cross modulation.*
This is ensured by feeding the screen through a series-resistance.

d) *Low frequency drift on short waves.*
Due to the very small amount of frequency drift, it is possible to control very effectively the mutual conductance in the short wave range. At a wavelength of 15 m and employing a tuning capacitance of 50 pF in the oscillator circuit, the drift at maximum control is less than 1.5 kc/s, provided the inductance effect is suppressed as much as possible, e.g. by means of a compensating condenser.

e) *The slope of the triode is very high at the point where oscillation starts* (3.2 mA/V). Oscillation is accordingly reliable, even under the most unfavourable conditions.

f) *Very steep grid current characteristic of the triode section.*
"Squegging-oscillation" is easily avoided and more latitude is thus provided in the choice of grid condenser and leak.

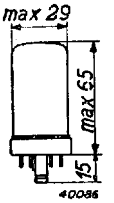

Fig. 2
Dimensions in mm.

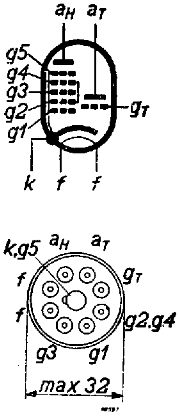

Fig. 3
Order of connection of the electrodes.

In the ECH 21 the grid of the triode is not shorted to the 3rd grid of the heptode as in the ECH 3; each grid has its own separate terminal and the range of application of the valve is accordingly very much greater. Its uses as mixing valve have already been mentioned; in this case the grids concerned are interconnected. When the grids are not joined the heptode section can be employed as a variable-mu I.F. amplifier and the triode part as resistance-capacitance (R—C) coupled A.F. amplifier. It is then of course essential to avoid any capacitive and / or inductive coupling between the two systems, and the design of the ECH 21 ensures this to a very high degree. The possibility of employing this valve as I.F. and A.F. amplifier is an outstanding feature, since in the same series of valves a double diode output pentode (EBL 21) can be used with it. In this way a superheterodyne receiver employing only three valves can be made to have the same characteristics as a normal 4-valve set; for instance, the receiver may be equipped with two ECH 21 valves and one EBL 21, giving a very high degree of sensitivity; or. if desired, normal sensitivity, with the surplus A.F. gain diverted to provide good A. F. feedback; or alternatively, to permit of a slight reduction in the gain, as in low-priced receivers where coils without trimmers are employed.

Then again, the ECH 21 provides a good solution in the matter of gramophone amplification in simple receivers, since the output valve is then preceded by an A.F. stage, guaranteeing ample sensitivity towards the pickup signal.

In this circuit one point must however be watched: the heptode and triode sections of the valve share a common cathode, so that if the I.F. amplification is controlled (heptode side) the cathode current drops. At the same time this current determines the grid bias of the A.F. side and this potential is accordingly reduced when the control voltage increases. This is, of course, not desirable and can be avoided in various ways, a very economical method being the one illustrated in Fig. 4. The cathodes of all valves are connected to chassis and the cathode-resistances with their appropriate decoupling condensers are therefore not required. The grid bias for the A.F. amplifier and output valve is then obtained by means of resistances (R_1 and R_2) in the negative feed line. This leaves bias to be found for the mixer and I.F. valves, as well as the delay voltage for the automatic gain control, and for this purpose a negative potential is applied to the anode of the A.G.C. diode. This potential is also carried across the A.G.C. system to the grids of the valves to be controlled. Since in this case the grid bias of the I.F. valve and that of the frequency changer are of the same value as the delay voltage, a compromise has to be found between the most suitable A.G.C. delay voltage and the initial voltage of the controlled valves. The circuit III on page 68 illustrates this principle, employing the UCH 21 and UBL 21 valves.

If the requirements of the receiver are on a higher level, this arrangement will naturally not be used, and steps will be taken to ensure the best possible value for the A.G.C. voltage. For example, the voltage drop across the cathode resistance of the output valve may be employed, this potential being applied to the grids of the controlled valves which in this instance will require a cathode resistance. In order to prevent the anode current of the triode section of the second ECH 21 from being affected by the control, the potentiometer R_7 and R_8 (see Fig. 5) is so arranged that the current flowing through it passes also through the cathode resistance R_2. The latter resistance then carries the constant current in question, as well as the anode current from the triode section, which is also fairly constant, and the control then affects only the relatively small anode current in the heptode section. This means that the anode current on the triode side is practically independent of the control exercised on the heptode. In this circuit the grid voltage of the triode fluctuates under maximum control of the heptode between — 2.2 V and —2.9 V, which is quite permissible.

The fact that the third grid of the heptode and the control grid of the triode have each their own separate connections further makes it possible to use the ECH 21 as pre-amplifier and phase inverter, preceding a push-pull output stage. In this case the two sections of the valve are employed as resistance-capacitance coupled A.F.amplifier. This arrangement is not suitable for driving push-pull amplifiers running into grid current, but the range of application of the normal type of push-pull amplifier without grid current is so extensive that this feature of the ECH 21 is sufficiently important. One or other of the two available valve systems must in any case be employed for A.F. amplification and for this purpose we select the heptode, seeing that this provides the greater amount of gain. The triode need then serve only for inversion of the phase of the voltage thus obtained, for which purpose a single time of amplification is sufficient. Feedback is obtained by returning a portion of the anode voltage to the grid of the same valve.

The theoretical circuit is shown in Fig. 6. The voltage V_i derived from either a diode or a gramophone pickup is applied across the points A and B. A coupling resistance of 200,000 Ohms is included in the anode circuit of the heptode. The screen grids are fed from the 250 V line through a resistance of 0.25 M Ohms. The A.F. gain factor on the heptode side is then about 100 without control, so that the alternating voltage (V_{01}) applied to the grid of the first output valve is 100 times as great as the input voltage V_i. Furthermore, the alternating voltage across the resistance R_1 is applied to the grid of the triode section across a resistance R_4 of 1 MOhm. Due to the resistances R_5 and R_4, the voltage on the grid in question is about one third of the value of the original alternating voltage.

A portion of the resultant potential across R_2 is used for feedback purposes, this being taken through R_5 to

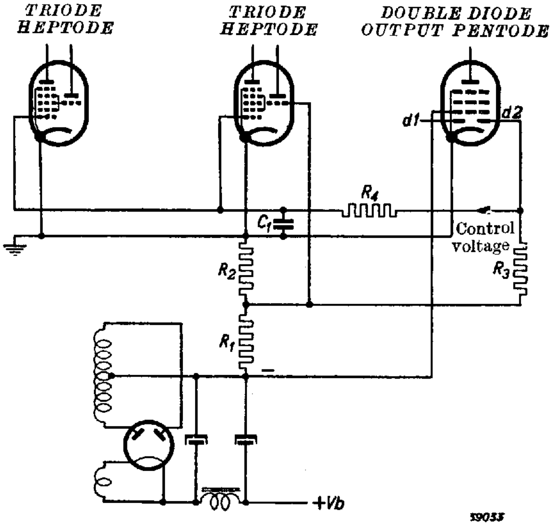

Fig. 4

Circuit details showing method of obtaining grid bias and automatic gain control, employing the ECH 21 as I.F. and A.F. amplifier with R-C coupling (economical compromise). The voltage drop across the resistances R_1 and R_2 in the negative lead is employed as grid bias for the output valve and I.F. amplifier triode. Part of this voltage is taken by way of the A.G.C.system to the grids of the controlled valves. In this circuit arrangement the voltage obtained is a compromise between the optimum A.G.C. delay voltage and the initial voltage of the controlled valves.

the grid of the triode section and thus superimposed on the existing alternating voltage. In this way the voltage across R_2 as applied to the grid of the second output valve is practically the same as that across R_1, but 180° out of phase. In absence of control on the valve, this arrangement produces a potential of 10 V for each output valve, with 0.8 % distortion, which is quite sufficient for modulation of two high-conductance EL 6 valves in a push-pull circuit. This type of output circuit can be used to advantage in high-class receivers, and the more so since the diodes of the EBL 21 can then be employed in a three-diode circuit, which is also well-known for the very slight degree of distortion it introduces.

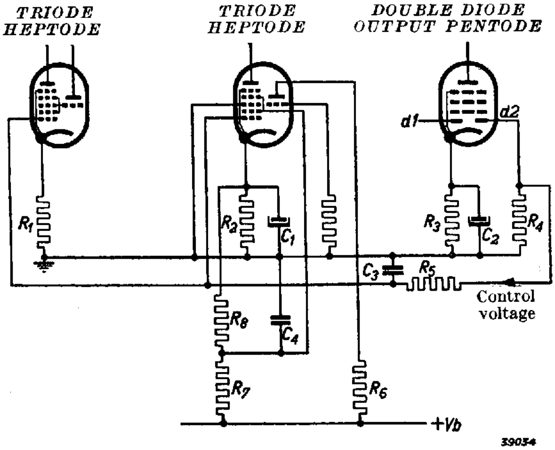

Fig. 5
Circuit diagram showing method of obtaining grid bias and automatic gain control when using the ECH 21 and EBL 21: the delay voltage for the AGC is now adjusted to the correct value, employing the voltage drop across the cathode resistance R_3 of the output valve. The current flowing through the potentiometer for the screen feed also passes through the cathode resistance of the second ECH 21 and the drop across the latter resistance (R_2) is therefore practically independent of the control on the heptode.

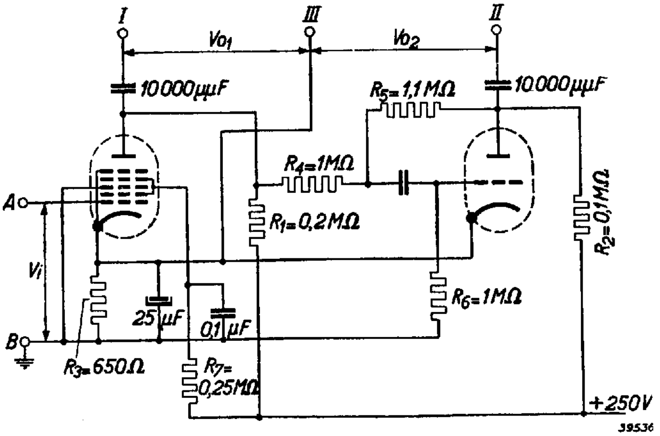

Fig. 6
Circuit diagram of the ECH 21 employed as A.F. amplifier and phase inverter preceding a push-pull output stage; the output voltages Vo_1 and Vo_2 are exactly in counter-phase and are applied to the grids of two output valves. For clarity, the triode and heptode sections are depicted as separate valves.

HEATER RATINGS

Feed: indirect, parallel on A.C.

Heater voltage	V_f	= 6.3 A
Heater current	I_f	= 0.33 A

CAPACITANCES

a) Heptode section:

$C_{g1} = 6.5$ pF $C_{g1g3} < 0.3$ pF
$C_a = 8.0$ pF $C_{g3} = 8$ pF
$C_{ag1} < 0.002$ pF $C_{g1f} < 0.007$ pF

b) Triode section:

$C_g = 3.8$ pF $C_{ak} = 1.6$ pF
$C_a = 3.1$ pF $C_{ag} = 1.1$ pF
$C_{gk} = 2.7$ pF $C_{gf} < 0.1$ pF

c) Between heptode and triode, and both combined:

$C_{gTg1H} < 0.1$ pF $C_{(gT+g3)g1H} < 0.35$ pF
$C_{(gT+g3)} = 12.3$ pF $C_{(gT+g3)aH} < 0.1$ pF

OPERATING DATA, HEPTODE SECTION USED as frequency changer (third grid connected to control grid of triode)

Anode and supply voltage	$V_a = V_b$	= 250 V		
Screen grid resistance	$R_{(g2+g4)}$	= 24,000 Ohms		
Cathode resistance	R_k	= 150 Ohms		
Grid leak, third grid and triode grid	$R_{(g3+gT)}$	= 50,000 Ohms		
Current of 3rd grid and triode grid	$I_{(g3+gT)}$	= 190 μA		
Grid bias	V_{g1}	= —2[1]	—24.5[2]	V
Screen voltage	$V_{(g2+g4)}$	= 100	250	V
Anode current	I_a	= 3	—	mA
Screen current	$I_{(g2+g4)}$	= 6.2	—	mA
Internal resistance	R_i	= 1.4	>3	M Ohm
Conversion conductance	S_c	= 750	7.5	μA/V
Equivalent noise resistance	R_{aeq}	= 55,000	—	Ohms

[1] Valve not controlled.
[2] Conversion conductance controlled to 1/100.

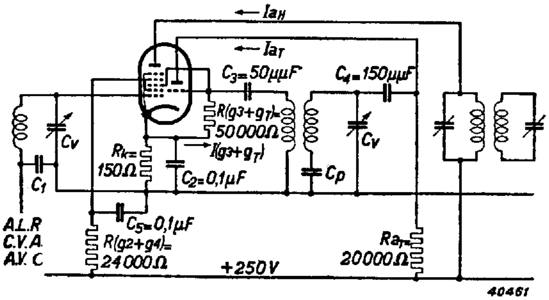

Fig. 7
Circuit diagram of the ECH 21 employed as frequency changer.

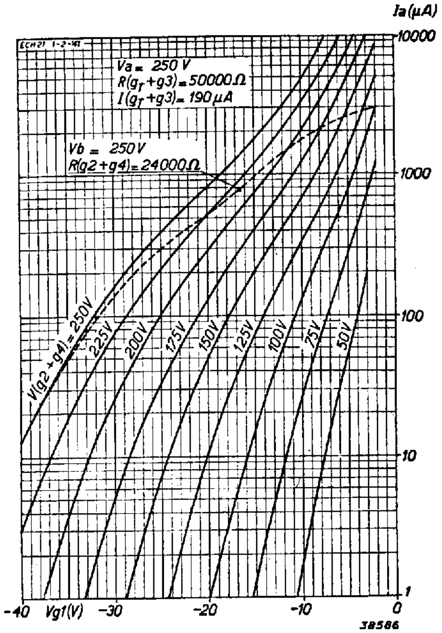

Fig. 8
Anode current of the heptode section as a function of grid bias, at an anode potential of 250 V, with screen voltage as parameter (valve used as frequency changer). The broken line refers to the conditions when the screen is fed across a resistance of 24,000 Ohms.

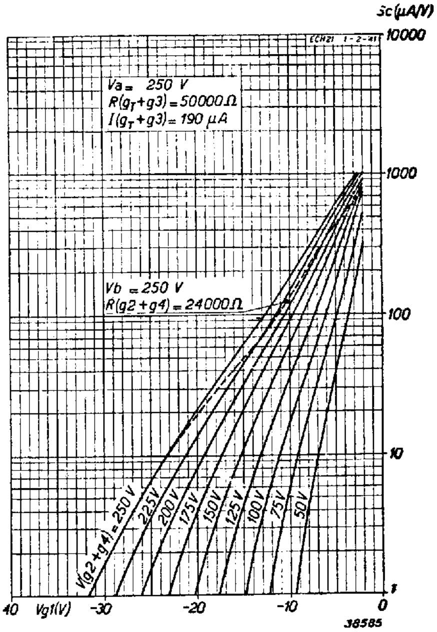

Fig. 9
Conversion conductance Sc as a function of grid bias Vg_1, at an anode potential of 250 V, with screen voltage as parameter. The broken line refers to conditions for screen fed through a resistance of 24,000 Ohms.

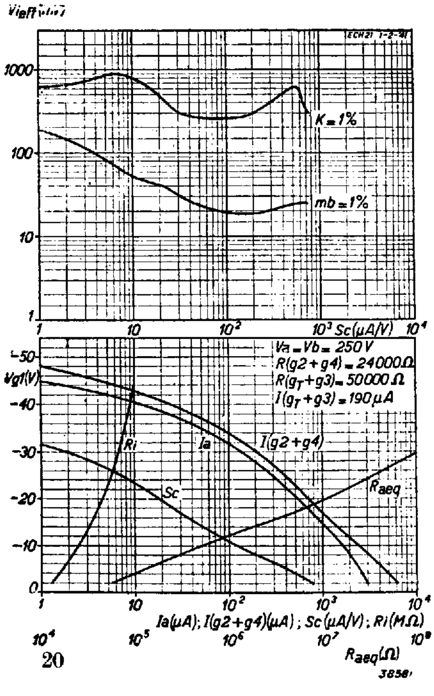

Fig. 10
At $Va = Vb = 250$ V and $R\ (g_2 + g_4) = 24{,}000$ Ohms:

Upper diagram; Highest permissible effective value of R.F. alternating voltage for cross modulation of 1 % ($K = 1$ %) and for 1 % modulation hum ($mb = 1$ %), both in respect of the interfering signal at the grid, as a function of the conversion conductance.

Lower diagram; Anode current Ia, screen current $I\ (g_2 + g_4)$, conversion conductance Sc, internal resistance Ri and equivalent noise resistance $Raeq$, as a function of the grid bias Vg_1.

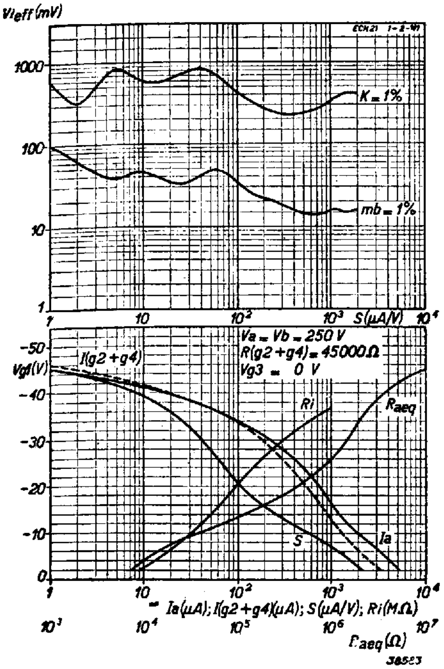

Fig 14
The heptode section used as I.F. amplifier at $Va = Vb = 250$ V, with the screen fed across a resistance of 45,000 Ohms.

Upper diagram. Highest permissible effective value of R.F voltage at 1 % cross modulation ($K = 1$ %) and with 1 % modulation hum ($mb = 1$ %), both in respect of the interfering signal on the grid, as a function of the mutual conductance.

Lower diagram. Anode current *Ia*, screen grid current $I(g_2 + g_4)$, mutual conductance *S*, internal resistance *Ri* and equivalent noise resistance *Raeq*, as a function of grid bias.

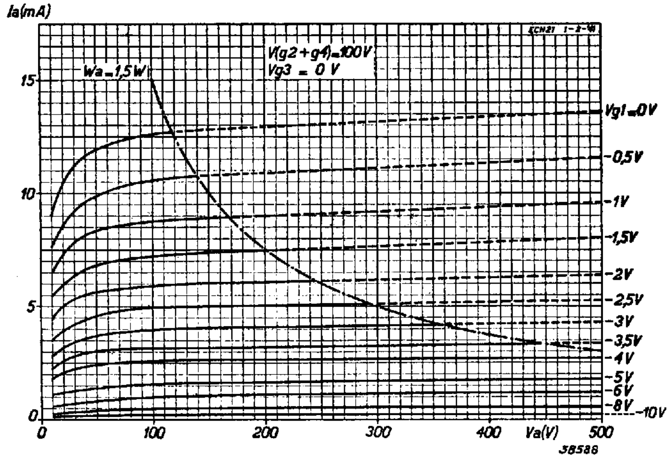

Fig. 15
Anode current as a function of anode voltage, with grid bias as parameter, at $V(g_2 + g_4) = 100$ V and $Vg_3 = 0$ V.

STATIC RATINGS: TRIODE SECTION

Anode voltage	V_a	= 100	V
Grid bias	V_g	= 0	V
Anode current	I_a	= 12	mA
Mutual conductance	S	= 3.2	mA/V
Gain factor	μ	= 22	

OPERATING DATA: TRIODE SECTION used as oscillator valve (triode grid connected to 3rd grid of the heptode section)

Supply voltage	V_b	= 250	V
External anode resistance	R_a	= 20,000	Ohms
Grid leak	$R_{(gT+g3)}$	= 50,000	Ohms
Current through grid leak to be adjusted to	$I_{(gT+g3)}$	= 190	μA
Anode current	I_a	= 4.5	mA
Effective mutual conductance	S_{eff}	= 0.55	mA/V

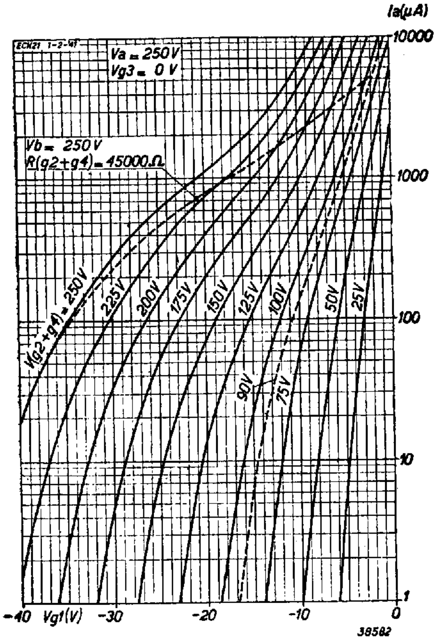

Fig. 12
The heptode section employed as I.F. amplifier. Anode current as a function of grid bias at $Va = 250$ V and $Vg_3 = 0$ V with screen voltage as parameter.

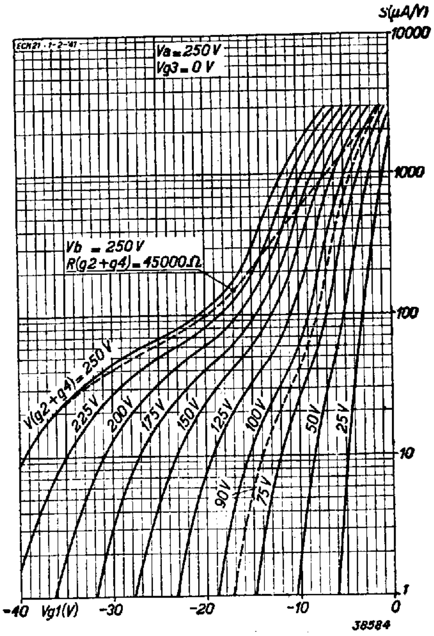

Fig. 13
Mutual conductance as a function of grid bias of the heptode section at $Va = 250$ V and $Vg_3 = 0$ V, with screen voltage as parameter.

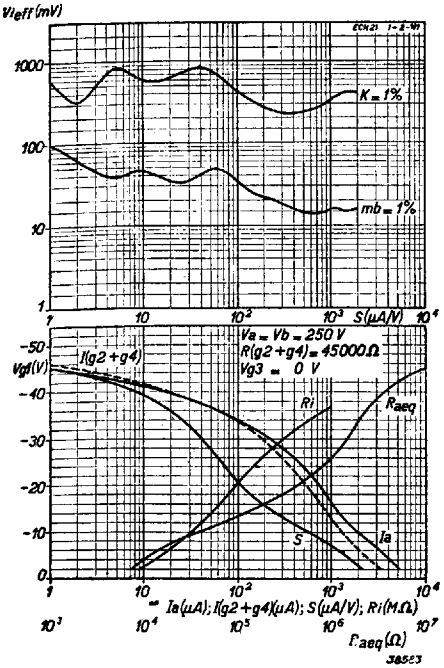

Fig 14
The heptode section used as I.F. amplifier at $Va = Vb = 250$ V, with the screen fed across a resistance of 45,000 Ohms.
Upper diagram. Highest permissible effective value of R.F voltage at 1 % cross modulation ($K = 1$ %) and with 1 % modulation hum ($mb = 1$ %), both in respect of the interfering signal on the grid, as a function of the mutual conductance.
Lower diagram. Anode current *Ia*, screen grid current $I(g_2 + g_4)$, mutual conductance *S*, internal resistance *Ri* and equivalent noise resistance *Raeq*, as a function of grid bias.

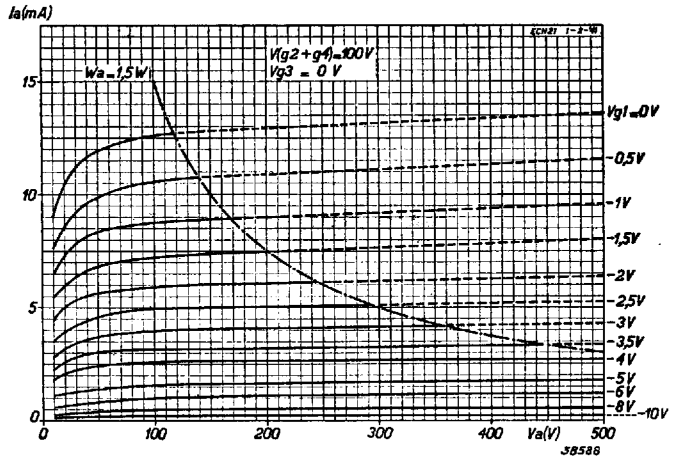

Fig. 15
Anode current as a function of anode voltage, with grid bias as parameter, at $V(g_2 + g_4) = 100$ V and $Vg_3 = 0$ V.

OPERATING DATA: TRIODE SECTION used as A.F. amplifier with R-C coupling (triode grid not connected to third grid of heptode)

Supply voltage . . .	V_b =	250		250		250		V
External anode res. .	R_a =	0.2		0.1		0.05		MOhm
Grid bias	V_g =	—2	—4	—2	—4	—2	—4	V
Anode current. . . .	I_a =	1.0	0.9	2	1.7	3.5	3	mA
A.C. output voltage .	V_{oeff} =	7.5	7.5	7.5	7.5	7.5	7.5	V
Total distortion . . .	d_{tot} =	2.5	2.0	2.1	1.6	2.1	1.5	%
Voltage gain	$\frac{V_{oeff}}{\lvert V_{g1eff}}$ =	13	12	14	13	14	13	

OPERATING DATA FOR THE ECH 21 used as phase inverter for the modulation of a balanced output stage

(Arrangement with feedback, see Fig. 16: triode grid not connected to 3rd grid of heptode.)

Supply voltage	V_b	= 250	V
External anode resistance: heptode section	R_{aH}	= 0.2	MOhms
External anode resistance: triode section	R_{aT}	= 0.1	MOhms
Screen grid feed resistance.	$R_{(g_2+g_4)}$	= 0.25	MOhms
Cathode resistance	R_k	= 650	Ohms

Neg. control voltage on heptode control grid: . . .	V_R =	0	—5	—10	—15	—20	V
Combined anode current: triode and heptode . . .	$I_{aH}+I_{aT}$ =	2.5	2.45	2.35	2.25	2.15	mA
Screen grid current	$I_{g_2+g_4}$ =	0.75	0.58	0.43	0.32	0.24	mA
A.C. input voltage	V_{g1eff} =	0.10	0.33	0.66	1.0	1.6	V
Voltage gain:.	$\frac{V_{oeff}}{V_{g1eff}}$ =	100	30	15	10	6	
A.C. output voltage. . . .	V_{oeff} =	10	10	10	10	10	V
Total distortion.	d_{tot} =	0.80	3.70	4.50	6.20	7.50	%

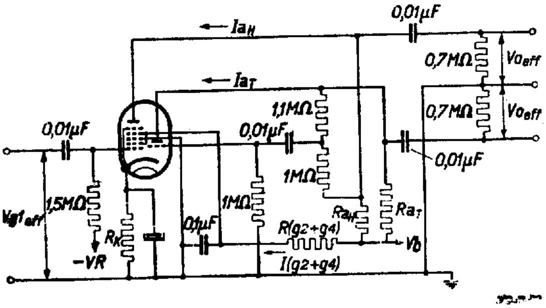

Fig. 16
Circuit diagram of the ECH 21 employed as phase inverter with feedback, to illustrate the above remarks and symbols.

MAXIMUM RATINGS FOR THE HEPTODE SECTION

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V
Anode dissipation	W_a	= max. 1.5 W
Screen voltage in cold condition	$V_{(g2+g4)}$	= max. 550 V
Screen voltage, valve not controlled ($I_a = 3$ mA).	$V_{(g2+g4)}$	= max. 100 V
Screen voltage, valve controlled ($I_a < 1$ mA)	$V_{(g2+g4)}$	= max. 300 V
Screen grid dissipation.	$W_{(g2+g4)}$	= max. 1 W
Cathode current.	I_k	= max. 15 mA
Grid current commences ($I_{g1} = +0.3\,\mu$A)	V_{g1}	= max. —1.3 V
Grid current commences ($I_{g3} = +0.3\,\mu$A)	V_{g3}	= max. —1.3 V
Max. external resistance between grid 1 and cathode	R_{g1k}	= max. 3 MOhms
Max. external resistance between grid 3 and cathode	R_{g3k}	= max. 3 MOhms
Max. external resistance between heater and cathode	R_{fk}	= max. 20,000 Ohms
Max. voltage between heater and cathode (D.C. voltage or effective value of the alternating voltage)	V_{fk}	= max. 50 V

MAXIMUM RATINGS FOR THE TRIODE SECTION

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 175 V
Anode dissipation	W_a	= max. 0.8 W
Grid current commences ($I_g = +0.3\,\mu$A)	V_g	= max. —1.3 V
Max. external resistance in the grid circuit	R_{gk}	= max. 3 M Ohms

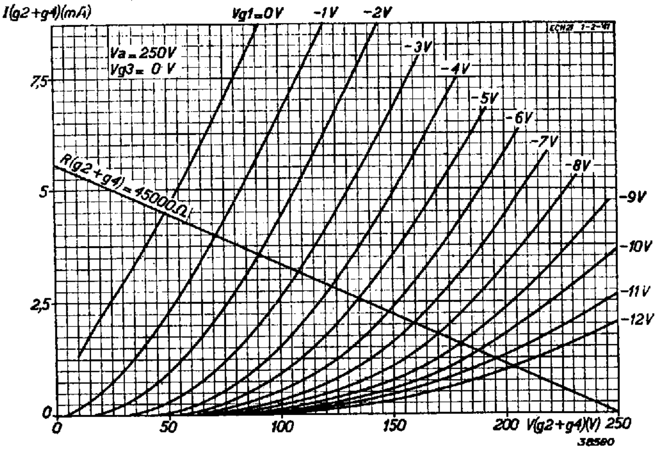

Fig. 17
Screen current as a function of screen voltage at $V_a = 250$ V, $V_{g_3} = 0$ V, with grid bias as parameter.

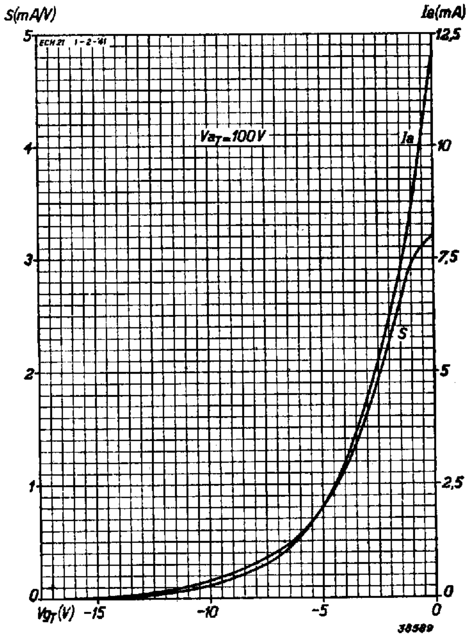

Fig. 18
Anode current and mutual conductance of the triode section as a function of grid bias, at $V_{aT} = 100$ V.