Appendix I

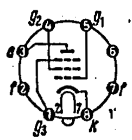
Data Sheets

EL 34
6 CA 7

Endpentode

Verwendung für Kraftverstärker

Power Pentode for Power Amplifier



Oktal

Kolben Nr. 23
Bulb No. 23

Allgemeine Daten / General Data

Heizung / Heating
U_f = 6,3 V
I_f = 1,5 A
Indirekt / Indirect

Kapazitäten / Capacitances
C_{eing} = 15,5 pF
C_{ausg} = 7,2 pF
C_{ag_1} < 1,0 pF
C_{g_1f} < 1,0 pF
C_{kf} = 11 pF

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Betriebsdaten / Typical Operation
Eintakt A / Class A

U_b	=	265	265 V
U_a	=	250	250 V
R_{g_2}	=	2	0 kΩ
U_{g_2}	=	0	0 V
U_{g_1}	=	−14,5	−13,5 V
I_a	=	70	100 mA
I_{g_2}	=	10	14,9 mA
S	=	9,0	11 mA/V
R_i	=	18	15 kΩ
R_a	=	3,0	2,0 kΩ
$U_{g_1\sim}$	=	9,3	8,7 V_{eff}
$N_\sim$	=	8	11 W
k	=	10	10 %
$U_{g_1\sim}$ $N_\sim$ (= 50 mW)	=	0,65	0,5 V_{eff}
$\mu_{g_2g_1}$	=	11	11

Grenzdaten / Maximum Ratings

$U_{a\,kalt}$ = 2000 V
U_a = 800 V
Q_a ($U_{g_1\sim}$ = 0) = 25 W)
Q_a ($U_{g_1\sim}$ > 0) = 27,5 W
$U_{g_2\,kalt}$ = 800 V
U_{g_2} = 425 V
Q_{g_2} = 8 W
I_k = 150 mA
R_{g_1} = 0,7 MΩ*
R_{g_1} = 0,5 MΩ**
U_{fk} = 100 V
R_{fk} = 20 kΩ

* Kl. A und AB

** Kl. B

EL 84
6 BQ 5

Endpentode

Power Pentode

Allgemeine Daten / General Data

Heizung / Heating
U_f = 6,3 V
I_f = 0,76 A
Indirekt / Indirect

Kapazitäten / Capacitances
C_e = 10,8 pF
C_a = 6,5 pF
C_{ag_1} < 0,5 pF
C_{g_1f} < 0,25 pF

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Kenndaten / Characteristics
U_a = 250 V, I_{g_2} = 5,5 mA
U_{g_2} = 250 V, S = 11,3 mA/V
U_{g_1} = −7,3 V, R_i = 40 kΩ
I_a = 48 mA, $\mu_{g_2g_1}$ = 19,5

Betriebsdaten / Typical Operation
Eintakt A / Class A

U_a	=		250		V
U_{g_2}	=		250		V
U_{g_1}	=		−7,3		V
R_k	=		135		Ω
R_a	=		5,2		kΩ
$U_{g_1\sim}$	=	0	0,3	4,3	V_{eff}
I_a	=	48	—	49,5	mA

Grenzdaten / Maximum Ratings

U_a = 300 V
Q_a = 12 W
U_{g_2} = 300 V
Q_{g_2} = 2 W ($U_{g_1\sim}$ = 0)
Q_{g_2} = 4 W ($U_{g_1\sim}$ > 0)
$-U_{g_1}$ = 100 V
I_k = 63 mA
U_{gk} = 100 V
R_{g_1} = 1 MΩ
R_{g_1} = 0,3 MΩ*
R_{fk} = 20 kΩ

* U_{g_1} fest
Fixed grid bias

Fortsetzung ↓

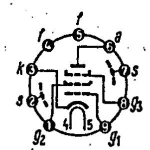
EF 86

NF-Pentode

Verwendung als NF-Verstärker

AF Pentode

AF Amplifier



Noval

Kolben Nr. 6
Bulb No. 6

Allgemeine Daten / General Data

Heizung / Heating
U_f = 6,3 V
I_f = 0,2 A
Indirekt / Indirect

Kapazitäten / Capacitances
C_{ausg} = 5,5 pF
C_{eing} = 4,0 pF
C_{ag_1} < 0,05 pF
C_{g_1f} < 0,0025 pF

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Kenndaten / Characteristics
U_a = 250 V
U_{g_3} = 0 V
U_{g_2} = 140 V
U_{g_1} = −2 V
I_a = 3,0 mA
I_{g_2} = 0,6 mA
S = 2,0 mA/V
R_i = 2,5 MΩ
$\mu_{g_2g_1}$ = 38

Betriebsdaten / Typical Operation
NF-Verstärker / AF Amplifier

U_b	=	200	250	200	250 V
R_a	=	100	100	220	220 kΩ
R_g	=	1	1	1	1 MΩ
R_g'	=	330	330	680	680 kΩ
R_{g_2}	=	0,39	0,39	1	1 MΩ
R_k	=	1	1	2,2	2,2 kΩ
I_k	=	1,7	2,1	0,8	0,9 mA
v	=	106	112	170	180
$U_{a\sim}$	=	40	50	36	46 V_{eff}[1]

[1] Bei k = 5%, der Klirrfaktor ist der Ausgangsspannung etwa proportional

The harmonic distorion is approx. proportional to the output voltage

Grenzdaten / Maximum Ratings

$U_{a\,kalt}$ = 550 V
U_a = 300 V
Q_a = 1 W
$U_{g_2\,kalt}$ = 550 V
U_{g_2} = 200 V
Q_{g_2} = 0,2 W
I_k = 6 mA
R_{g_1} = 10 MΩ[1]
R_{g_1} = 3 MΩ[2]
R_{g_1} = 22 MΩ[4]
U_{fk} (k pos) = 100 V
U_{fk} (k neg) = 50 V
R_{fk} = 20 kΩ[3]

[1] (Q_a < 0,2 W)
[2] (Q_a > 0,2 W)
[4] selbstanlaufend
U_{g_1} only produced by R_{g_1}

[3] In Phasenumkehrstufen max. 120 kΩ
In phase-splitter stages max. 120 kΩ

ECC 83
12 AX 7

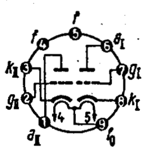
NF-Doppeltriode

Verwendung als NF-Verstärker und Phasenumkehrröhre

AF Twin Triode

AF Amplifier

Phase-splitter



Noval

Kolben Nr. 6

Bulb No. 6

Allgemeine Daten / General Data

Heizung / Heating

U_f = 6,3 V
I_f = 0,3 A
oder
U_f = 12,6 V
I_f = 0,15 A
Indirekt
Indirect

Kapazitäten / Capacitances

$C_{a_I k_I}$ = 0,33 pF
$C_{a_{II} k_{II}}$ = 0,23 pF
$C_{g_I k_I}$ = $C_{g_{II} k_{II}}$ = 1,65 pF
$C_{a_I g_I}$ = $C_{a_{II} g_{II}}$ = 1,60 pF
$C_{g_I f}$ = $C_{g_{II} f}$ < 150 mpF

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Kenndaten / Characteristics

U_a = 250 V S = 1,6 mA/V
U_g = −2,0 V μ = 100
I_a = 1,2 mA R_i = 62,5 kΩ

Betriebsdaten / Typical Operation

NF-Verstärker / AF Amplifier

U_b =	200	250	300	350 V
R_a =	220	220	220	220 kΩ
R_g =	1	1	1	1 MΩ
R_g' =	680	680	680	680 kΩ
R_k =	3,3	2,7	2,2	1,5 kΩ
C_k =	50	50	50	50 µF
I_a =	0,36	0,48	0,63	0,85 mA
v =	56,0	66,5	72,0	75,5
$U_{a\sim}$ =	24	28	36	37 V_{eff}
k =	4,6	3,4	2,6	1,6 %

Grenzdaten / Maximum Ratings

Je System / per section

$U_{a\,kalt}$ = 550 V
U_a = 300 V
Q_a = 1 W
I_k = 8 mA
U_g = −50 V
R_g = 2 MΩ
R_g = 22 MΩ*
U_{fk} = 180 V
R_{fk} = 20 kΩ**

* selbstanlaufend = 22 MΩ
U_{g_1} only produced by R_{g_1} = 22 MΩ

** In Phasenumkehrstufen max. 150 kΩ
In phase-splitter stages max. 150 kΩ

ECC 81
12 AT 7

HF-Doppeltriode

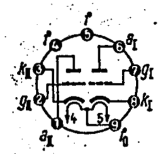
Verwendung als UKW-Oszillator, UKW-Mischröhre und HF-Verstärker

RF Twin Triode

VHF Oscillator

VHF Mixer

RF Amplifier



Noval

Kolben Nr. 6

Bulb No. 6

Allgemeine Daten / General Data

Heizung / Heating

U_f = 6,3 V
I_f = 0,3 A
oder
U_f = 12,6 V
I_f = 0,15 A
Indirekt
Indirect

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Kenndaten / Characteristics

U_a = 250 V
U_{g_1} = −2 V
I_a = 10 mA
S = 5,5 mA/V
μ = 60
R_i = 11 kΩ

Grenzdaten / Maximum Ratings

Je System / per section

$U_{a\,kalt}$ = 550 V
U_a = 300 V
Q_a = 2,5 W
I_k = 15 mA
U_{g_1} = −50 V
R_{g_1} = 1 MΩ
U_{fk} = 90 V
R_{fk} = 20 kΩ

Kapazitäten / Capacitances

C_{g_I} = 2,3 pF
C_{a_I} = 0,45 pF
$C_{a_I g_I}$ = 1,6 pF
$C_{a_I k_I}$ = 0,20 pF
$C_{k_I f}$ = 2,5 pF
$C_{k_I}/(g_I+f)$ = 4,8 pF
$C_{a_I}/(g_I+f)$ = 1,9 pF
$C_{a_I a_{II}}$ < 0,4 pF
$C_{a_I g_{II}}$ < 0,07 pF
$C_{g_{II}}$ = 2,3 pF
$C_{a_{II}}$ = 0,35 pF
$C_{a_{II} g_{II}}$ = 1,6 pF
$C_{a_{II} k_{II}}$ = 0,20 pF
$C_{k_{II} f}$ = 2,5 pF
$C_{k_{II}}/(g_{II}+f)$ = 4,7 pF
$C_{a_{II}}/(g_{II}+f)$ = 1,8 pF
$C_{g_I g_{II}}$ < 0,005 pF
$C_{a_{II} g_I}$ < 0,04 pF

ECC 85
6 AQ 8

HF-Doppeltriode

Verwendung als HF-Verstärker und selbstschwingende Mischröhre

RF Twin Triode

RF Amplifier

Self-Excited Mixer

Fortsetzung ↓

Allgemeine Daten / General Data

Heizung / Heating

U_f = 6,3 V
I_f = 0,435 A
Indirekt
Indirect

Kapazitäten / Capacitances

$C_{g_I}/(k_I+f+s)$ = 3,0 pF
$C_{a_I g_I}$ = 1,5 pF
$C_{a_I k_I}$ = 0,18 pF
$C_{g_{II}}/(k_{II}+ +s)$ = 3 pF
$C_{a_{II} g_{II}}$ = 1,5 pF
$C_{a_{II} k_{II}}$ = 0,18 pF

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Kenndaten / Characteristics

U_a = 250 V S = 6,0 mA/V
U_{g_1} = −2,2 V μ = 57
I_a = 10,0 mA

Betriebsdaten / Typical Operation

HF-Verstärker (System I) / RF Amplifier (Section I)

U_b = 250 V
R_{av} = 1,8 kΩ
U_a = 230 V
R_k = 200 Ω
U_{g_1} = −2 V
I_a = 10 mA
S = 6,0 mA/V
R_i = 9,7 kΩ
R_{ei} (100 MHz) = 6 kΩ
$R_{äq}$ = 0,5 kΩ

Grenzdaten / Maximum Ratings

Je System / per section

$U_{a\,kalt}$ = 550 V
U_a = 300 V
Q_a = 2,5 W
$Q_{a_I}+Q_{a_{II}}$ = 4,5 W
I_k = 15 mA
U_{g_1} = −100 V
R_{g_1} = 1 MΩ
U_{fk} = 90 V
R_{fk} = 20 kΩ

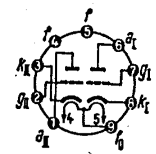
ECC 82
12 AU 7

NF-Doppeltriode

Verwendung als NF-Verstärker, Phasenumkehrröhre, Synchronisations-Trennröhre, Multivibrator und Sperrschwinger

AF Twin Triode

AF Amplifier



Noval

Kolben Nr. 6

Bulb No. 6

Allgemeine Daten / General Data

Heizung / Heating

U_f = 6,3 V
I_f = 0,3 A oder
U_f = 12,6 V
I_f = 0,15 A
Indirekt / Indirect

Kapazitäten / Capacitances

$C_{eing\,II}$ = 1,8 pF
$C_{ausg\,II}$ = 0,25 pF
$C_{a_{II} g_{II}}$ = 1,5 pF
$C_{g_{II} f}$ < 135 mpF
$C_{g_I g_{II}}$ < 10 pF
$C_{a_{II} g_I}$ < 60 mpF
$C_{eing\,I}$ = 1,8 pF
$C_{ausg\,I}$ = 0,37 pF
$C_{a_I g_I}$ = 1,5 pF
$C_{g_I f}$ < 135 mpF
$C_{a_I a_{II}}$ < 1,1 pF
$C_{a_I g_{II}}$ < 110 mpF

Kenn- und Betriebsdaten / Characteristics and Typical Operation

Kenndaten / Characteristics

Je System / per section

U_a = 250 V
U_g = −8,5 V
I_a = 10,5 mA
S = 2,2 mA/V
μ = 17
R_i = 7,7 kΩ

Betriebsdaten / Typical Operation

NF-Verstärker / AF Amplifier

U_b =	150	200	250	300 V
R_a =	100	100	100	100 kΩ
R_g =	1	1	1	1 MΩ
R_g' =	330	330	330	330 kΩ
C_k =	50	50	50	50 µF
R_k =	2,2	2,2	2,2	2,2 kΩ
I_a =	0,98	1,30	1,63	1,97 mA
v =	14	14	14	14
$U_{a\sim}$ =	17	25	32	41 V_{eff}
k =	5,6	5,8	5,9	6,0 %

Grenzdaten / Maximum Ratings

Je System / per section

U_a = 300 V
Q_a = 2,75 W
I_k = 20 mA
$-U_g$ = 100 V
$I_{k\,sp}$ = 250 mA*
R_g = 1 MΩ
U_{fk} = 180 V
R_{fk} = 20 kΩ**

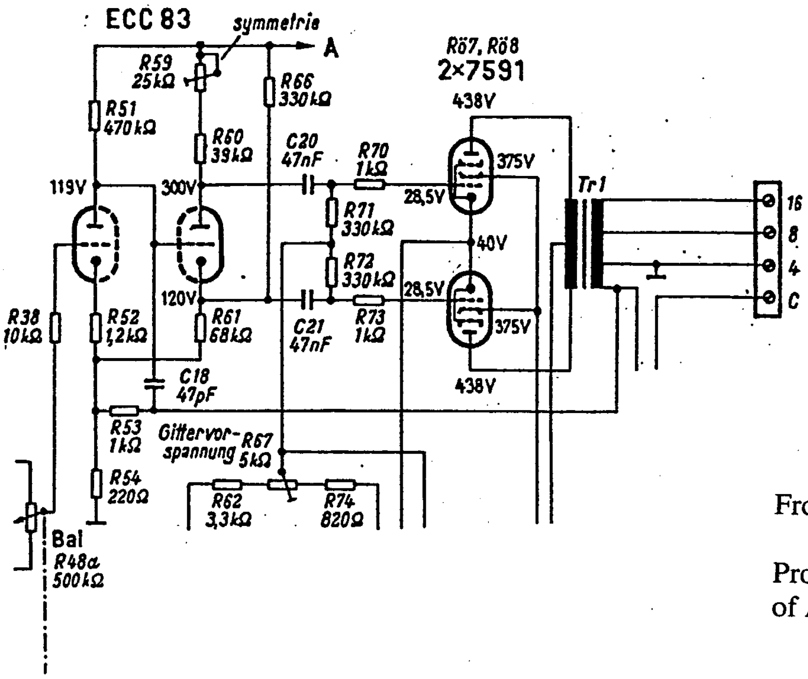
* Impulsdauer = 10% einer Periode, t_{max} = 2 ms
Pulse time = 10% per cycle, t_{max} = 2 ms

** In Phasenumkehrstufen max. 150 kΩ
In phase-splitter stages max. 150 kΩ

Appendix II

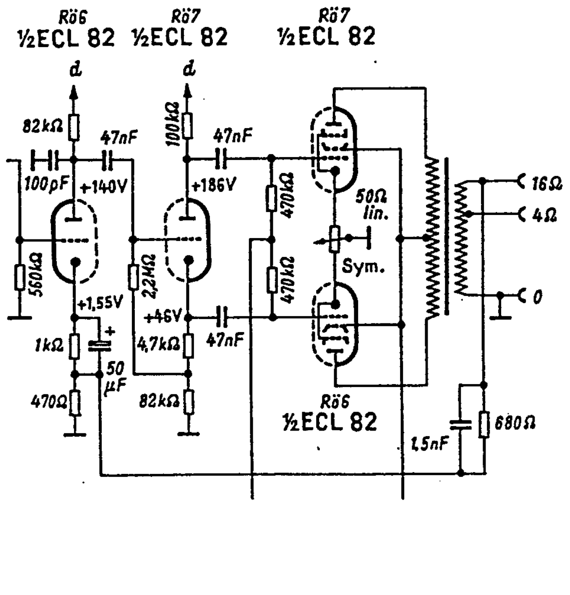
parts of diagrams
The Marantz 8B
The Williamson

The Quad II



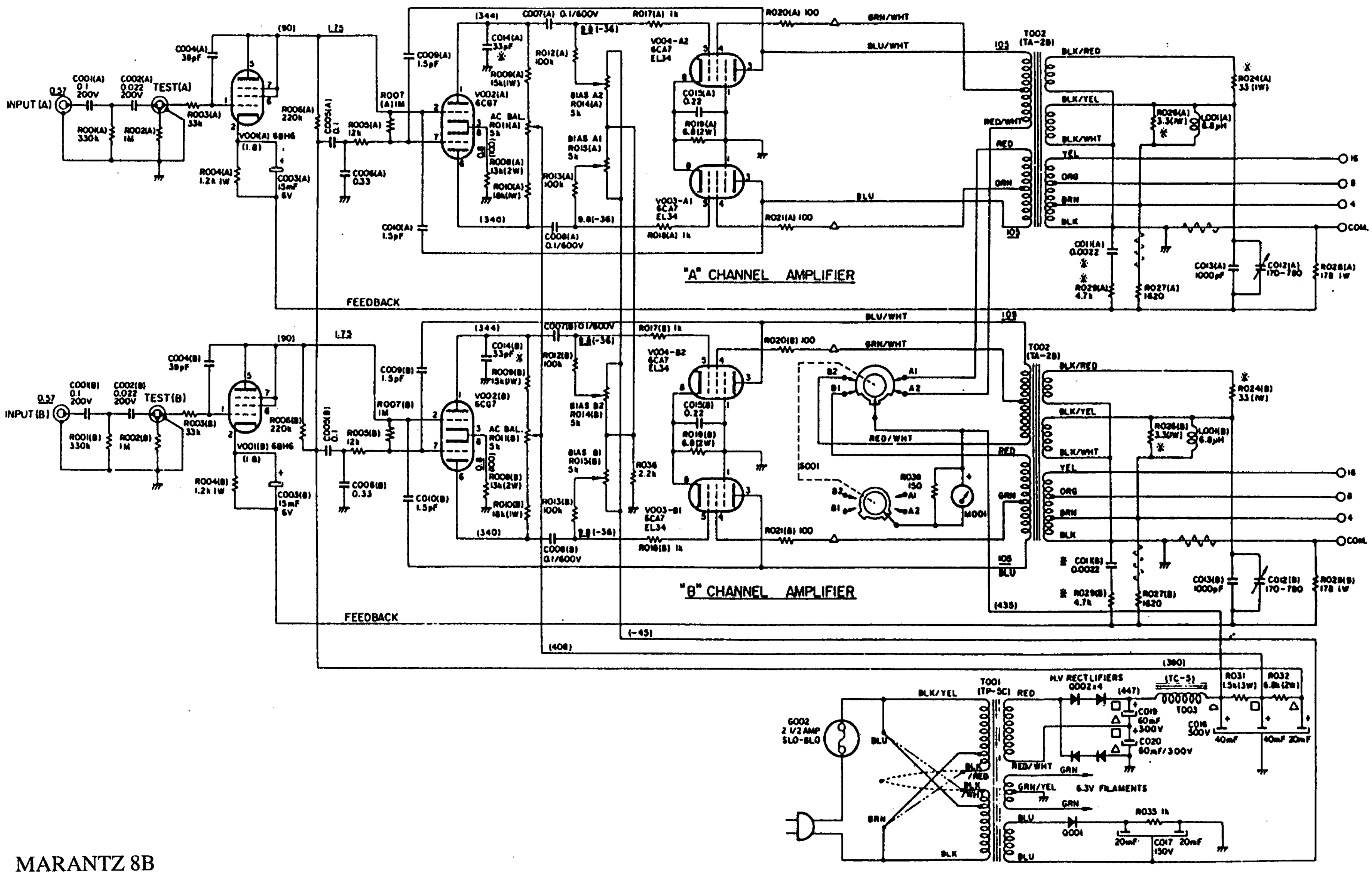
From Fisher X 101C (1964)

Provision for adjustment
of AC-balance.



TELEWATT VS56 (1963)

Different load resistors in anode
and cathode of the phase-splitter to
compensate for difference in output
resistances.



MARANTZ 8B

A very respected amplifier following a similar scheme as the amplifier described in this paper. The global feedback system is very elaborated in order to compensate for imperfections in the output transformer.

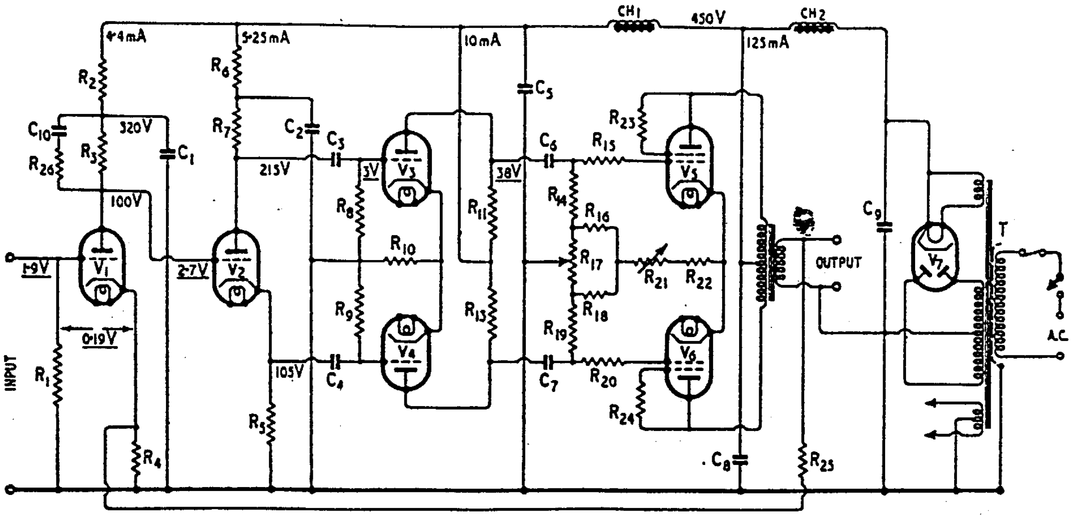


Fig. 1. Circuit diagram of complete amplifier. Voltages underlined are peak signal voltages at 15 watts output.

R_1	1MΩ	¼ watt ± 20%
R_2	33,000Ω	1 watt ± 20%
R_3	47,000Ω	1 watt ± 20%
R_4	470Ω	¼ watt ± 10%
R_5, R_7	22,000Ω	1 watt ± 5% (or matched)
R_6	22,000Ω	1 watt ± 20%
R_8, R_9	0.47MΩ	¼ watt ± 20%
R_{10}	390Ω	¼ watt ± 10%
R_{11}, R_{12}	47,000Ω	2 watt ± 5% (or matched)
R_{14}, R_{19}	0.1MΩ	¼ watt ± 10%
R_{15}, R_{20}	1,000Ω	¼ watt ± 20%
R_{16}, R_{18}	100Ω	1 watt ± 20%
R_{17}, R_{21}	100Ω	2 watt wirewound variable
R_{22}	150Ω	3 watt ± 20%
R_{23}, R_{24}	100Ω	½ watt ± 20%
R_{25}	$1{,}200\sqrt{\text{speech coil impedance}}$	½ watt (see table)
R_{26}	4,700Ω	¼ watt ± 20%
C_1, C_2, C_5, C_8	8μF	500V wkg.
C_3, C_4	0.05μF	350V wkg.
C_6, C_7	0.25μF	350V wkg.
C_9	8μF	600V wkg.
C_{10}	200pF	350V wkg.
CH_1	30H at 20mA	
CH_2	10H at 150mA	
T	Power transformer	

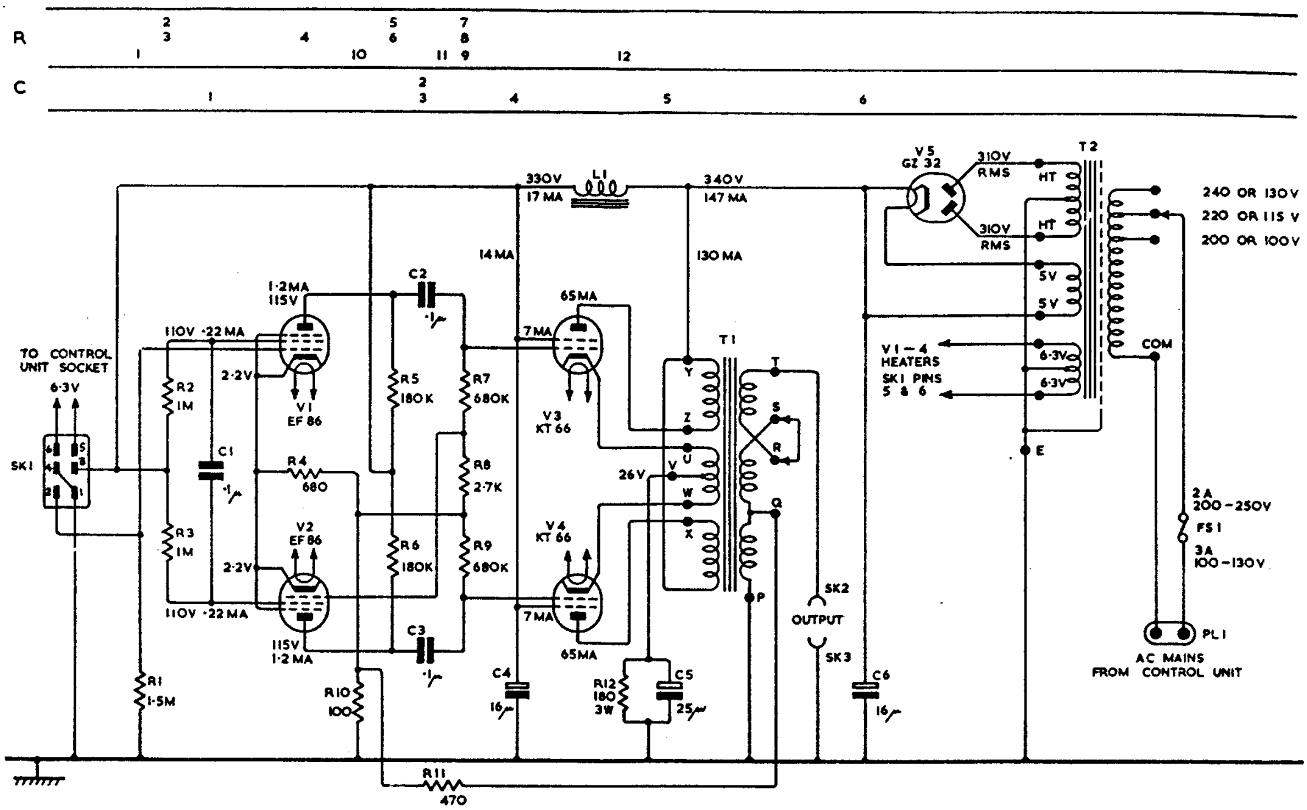
Secondary 425-0-425V 150 mA, 5V. 3A, 6.3V 4A, centre-tapped

V_1, V_2 2×L63 or 6J5, 6SN7 or B65
V_3, V_4 do. do.
V_5, V_6 KT66 V_7 Cossor 53KU, 5V4

The Williamson Amplifier

D.T.N. Williamson was employed at Osram-Marconi, the company who developed and manufactured the K66 beam tetrode. His famous design was published in 1947 and it was a major step forward in terms of quality. Up to that time phase-splitting was normally performed by a transformer with a center-tapped secondary. The inclusion of two transformers in the signal path, made global feedback virtually impossible. The Williamson was able to deliver 15 Watts with a THD at 0.1% (at 1000Hz). It became a reference standard for more than a decade.

QUAD II POWER AMPLIFIER



DRG 11175. ISSUE 1.

THE VOLTAGE AND CURRENT MEASUREMENTS SHEWN ARE APPROXIMATE, AND ARE ONLY PROVIDED AS A GUIDE. ALLOWANCE SHOULD BE MADE FOR THE LOADING EFFECTS OF A VOLTMETER.

Shown here is the famous Quad II. It was a very well-made amplifier, and many of them are still in use after more than 30 years of service.

At first sight the diagram looks confusing, but after a closer look it becomes very simple.

The upper EF86 is quite a normal input stage. Signal for the lower EF86 is taken from the output of the upper via a voltage divider consisting of the 680 kW grid resistor of the upper KT66 and a 2.7 kW resistor.

The EF86s both invert the signal so the driving voltages for the output stage are in opposite phase as required.

The voltage divider compensates for the gain of the lower EF86, where a gain of 680:2,7 » 250 apparently is expected. The actual gain is however much lower, but we find the explanation in the global feedback loop, where feedback is normal NFB to the upper EF86, but due to the inversion it is positive feedback to the lower EF86! This accounts for the high gain of that valve.

This combined input, phase splitter and driver stage is elegant, but the fact that the driving voltage to the lower EF86 has been exposed to HF cut-off and phase shift introduced by the loading of the output stage of the upper EF86 should not be overlooked.

It is unusual to tie the screen grids of the two valves together signal-wise instead of keeping them signal-free by connecting capacitors to ground from each grid, but this arrangement will keep the grids free from signal if they carry the same signal in opposite phase. If not, C_1 will help to restore AC balance from the two EF86s.

Another unusual feature is the local feedback of the output stage by the cathode coils of the output transformer. It could be thought that this negative current feedback would raise output resistance of the entire stage. Because of the close coupling of all coils quite the opposite is the case. If output voltage decreases because of external load, the feedback voltage from the cathode coil will decrease too, which helps to restore the output signal. This local feedback of the output stage is a brilliant idea (but it raises demands for voltage swing on the grids!) and I should wish that such transformers were available. The ratio between anode – and cathode coils is approximately 10:1.

Despite its heavy weight and big transformers the Quad II was only rated as a 12W amplifier – and despite the measured performance is average, the sound is very good.

Because KT66 is hard to obtain and very expensive, it is often replaced by EL34 when Quad^{s} are restored. EL34^{s} works quite well, but remember to connect the 3rd grid to cathode as this is not done internally in EL34 (Pin 1 strapped to 8). Apart from that, the socket connections are the same. The 180W cathode resistor should be replaced by a 240W resistor (two 470W 5W resistors in parallel). As there is no provision for adjusting DC balance (and no self-balancing!) the output valves should preferably be matched. A 220W resistor in the supply line to the screen grids is recommended.

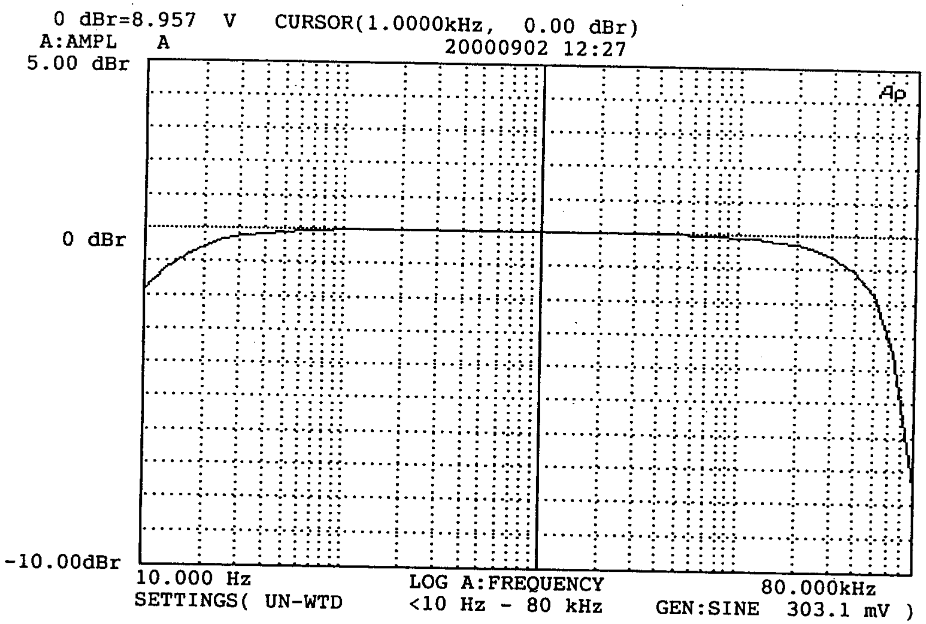
The GZ32 rectifier is often replaced by solid state diodes (1N4007), which also allows for a higher value of the surge capacitor C6, where 100m/450V would be a considerably improvement. Remember that this is not allowable with the GZ32 because it can’t cope with the peak currents of a 100mF capacitor.

You cannot change the amount of feedback without changing the ratio of the voltage divider in the grid resistor of the upper KT66, and this is not advisable.

Despite reservations, I have always been fascinated by the circuit. Although it is easy to understand how it works, it has always been an enigma to me how it was conceived!

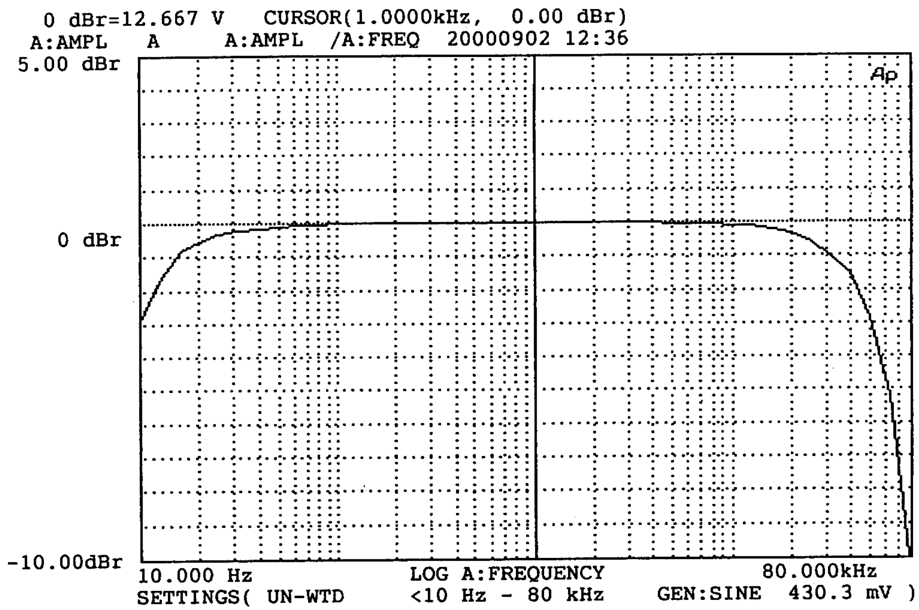
Appendix III

performance curves



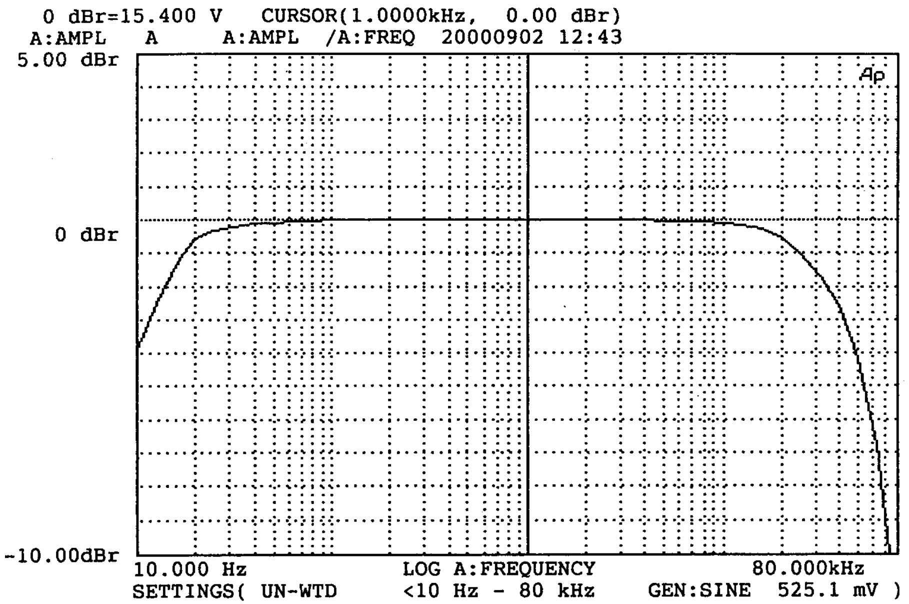
AGEN FREQ	AMPL	A	AGEN FREQ	AMPL	A	AGEN FREQ	AMPL	A Ap
10.000 Hz	-1.88	dBr	250.00 Hz	0.00	dBr	6.3000kHz	-0.05	dBr
12.500 Hz	-1.28	dBr	315.00 Hz	0.00	dBr	8.0000kHz	-0.08	dBr
16.000 Hz	-0.82	dBr	400.00 Hz	0.00	dBr	10.000kHz	-0.10	dBr
20.000 Hz	-0.54	dBr	500.00 Hz	0.00	dBr	12.500kHz	-0.14	dBr
25.000 Hz	-0.36	dBr	630.00 Hz	0.00	dBr	16.000kHz	-0.20	dBr
31.500 Hz	-0.23	dBr	800.00 Hz	0.00	dBr	20.000kHz	-0.30	dBr
40.000 Hz	-0.15	dBr	1.0000kHz	0.00	dBr	25.000kHz	-0.46	dBr
50.000 Hz	-0.10	dBr	1.2500kHz	-0.01	dBr	31.500kHz	-0.72	dBr
63.000 Hz	-0.06	dBr	1.6000kHz	-0.01	dBr	40.000kHz	-1.09	dBr
80.000 Hz	-0.04	dBr	2.0000kHz	-0.01	dBr	50.000kHz	-1.74	dBr
100.00 Hz	-0.03	dBr	2.5000kHz	-0.01	dBr	63.000kHz	-3.47	dBr
125.00 Hz	-0.01	dBr	3.1500kHz	-0.01	dBr	80.000kHz	-7.48	dBr
160.00 Hz	-0.01	dBr	4.0000kHz	-0.02	dBr			
200.00 Hz	0.00	dBr	5.0000kHz	-0.03	dBr			

Frequency response measured at 10W out



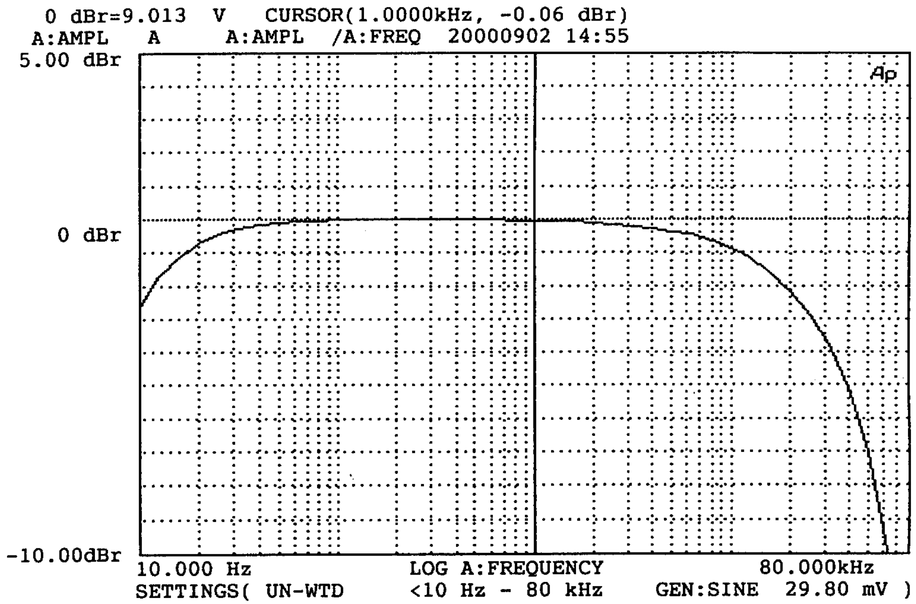
AGEN FREQ	AMPL	A	AGEN FREQ	AMPL	A	AGEN FREQ	AMPL	A Ap
10.000 Hz	-2.90	dBr	250.00 Hz	0.00	dBr	6.3000kHz	-0.05	dBr
12.500 Hz	-1.69	dBr	315.00 Hz	0.00	dBr	8.0000kHz	-0.08	dBr
16.000 Hz	-0.82	dBr	400.00 Hz	0.00	dBr	10.000kHz	-0.10	dBr
20.000 Hz	-0.54	dBr	500.00 Hz	0.00	dBr	12.500kHz	-0.14	dBr
25.000 Hz	-0.36	dBr	630.00 Hz	0.00	dBr	16.000kHz	-0.21	dBr
31.500 Hz	-0.22	dBr	800.00 Hz	0.00	dBr	20.000kHz	-0.34	dBr
40.000 Hz	-0.14	dBr	1.0000kHz	0.00	dBr	25.000kHz	-0.60	dBr
50.000 Hz	-0.09	dBr	1.2500kHz	0.00	dBr	31.500kHz	-1.02	dBr
63.000 Hz	-0.06	dBr	1.6000kHz	0.00	dBr	40.000kHz	-1.51	dBr
80.000 Hz	-0.03	dBr	2.0000kHz	-0.01	dBr	50.000kHz	-2.83	dBr
100.00 Hz	-0.02	dBr	2.5000kHz	-0.01	dBr	63.000kHz	-5.18	dBr
125.00 Hz	-0.02	dBr	3.1500kHz	-0.01	dBr	80.000kHz	-10.15	dBr
160.00 Hz	-0.01	dBr	4.0000kHz	-0.02	dBr			
200.00 Hz	0.00	dBr	5.0000kHz	-0.03	dBr			

Frequency response measured at 20W out



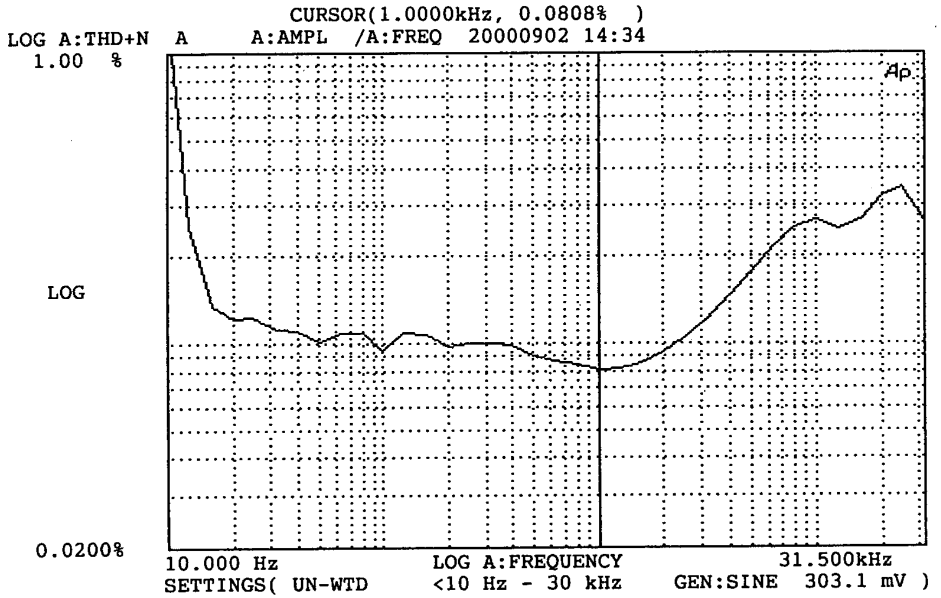
AGEN FREQ	AMPL A	AGEN FREQ	AMPL A	AGEN FREQ	AMPL A Ap
10.000 Hz	-3.87 dBr	250.00 Hz	0.00 dBr	6.3000kHz	-0.05 dBr
12.500 Hz	-2.51 dBr	315.00 Hz	0.00 dBr	8.0000kHz	-0.08 dBr
16.000 Hz	-1.25 dBr	400.00 Hz	0.00 dBr	10.000kHz	-0.11 dBr
20.000 Hz	-0.54 dBr	500.00 Hz	-0.01 dBr	12.500kHz	-0.16 dBr
25.000 Hz	-0.35 dBr	630.00 Hz	0.00 dBr	16.000kHz	-0.29 dBr
31.500 Hz	-0.22 dBr	800.00 Hz	0.00 dBr	20.000kHz	-0.55 dBr
40.000 Hz	-0.14 dBr	1.0000kHz	0.00 dBr	25.000kHz	-1.07 dBr
50.000 Hz	-0.09 dBr	1.2500kHz	0.00 dBr	31.500kHz	-1.69 dBr
63.000 Hz	-0.05 dBr	1.6000kHz	-0.01 dBr	40.000kHz	-2.58 dBr
80.000 Hz	-0.03 dBr	2.0000kHz	-0.01 dBr	50.000kHz	-4.16 dBr
100.00 Hz	-0.02 dBr	2.5000kHz	-0.01 dBr	63.000kHz	-6.80 dBr
125.00 Hz	-0.01 dBr	3.1500kHz	-0.01 dBr	80.000kHz	-11.78dBr
160.00 Hz	0.00 dBr	4.0000kHz	-0.02 dBr		
200.00 Hz	0.00 dBr	5.0000kHz	-0.04 dBr		

Frequency response measured at 30W out



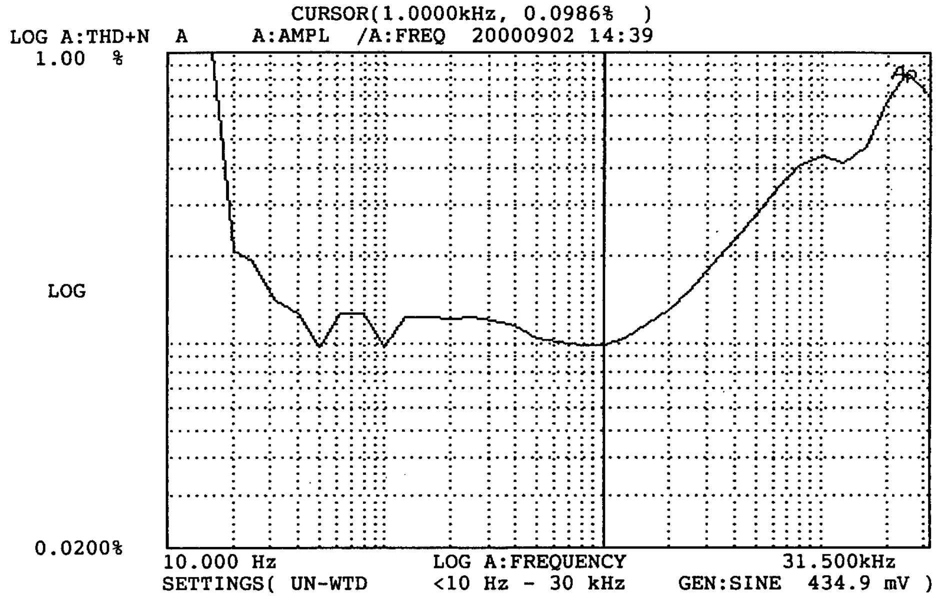
AGEN FREQ	AMPL A	AGEN FREQ	AMPL A	AGEN FREQ	AMPL A Ap
10.000 Hz	-2.61 dBr	250.00 Hz	-0.02 dBr	6.3000kHz	-0.44 dBr
12.500 Hz	-1.67 dBr	315.00 Hz	-0.03 dBr	8.0000kHz	-0.68 dBr
16.000 Hz	-1.08 dBr	400.00 Hz	-0.02 dBr	10.000kHz	-0.89 dBr
20.000 Hz	-0.71 dBr	500.00 Hz	-0.02 dBr	12.500kHz	-1.15 dBr
25.000 Hz	-0.46 dBr	630.00 Hz	-0.02 dBr	16.000kHz	-1.63 dBr
31.500 Hz	-0.30 dBr	800.00 Hz	-0.04 dBr	20.000kHz	-2.17 dBr
40.000 Hz	-0.17 dBr	1.0000kHz	-0.06 dBr	25.000kHz	-2.88 dBr
50.000 Hz	-0.09 dBr	1.2500kHz	-0.06 dBr	31.500kHz	-3.78 dBr
63.000 Hz	-0.08 dBr	1.6000kHz	-0.08 dBr	40.000kHz	-5.09 dBr
80.000 Hz	-0.04 dBr	2.0000kHz	-0.10 dBr	50.000kHz	-7.02 dBr
100.00 Hz	-0.02 dBr	2.5000kHz	-0.15 dBr	63.000kHz	-10.24dBr
125.00 Hz	0.00 dBr	3.1500kHz	-0.22 dBr	80.000kHz	-15.76dBr
160.00 Hz	-0.01 dBr	4.0000kHz	-0.29 dBr		
200.00 Hz	0.00 dBr	5.0000kHz	-0.38 dBr		

Frequency response measured at 10W out
without negative feedback



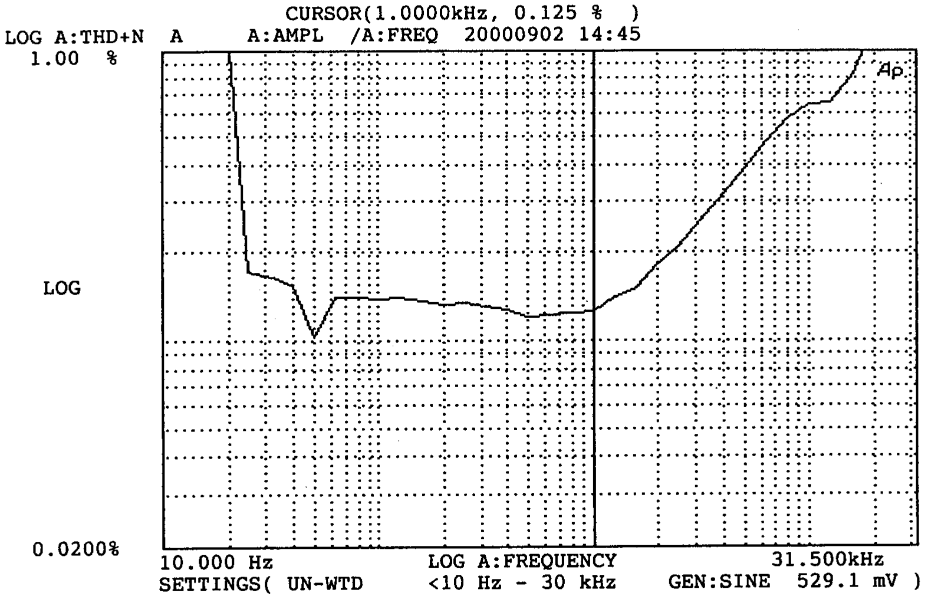
AGEN FREQ	THD+N A	AGEN FREQ	THD+N A	AGEN FREQ	THD+N A Ap
10.000 Hz	1.35 %	200.00 Hz	0.0973%	4.0000kHz	0.147 %
12.500 Hz	0.257 %	250.00 Hz	0.100 %	5.0000kHz	0.177 %
16.000 Hz	0.134 %	315.00 Hz	0.100 %	6.3000kHz	0.216 %
20.000 Hz	0.121 %	400.00 Hz	0.0985%	8.0000kHz	0.252 %
25.000 Hz	0.124 %	500.00 Hz	0.0910%	10.000kHz	0.265 %
31.500 Hz	0.111 %	630.00 Hz	0.0868%	12.500kHz	0.249 %
40.000 Hz	0.111 %	800.00 Hz	0.0837%	16.000kHz	0.267 %
50.000 Hz	0.101 %	1.0000kHz	0.0808%	20.000kHz	0.320 %
63.000 Hz	0.109 %	1.2500kHz	0.0823%	25.000kHz	0.343 %
80.000 Hz	0.109 %	1.6000kHz	0.0851%	31.500kHz	0.262 %
100.00 Hz	0.0950%	2.0000kHz	0.0933%		
125.00 Hz	0.108 %	2.5000kHz	0.103 %		
160.00 Hz	0.107 %	3.1500kHz	0.121 %		

Total harmonic distortion + noise measured at 10W out



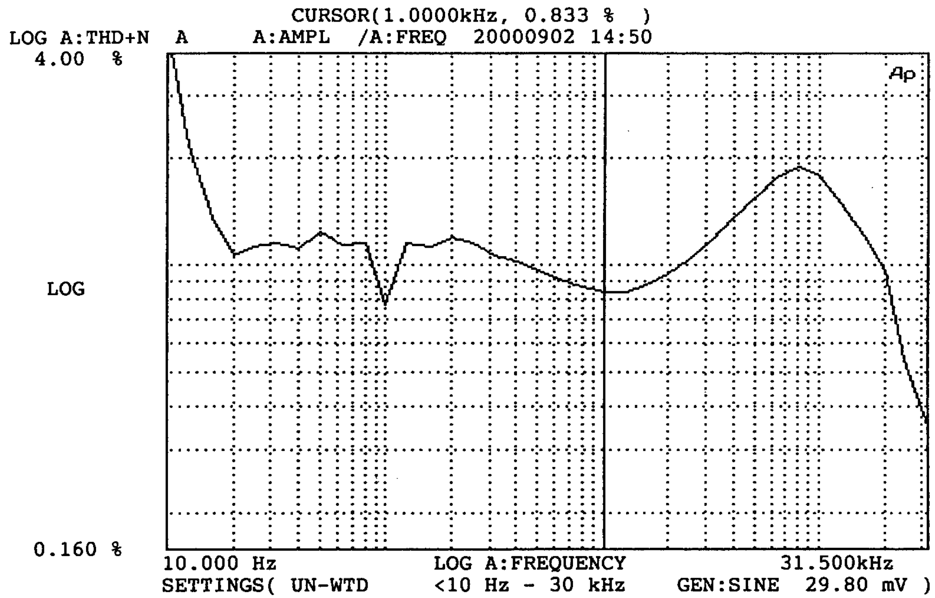
AGEN FREQ	THD+N A	AGEN FREQ	THD+N A	AGEN FREQ	THD+N A Ap
10.000 Hz	35.36 %	200.00 Hz	0.121 %	4.0000kHz	0.228 %
12.500 Hz	21.53 %	250.00 Hz	0.123 %	5.0000kHz	0.280 %
16.000 Hz	1.08 %	315.00 Hz	0.120 %	6.3000kHz	0.344 %
20.000 Hz	0.209 %	400.00 Hz	0.114 %	8.0000kHz	0.412 %
25.000 Hz	0.192 %	500.00 Hz	0.103 %	10.000kHz	0.439 %
31.500 Hz	0.140 %	630.00 Hz	0.101 %	12.500kHz	0.416 %
40.000 Hz	0.127 %	800.00 Hz	0.0984%	16.000kHz	0.474 %
50.000 Hz	0.0976%	1.0000kHz	0.0986%	20.000kHz	0.680 %
63.000 Hz	0.126 %	1.2500kHz	0.104 %	25.000kHz	0.844 %
80.000 Hz	0.127 %	1.6000kHz	0.117 %	31.500kHz	0.702 %
100.00 Hz	0.0969%	2.0000kHz	0.131 %		
125.00 Hz	0.123 %	2.5000kHz	0.154 %		
160.00 Hz	0.123 %	3.1500kHz	0.186 %		

Total harmonic distortion + noise measured at 20W out



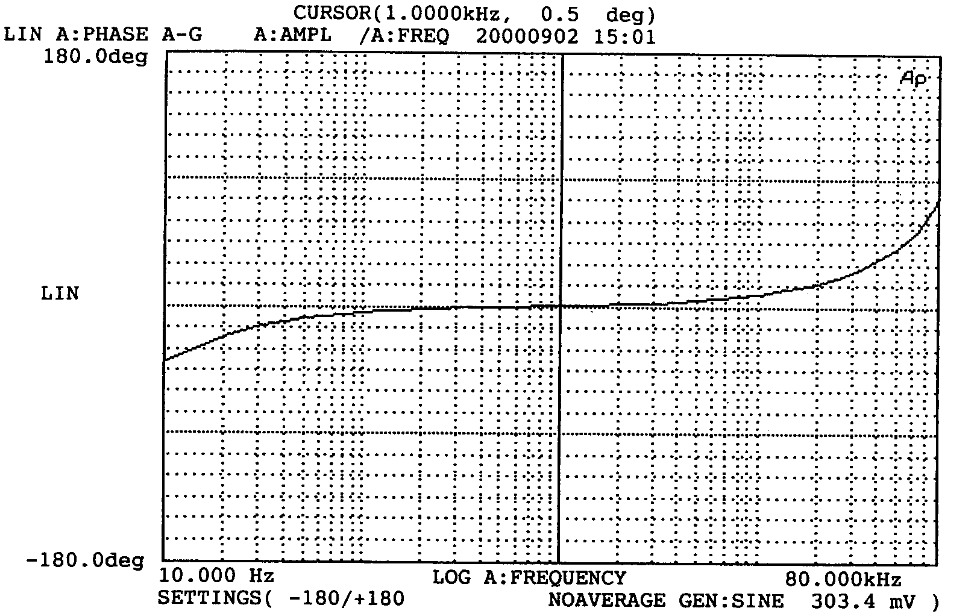
AGEN FREQ	THD+N A	AGEN FREQ	THD+N A	AGEN FREQ	THD+N A Ap
10.000 Hz	45.45 %	200.00 Hz	0.132 %	4.0000kHz	0.316 %
12.500 Hz	37.83 %	250.00 Hz	0.135 %	5.0000kHz	0.388 %
16.000 Hz	21.53 %	315.00 Hz	0.131 %	6.3000kHz	0.481 %
20.000 Hz	1.01 %	400.00 Hz	0.128 %	8.0000kHz	0.576 %
25.000 Hz	0.171 %	500.00 Hz	0.120 %	10.000kHz	0.645 %
31.500 Hz	0.165 %	630.00 Hz	0.122 %	12.500kHz	0.657 %
40.000 Hz	0.152 %	800.00 Hz	0.123 %	16.000kHz	0.827 %
50.000 Hz	0.102 %	1.0000kHz	0.125 %	20.000kHz	1.20 %
63.000 Hz	0.141 %	1.2500kHz	0.140 %	25.000kHz	1.74 %
80.000 Hz	0.140 %	1.6000kHz	0.150 %	31.500kHz	1.12 %
100.00 Hz	0.138 %	2.0000kHz	0.180 %		
125.00 Hz	0.139 %	2.5000kHz	0.209 %		
160.00 Hz	0.137 %	3.1500kHz	0.256 %		

Total harmonic distortion + noise vs. frequency at 30W out



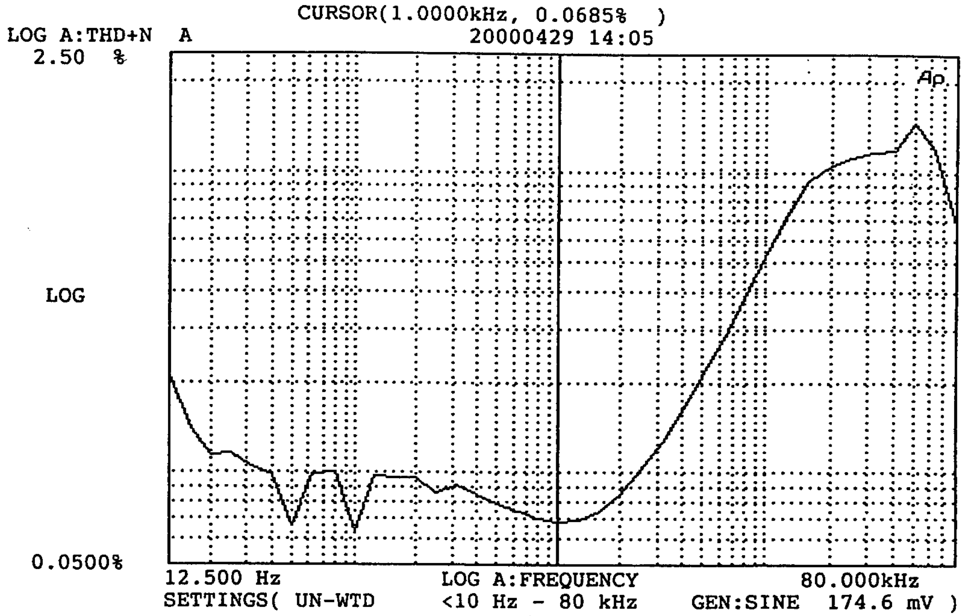
AGEN FREQ	THD+N A	AGEN FREQ	THD+N A	AGEN FREQ	THD+N A Ap
10.000 Hz	4.60 %	200.00 Hz	1.19 %	4.0000kHz	1.34 %
12.500 Hz	2.16 %	250.00 Hz	1.15 %	5.0000kHz	1.54 %
16.000 Hz	1.34 %	315.00 Hz	1.05 %	6.3000kHz	1.75 %
20.000 Hz	1.05 %	400.00 Hz	1.02 %	8.0000kHz	1.87 %
25.000 Hz	1.12 %	500.00 Hz	0.958 %	10.000kHz	1.76 %
31.500 Hz	1.14 %	630.00 Hz	0.902 %	12.500kHz	1.48 %
40.000 Hz	1.10 %	800.00 Hz	0.861 %	16.000kHz	1.20 %
50.000 Hz	1.23 %	1.0000kHz	0.833 %	20.000kHz	0.960 %
63.000 Hz	1.13 %	1.2500kHz	0.838 %	25.000kHz	0.540 %
80.000 Hz	1.14 %	1.6000kHz	0.875 %	31.500kHz	0.350 %
100.00 Hz	0.768 %	2.0000kHz	0.941 %		
125.00 Hz	1.14 %	2.5000kHz	1.02 %		
160.00 Hz	1.11 %	3.1500kHz	1.16 %		

Total harmonic distortion + noise vs. frequency
measured at 10W out *without NFB*



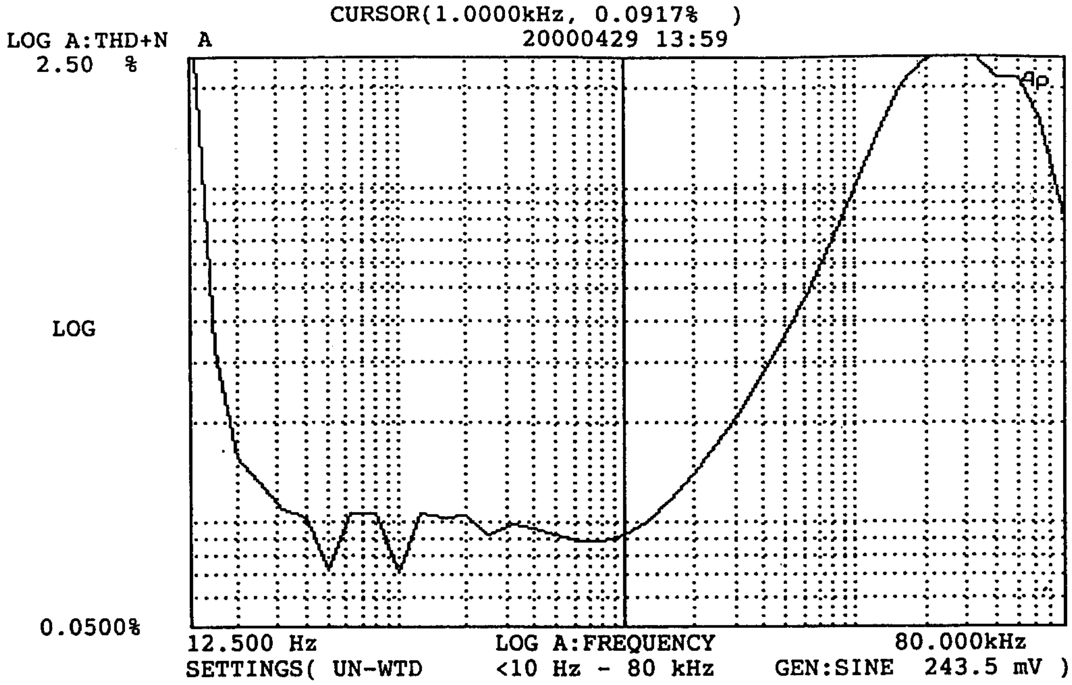
AGEN FREQ	PHASE A-G		AGEN FREQ	PHASE A-G		AGEN FREQ	PHASE A-G	Ap
10.000 Hz	-39.5	deg	250.00 Hz	-1.4	deg	6.3000kHz	5.6	deg
12.500 Hz	-32.7	deg	315.00 Hz	-1.0	deg	8.0000kHz	7.0	deg
16.000 Hz	-26.3	deg	400.00 Hz	-0.6	deg	10.000kHz	8.7	deg
20.000 Hz	-21.4	deg	500.00 Hz	-0.3	deg	12.500kHz	10.9	deg
25.000 Hz	-17.2	deg	630.00 Hz	0.0	deg	16.000kHz	13.7	deg
31.500 Hz	-13.8	deg	800.00 Hz	0.2	deg	20.000kHz	17.1	deg
40.000 Hz	-10.9	deg	1.0000kHz	0.5	deg	25.000kHz	21.1	deg
50.000 Hz	-8.7	deg	1.2500kHz	0.9	deg	31.500kHz	26.4	deg
63.000 Hz	-6.9	deg	1.6000kHz	1.3	deg	40.000kHz	33.2	deg
80.000 Hz	-5.4	deg	2.0000kHz	1.7	deg	50.000kHz	41.5	deg
100.00 Hz	-4.2	deg	2.5000kHz	2.2	deg	63.000kHz	53.8	deg
125.00 Hz	-3.3	deg	3.1500kHz	2.8	deg	80.000kHz	75.0	deg
160.00 Hz	-2.5	deg	4.0000kHz	3.6	deg			
200.00 Hz	-1.9	deg	5.0000kHz	4.4	deg			

Phase shift input to output (measured at 10W out)



AGEN FREQ	THD+N A	AGEN FREQ	THD+N A	AGEN FREQ	THD+N A Ap
12.500 Hz	0.211 %	315.00 Hz	0.0908%	8.0000kHz	0.383 %
16.000 Hz	0.140 %	400.00 Hz	0.0850%	10.000kHz	0.524 %
20.000 Hz	0.114 %	500.00 Hz	0.0791%	12.500kHz	0.708 %
25.000 Hz	0.116 %	630.00 Hz	0.0748%	16.000kHz	0.935 %
31.500 Hz	0.104 %	800.00 Hz	0.0699%	20.000kHz	1.04 %
40.000 Hz	0.0982%	1.0000kHz	0.0685%	25.000kHz	1.11 %
50.000 Hz	0.0667%	1.2500kHz	0.0693%	31.500kHz	1.16 %
63.000 Hz	0.0994%	1.6000kHz	0.0749%	40.000kHz	1.18 %
80.000 Hz	0.100 %	2.0000kHz	0.0851%	50.000kHz	1.46 %
100.00 Hz	0.0633%	2.5000kHz	0.102 %	63.000kHz	1.19 %
125.00 Hz	0.0977%	3.1500kHz	0.125 %	80.000kHz	0.670 %
160.00 Hz	0.0962%	4.0000kHz	0.161 %		
200.00 Hz	0.0965%	5.0000kHz	0.209 %		
250.00 Hz	0.0859%	6.3000kHz	0.278 %		

Total harmonic distortion + noise at 8W
Output valves operating as triodes (R_{g2} connected to anode)
15dB of negative feedback



AGEN FREQ	THD+N A
12.500 Hz	4.69 %
16.000 Hz	0.327 %
20.000 Hz	0.155 %
25.000 Hz	0.132 %
31.500 Hz	0.110 %
40.000 Hz	0.103 %
50.000 Hz	0.0724%
63.000 Hz	0.105 %
80.000 Hz	0.106 %
100.00 Hz	0.0715%
125.00 Hz	0.106 %
160.00 Hz	0.103 %
200.00 Hz	0.104 %
250.00 Hz	0.0920%

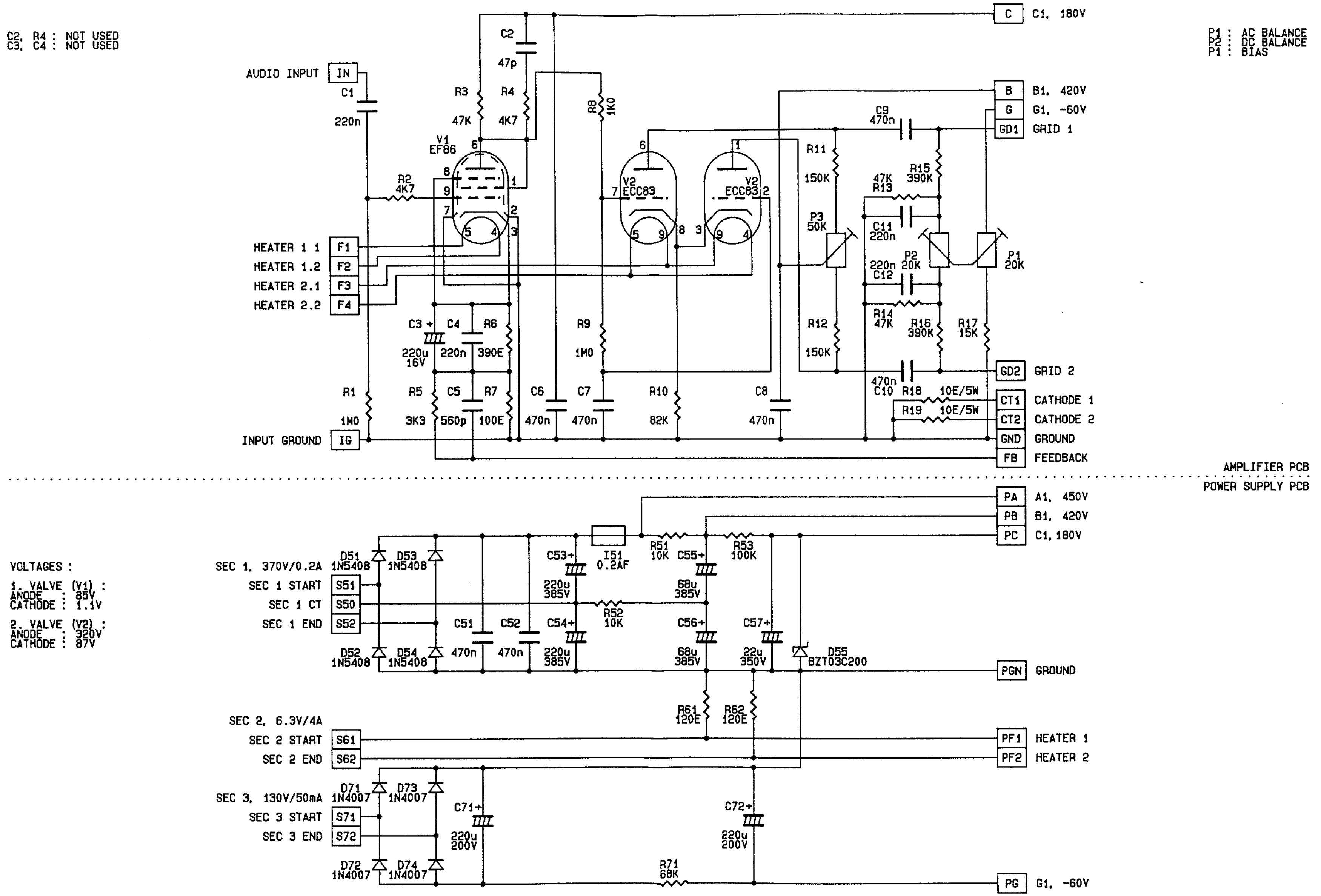
AGEN FREQ	THD+N A
315.00 Hz	0.0997%
400.00 Hz	0.0958%
500.00 Hz	0.0919%
630.00 Hz	0.0885%
800.00 Hz	0.0881%
1.0000kHz	0.0917%
1.2500kHz	0.100 %
1.6000kHz	0.117 %
2.0000kHz	0.140 %
2.5000kHz	0.169 %
3.1500kHz	0.212 %
4.0000kHz	0.278 %
5.0000kHz	0.362 %
6.3000kHz	0.494 %

AGEN FREQ	THD+N A Ap
8.0000kHz	0.695 %
10.000kHz	0.991 %
12.500kHz	1.43 %
16.000kHz	2.05 %
20.000kHz	2.44 %
25.000kHz	2.55 %
31.500kHz	2.55 %
40.000kHz	2.15 %
50.000kHz	2.13 %
63.000kHz	1.58 %
80.000kHz	0.799 %

Total harmonic distortion + noise at 16W
Output valves operating as triodes (R_{g2} connected to anode)
15dB of negative feedback

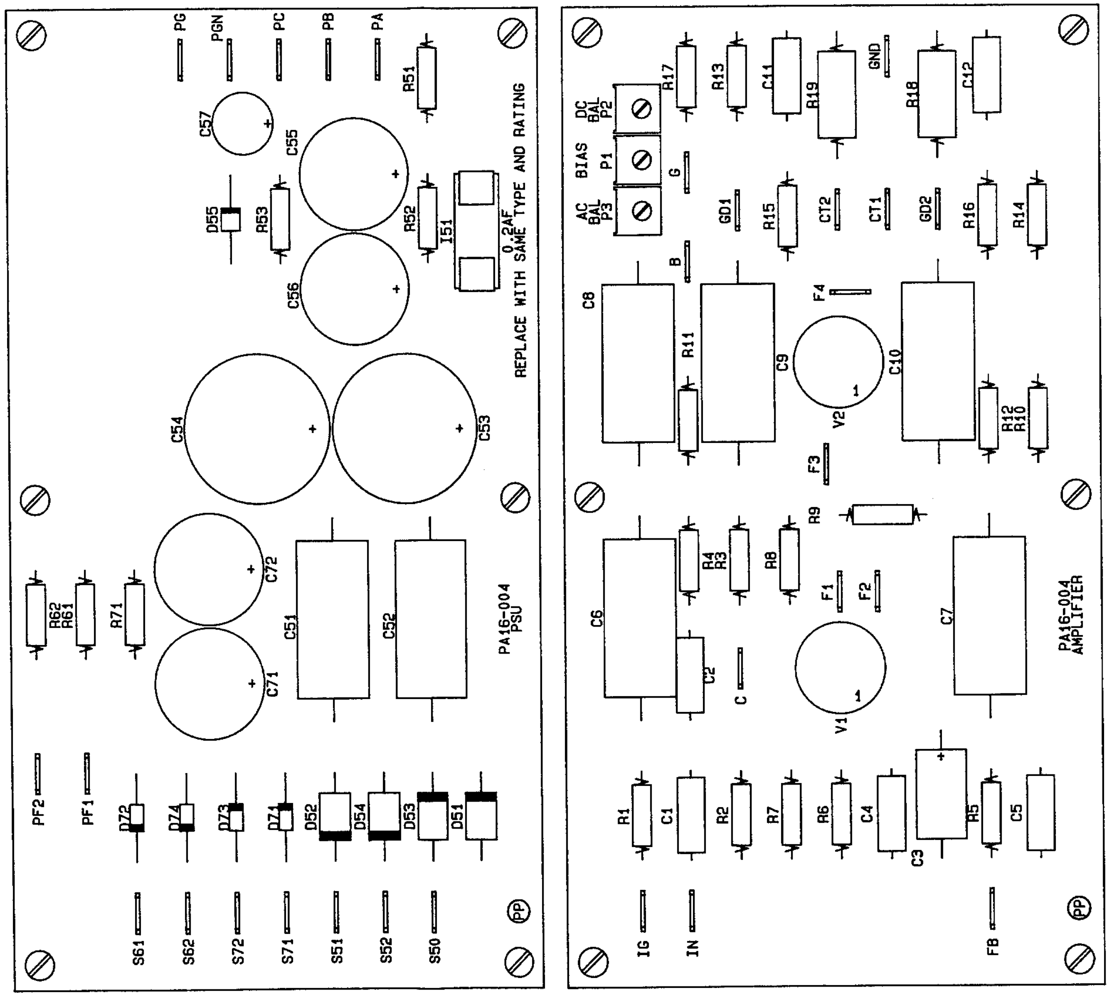
Appendix IV

PCB’s and layout



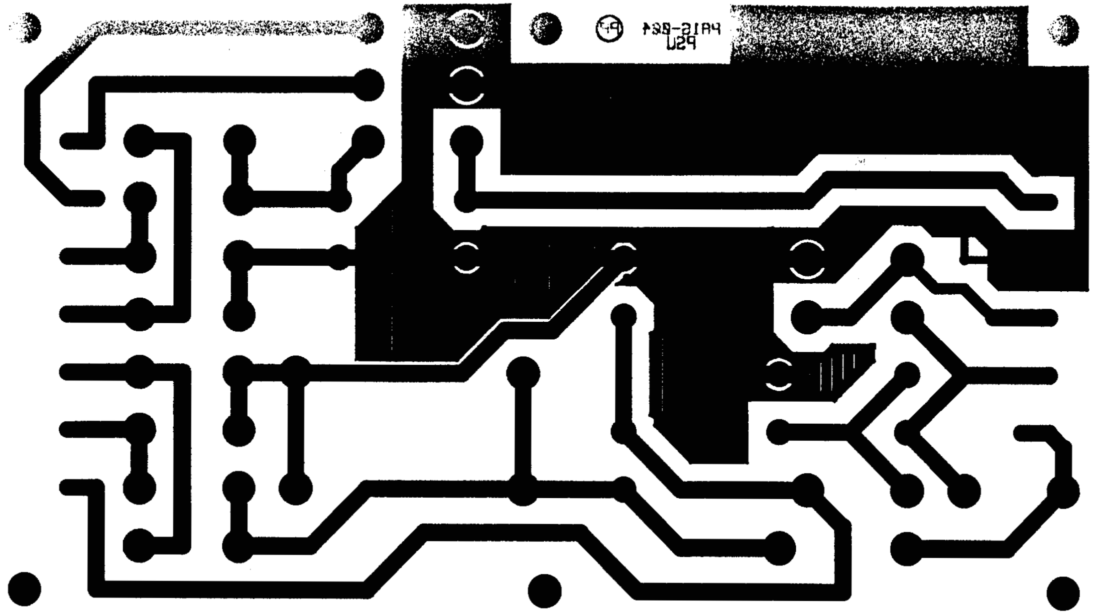
The values of R51 and R53 are valid for mono blocks

VALVEAMPLIFIER PA16	ENG	PP
	VERS	0031.3
	REPL	0004.2
SCALE	NPN ELEKTRONIK APS	DRAWING NUMBER 00012901	

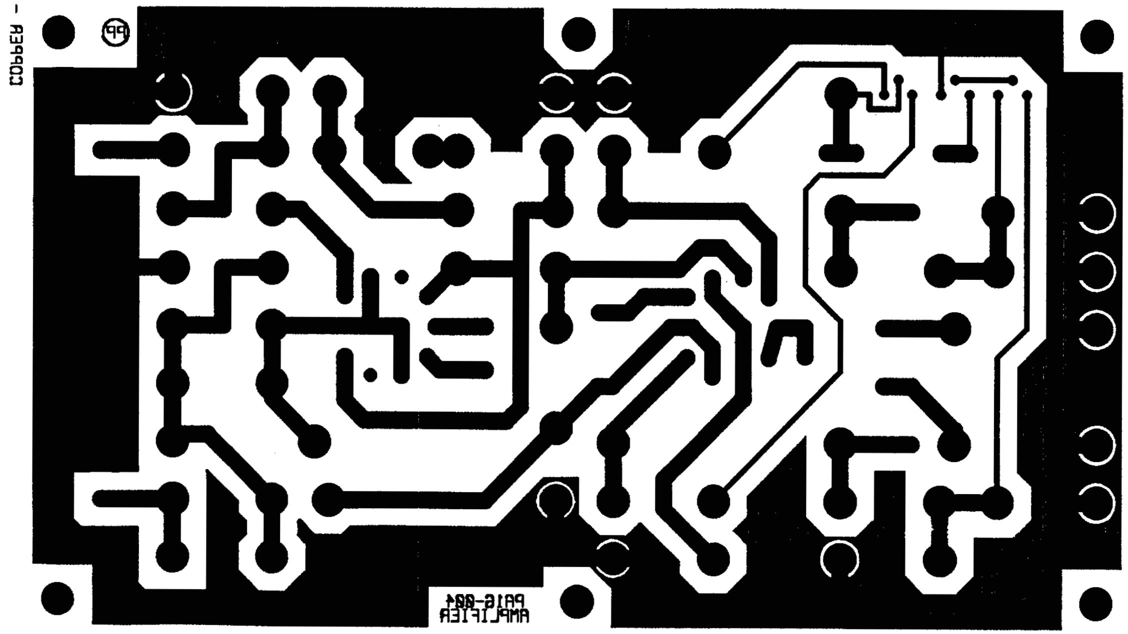


COMPONENTS D55, GND, IG, PGN, R61, R62 AND V1 MUST BE SOLDERED ON BOTH SIDES OF PCB.
OTHER COMPONENTS CONNECTED TO GROUND ON COMPONENTSIDE SHOULD BE SOLDERED ON COMPONENTSIDE IF POSSIBLE.

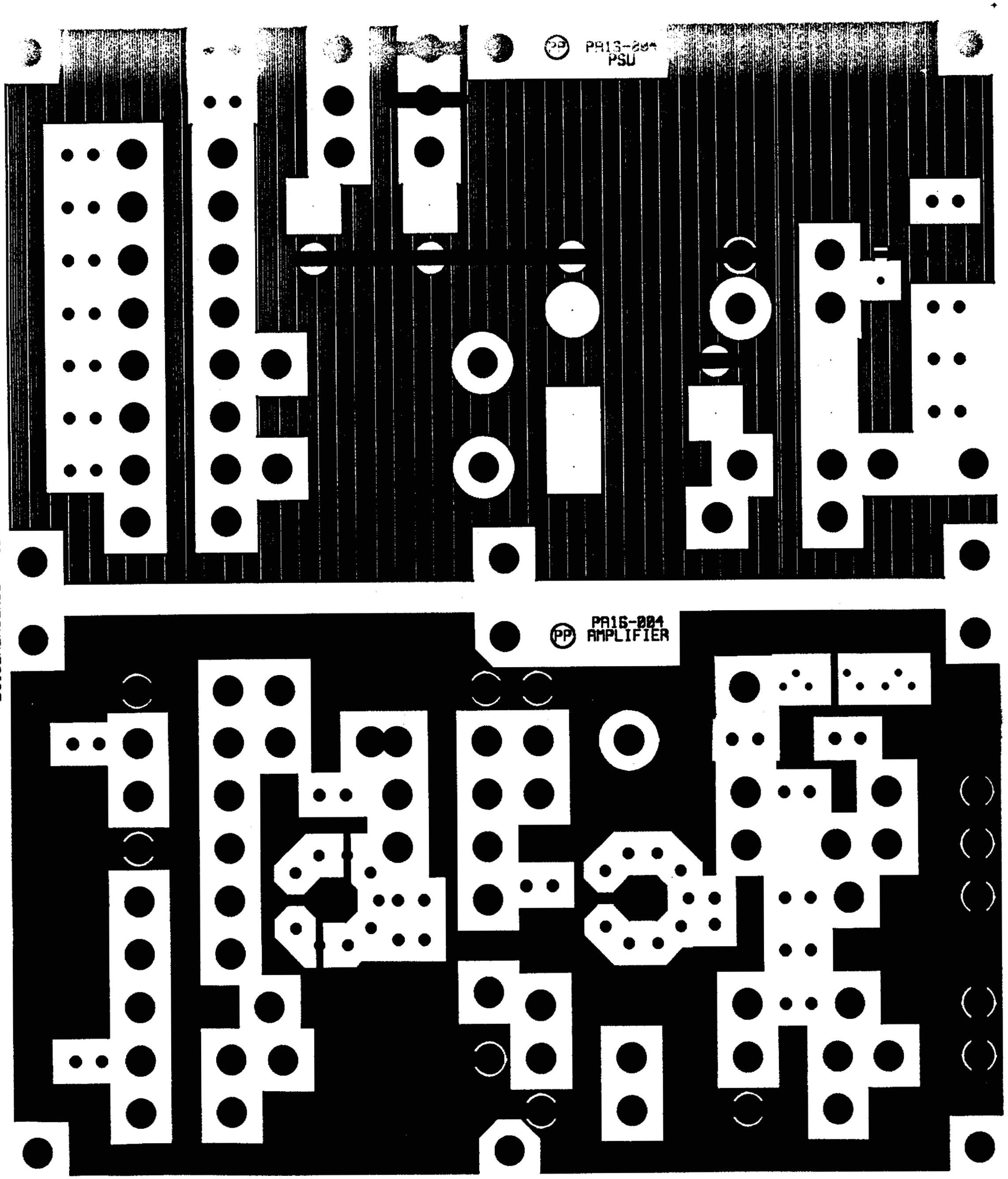
SCALE	PA16 COMPONENTLAYOUT	ENG: PP VERS: 0031.3 REPL: 0004.2
	NPN ELEKTRONIK APS	DRAWING NUMBER 00012903



Power supply PCB
Track side



Amplifier PCB
Track side
resistors and capacitors mounted here



COPPER - COMPONENTSIDE

Power supply PCB
Component side

Amplifier PCB
Screen side
Trimpots and sockets mounted here

DET JYSKE
MUSIKKONSERVATORIUM