Rectifying valves for amplifiers

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In general, the current and voltage required for an amplifier need to be higher than in the case of radio receivers, and the rectifiers employed, therefore, have to be capable of supplying more power. It is also important that the voltage delivered by the rectifier should remain as constant as possible in spite of wide fluctuations in the load in view of the fact that the output stages of amplifiers are usually of the belanced type as, in that case, the current varies more or less, according to whether a Class B or Class AB circuit is employed.

A low internal resistance of the rectifier is therefore a necessity, which means that the power transformer and choke should be generously proportioned, whilst the internal resistance of the rectifying valve itself should also be low. As is generally known, the internal resistance of gas-filled rectifying valves is very low indeed, since the voltage drop within the valve is constant at almost any value of the current; this voltage drop is actually equal to the arc voltage of the gas-filling, that is, about 13 V.

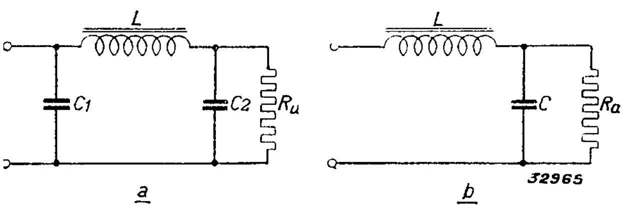

Fig. 1
a) Smoothing circuit commencing with a capacitor.
b) Smoothing circuit in which the first element is a choke.

Uniformity of the voltage on varying loads can be further increased by placing a choke of sufficiently high inductance first in the sequence of the smoothing circuit, instead of a capacitor. The direct voltage obtainable from a given alternating voltage is then certainly slightly lower, but it is at the same time much less dependent on the load. The low internal resistance of the rectifier circuit therefore only comes into its own when the first element in the smoothing circuit is the choke; if a capacitor occupies this position the average value of the direct voltage with a low current rises almost to the peak value of the alternating voltage on the transformer, so that the direct voltage output is actually more dependent on the current delivered than might be concluded from the low internal resistance of the transformer and rectifying valve. The same thing applies when the smoothing circuit commences with a choke of insufficient inductance, only in this case it is due to the smoothing capacitor following the choke; the inductance of the choke must therefore exceed a certain minimum value which can be found very simply by means of the following formula:

$$L > \frac{R_a}{1000},$$

where L is the inductance of the choke in Henries and R_a the resistance of the external load in ohms ($R_a = \frac{\text{direct voltage}}{\text{current delivered}}$).

It follows, then, that the choke must be larger according as the current delivered is less. The loading characteristics of gas-filled rectifying valves show that the voltage varies only very slightly as a result of very wide fluctuations in the current; at low values of the current the voltage does rise rather rapidly, but this is explained by the presence of the smoothing capacitor at the output side of the choke.

In a smoothing circuit commencing with a capacitor the internal resistance of the transformer should not be merely as low as possible, as the current surge passing through the valve during the time that the capacitor is charging then becomes too

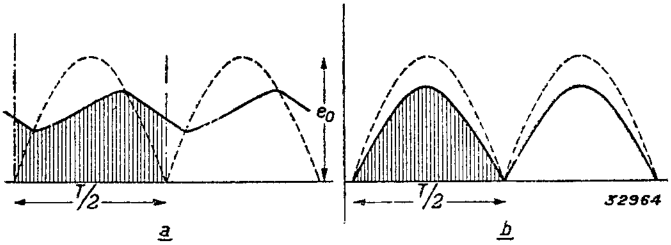

Fig. 2
a) Direct voltage across the reservoir condenser in a full-wave rectifier circuit.
b) Direct voltage across the load resistance when no smoothing circuit or reservoir condenser is used.
In both figures the alternating transformer voltage is shown by a broken line. When the hatched areas in the two figures a) and b) are equal, the average direct voltage in both cases will also be equal.

great; when the choke is the first element in the circuit this does not apply.

For smaller amplifier equipment Philips are now supplying their AX 1 and AX 50, both of which are designed for use with a transformer giving a maximum of 2 × 500 V on no load; the first-mentioned valve delivers 125 mA and the second 250 mA, D.C. The AX 1 is therefore suitable for amplifiers of which the output stage consists of two 4683 or 4694 valves, whilst the AX 50 will operate an amplifier using two 4654 valves (at 425 V) or 4699 valves (at 425 V); for larger amplifiers, half-wave gas-filled rectifying valves are supplied in the transmitting range, e.g., the DCG 1/150 or the DCG 4/4000. Details will be furnished on application.

AX 1 Full-wave gas-filled rectifying valve

The AX 1 is a full-wave gas-filled rectifying valve for use in the smaller class of amplifiers.

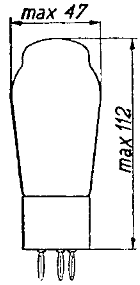

Fig. 1. Dimensions in mm.

FILAMENT RATINGS

Heating: direct, by A.C.

Filament voltage	V_f	= 4.0 V
Filament current	I_f	= 2.4 A

MAXIMUM RATINGS

Secondary (A.C.) voltage of the power transformer on no load	V_{tr}	= max. 2×500 V_{eff}
D.C. output	I_o	= max. 125 mA
Voltage drop in the valve	V_{arc}	= max. 15 V
Capacitance of the capacitor across the input of the smoothing circuit	C	= max. 64 μF

When a capacitor is connected across the input of the smoothing circuit:

The ohmic resistance in the D.C. circuit, with C = 64 μF	R_t	= min. 200 ohms
The ohmic resistance in the D.C. circuit, with C = 32 μF	R_t	= min. 150 ohms
The ohmic resistance in the D.C. circuit, with C = 10 μF	R_t	= min. 100 ohms

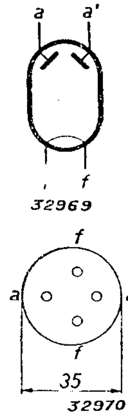

Fig. 2
Arrangement of electrodes and base connections

KEY TO SYMBOLS

The ohmic resistance R_t in the D.C. circuit, when the smoothing circuit commences with a capacitor, constitutes the ohmic resistance of the secondary winding of the transformer together with that of the transformer primary, i.e. $R_t = R_s + n^2 R_p$. If the first component of the smoothing circuit is a choke, however, this resistance value must be augmented to the extent of the ohmic resistance of that choke:
$R_t = R_L + R_s + n^2 R_p$. The voltage delivered may be calculated from the expression: $V_o = 0.45\ V_{tr} - I_o R_t - V_{arc}$, in which V_{tr} is the effective alternating voltage of the secondary winding of the transformer, for example $V_{tr} = 2 \times 500$ V. The inductance of the choke should be at least equal to $\frac{R_a}{1{,}000}$ or $\frac{V_o}{V_i}$ (V_o in volts and I_o in mA), where I_o is taken to be the lowest value occurring; in an amplifier having two output valves in a balanced output stage, this will be the current flowing in the amplifier without excitation. From this it will be seen that with a 12-henry choke, the characteristics begin to flatten out only at I_o = 30 mA approx. At lower current values the loading curves rise steeply, owing to the effect of the smoothing capacitor. A choke having a higher inductance will produce straight characteristics down to lower current values, for instances 42 henries — 10 mA.
Fig. 4 shows the loading characteristics of the AX 1 used in a circuit in which a capacitor is the first smoothing element, and comparison of these with the corresponding curves for a high vacuum valve such as the AZ 4 shows clearly that the former are

very much flatter with a low value of the internal resistance R_t; also that the direct voltage is higher for the same alternating input. The direct voltages obtained from a smoothing circuit in which a capacitor is the first component are, further, higher than those in a circuit containing a choke as the first smoothing element.

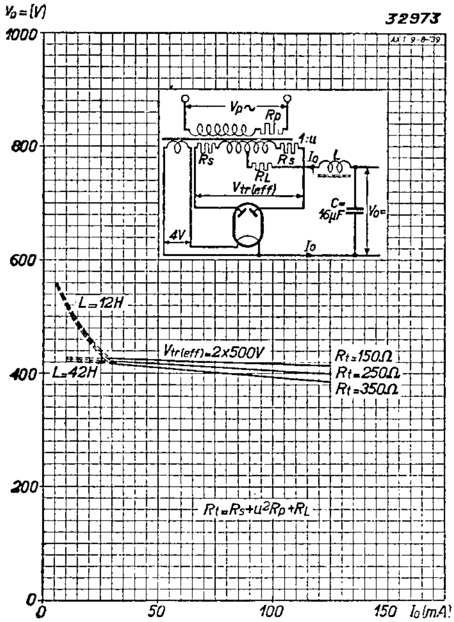

Fig. 3
Loading curves (D.C. voltage as a function of the current delivered) for various values of the resistance $Rt = (R_L + Rs + n^2\ Rp)$, in a smoothing circuit commencing with a choke. The voltages at lower current values wih a choke of 12 or 42 henries are shown by broken lines.

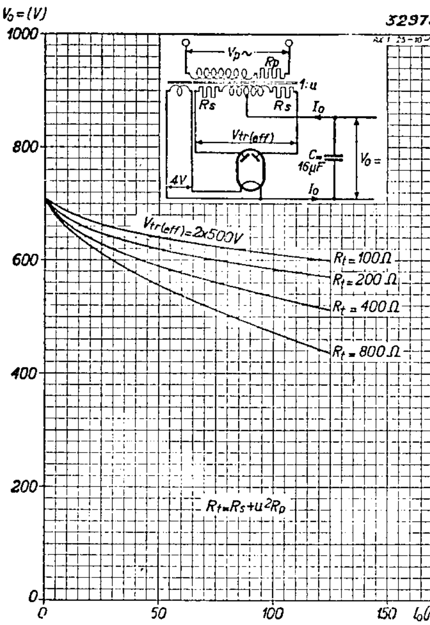

Fig. 4
Loading curves (D.C. voltage as a function of the delivered current) for various values of the total resistance $Rt = (Rs + n^2 Rp)$, in a smoothing circuit commencing with a capacitor.

AX 50 Full-wave gas-filled rectifying valve

The AX 50 is a full-wave gas-filled rectifying valve for use in fairly large amplifier equipment.

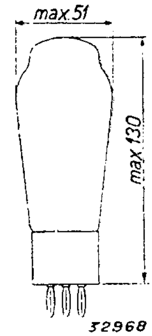

Fig. 1
Dimensions in mm.

FILAMENT RATINGS

Heating: direct by A.C.
Heater voltage . . . . $V_f = 4$ V
Heater current . . . . $I_f = 3.75$ A

MAXIMUM RATINGS

Secondary (A.C) voltage of the power transformer on no load . . . . . . V_{tr} = max. 2×500 V_{eff}
D.C. output . . . . I_o = max. 250 mA
Voltage drop in the valve . . . . . V_{arc} = max. 15 V
Permissible capacitance of capacitor across input of the smoothing circuit: C = max. 64 μF
When a capacitor is connected across the smoothing circuit:
The ohmic resistance in the D.C. circuit, with $C = 64\ \mu$F . . . . . . R_t = min. 200 ohms
with $C = 32\ \mu$F . . . . . . R_t = min. 150 ohms
with $C = 16\ \mu$F . . . . . . R_t = min. 100 ohms

For the correct operation of this valve reference should be made to the notes on the AX 1.

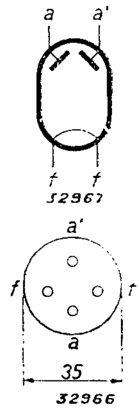

Fig. 2
Arrangement of base connections and electrodes.

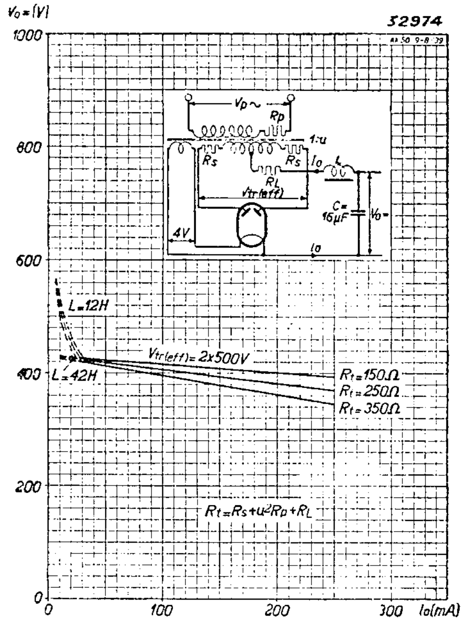

Fig. 3
Loading curves (direct voltage as a function of the output current) with respect to different values of the total resistance $Rt = (R_L + Rs + n^2 Rp)$ in a smoothing circuit in which a choke is the first component. The voltage curves relating to lower values of current for chokes of 12 and 42 H are shown by the broken lines.

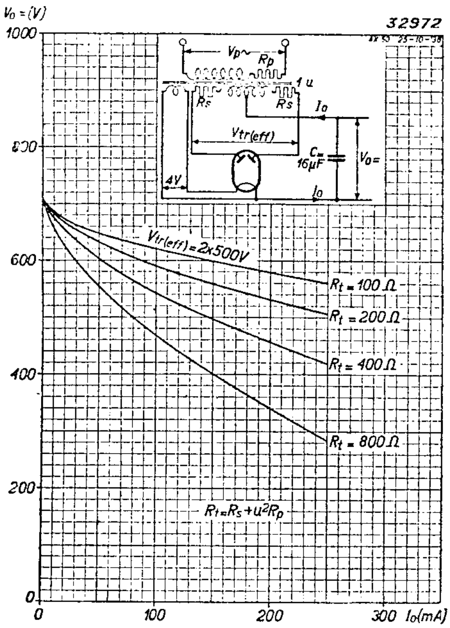

Fig. 4
Loading curves (direct voltage as a function of the output current) for different values of the total resistance $Rt = Rs + n^2 Rp$ in a smoothing circuit in which the first component is a capacitor.

OPERATING DATA: EF 9 used as resistance-coupled A.F. amplifier with controlled amplification

(in amplifiers or A.C. receivers)

Supply voltage *Vb* (V)	Anode coupling res. *Ra* (M ohm)	Screen series res. Rg_2 (M ohm)	Cathode res. *Rk* (ohm)	Control voltage on control grid *VR* (V)	Anode current *Ia* (mA)	Screen current Ig_2 (mA)	Alternating input volts Vi (*Veff*)	Alternating output volts Vo (*Veff*)	Voltage gain $\frac{Vo}{Vi}$	Total distortion. *dtot* (%)
250	0.2	0.8	1,750	0	0.87	0.26	0.028	3	106	0.8
250	0.2	0.8	1,750	—5	0.69	0.21	0.075	3	40	0.8
250	0.2	0.8	1,750	—10	0.55	0.17	0.13	3	23	1.1
250	0.2	0.8	1,750	—18	0.37	0.11	0.27	3	11.6	1.5
250	0.2	0.8	1,750	—25	0.17	0.05	0.45	3	6.7	2.7
250	0.2	0.8	1,750	0	0.87	0.26	0.047	5	106	2.4
250	0.2	0.8	1,750	—5	0.69	0.21	0.125	5	40	2.4
250	0.2	0.8	1,750	—10	0.55	0.17	0.22	5	23	1.9
250	0.2	0.8	1,750	—18	0.37	0.11	0.42	5	11.6	2.4
250	0.2	0.8	1,750	—25	0.17	0.05	0.75	5	6.7	4.4
250	0.2	0.8	1,750	0	0.87	0.26	0.094	10	106	2.7
250	0.2	0.8	1,750	—5	0.69	0.21	0.25	10	40	2.7
250	0.2	0.8	1,750	—10	0.55	0.17	0.43	10	23	3.7
250	0.2	0.8	1,750	—18	0.37	0.11	0.86	10	11.6	4.8
250	0.2	0.8	1,750	—25	0.17	0.05	1.46	10	6.7	8.8
250	0.1	0.4	1,000	0	1.6	0.45	0.035	3	85	0.8
250	0.1	0.4	1,000	—5	1.22	0.36	0.083	3	36	0.8
250	0.1	0.4	1,000	—10	0.92	0.28	0.15	3	20	1.2
250	0.1	0.4	1,000	—18	0.57	0.18	0.33	3	9.2	1.8
250	0.1	0.4	1,000	—25	0.36	0.11	0.55	3	5.5	2.8
250	0.1	0.4	1,000	0	1.6	0.45	0.059	5	85	1.3
250	0.1	0.4	1,000	—5	1.22	0.36	0.14	5	36	1.4
250	0.1	0.4	1,000	—10	0.92	0.28	0.25	5	20	2.1
250	0.1	0.4	1,000	—18	0.57	0.18	0.55	5	9.2	3.1
250	0.1	0.4	1,000	—25	0.36	0.11	0.91	5	5.5	4.8
250	0.1	0.4	1,000	0	1.6	0.45	0.118	10	85	2.5
250	0.1	0.4	1,000	—5	1.22	0.36	0.28	10	36	2.7
250	0.1	0.4	1,000	—50	0.92	0.28	0.49	10	20	4.1
250	0.1	0.4	1,000	—18	0.57	0.18	1.08	10	9.2	6.1
250	0.1	0.4	1,000	—25	0.36	0.11	1.83	10	5.5	9.5

Note. The values for the voltage gain relate to cases where the grid leak of the next valve is 0.7 megohm. The control voltage on the grid must not be interchanged with the grid bias, which consists of the control voltage augmented by the voltage drop across the cathode resistor.