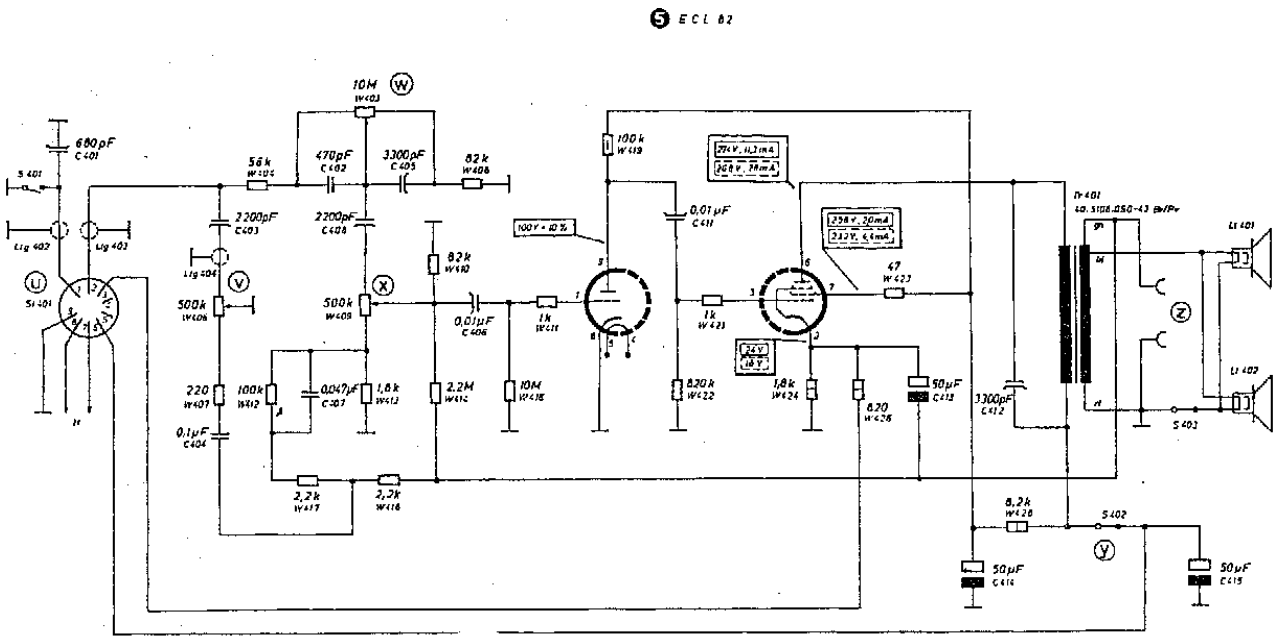
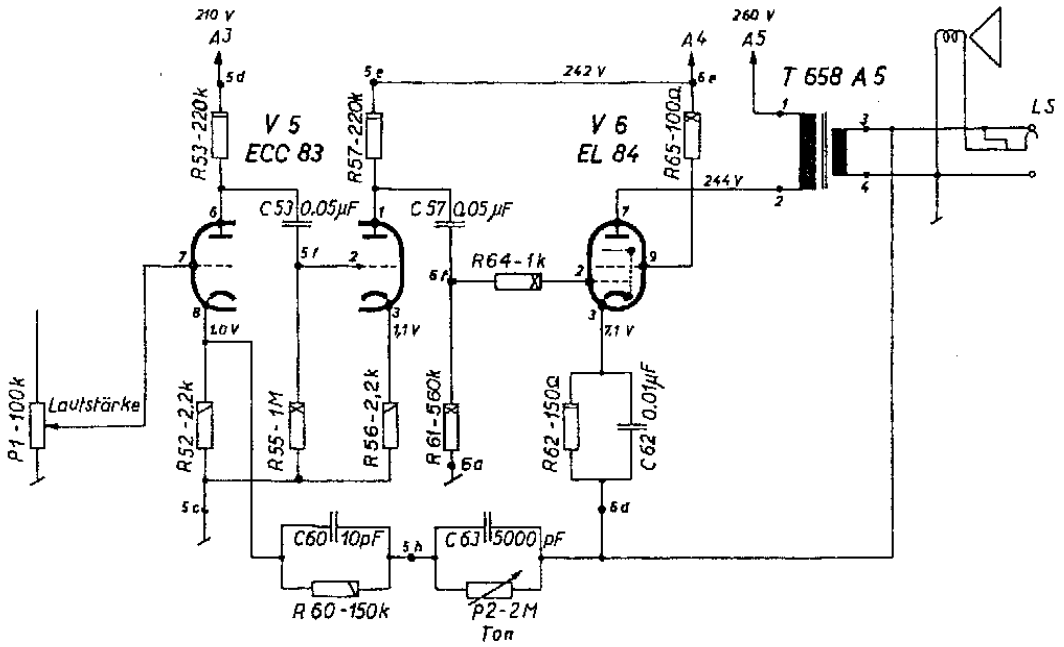
Appendix

- **Typical 1960 SE-amplifiers**

- **Data of the valves used (ECC83, EL34)**

- **Audio Precision plots of some of the measurements on the amplifier described in this paper**



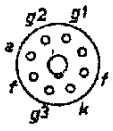


Two diagrams showing typical SE-amplifiers from the late fifties.

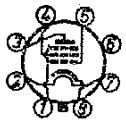
The upper, from a TELEFUNKEN tape recorder, 1960, could deliver 3 Watts at 10% distortion to the speakers and the lower, from a REVOX tape recorder, 1957, could provide 5 Watts at 10% distortion. Both have adjustable tone-correction networks in the NFB path.

The only share low output power with a modern high-quality SE amplifier as the one described.

EL 34 Class A final amplifier		V_a = 250 V V_{g2} = 265 V V_{g1} = −13.5 V V_{g3} = 0 V	I_a = 100 I_{g2} = 15	S = 11 mA/V R_i = 15 kΩ R_a = 2 kΩ W_o = 11 W W_a = 25 W
EL 34 Output pentode Class AB push-pull amplifier Class B push-pull amplifier	V_f = 6.3 V I_f = 1.5 A	V_b = 375 V R_{g2}[1]) = 470 Ω R_k = 130 Ω V_{g3} = 0 V	I_{amin} = 2× 75 I_{amax} = 2× 95 I_{g2min} = 2×11.5 I_{g2max} = 2×22.5	R_{aa} = 4 kΩ W_o = 37 W
		V_b = 425 V R_{g2}[1]) = 1 kΩ V_{g1} = −38 V V_{g3} = 0 V	I_{amin} = 2× 30 I_{amax} = 2× 120 I_{g2min} = 2× 4.4 I_{g2max} = 2× 25	R_{aa} = 3.4 kΩ W_o = 55 W
		V_{ba} = 800 V V_{bg2} = 400 V V_{g1} = −39 V R_{g2} = 750 Ω V_{g3} = 0 V	I_{amin} = 2× 25 I_{amax} = 2× 91 I_{g2min} = 2× 3 I_{g2max} = 2× 19	R_{aa} = 11 kΩ W_o = 100 W



Octal



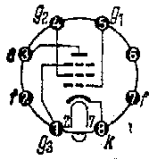
EL 34
6 CA 7

Endpentode

Verwendung für Kraftverstärker

Power Pentode

for Power Amplifier



Oktal

Kolben Nr. 23
Bulb No. 23

Allgemeine Daten General Data	Kenn- und Betriebsdaten Characteristics and Typical Operation		Grenzdaten Maximum Ratings
Heizung Heating	**Betriebsdaten** Typical Operation		U_{akalt} = 2000 V
U_f = 6,3 V	**Eintakt A**		U_a = 800 V
I_f = 1,5 A	Class A		Q_a ($U_{g_1\sim}$ = 0)
indirekt indirect	U_b = 265	265 V	= 25 W)
	U_a = 250	250 V	Q_a ($U_{g_1\sim}$ > 0)
	R_{g_2} = 2	0 kΩ	= 27,5 W
	U_{g_3} = 0	0 V	U_{g_2kalt} = 800 V
Kapazitäten Capacitances	U_{g_1} = −14;5	−13,5 V	U_{g_2} = 425 V
	I_a = 70	100 mA	Q_{g_2} = 8 W
C_{ein} = 15,5 pF	I_{g_2} = 10	14,9 mA	I_k = 150 mA
C_{ausg} = 7,2 pF	S = 9,0	11 mA/V	R_{g_1} = 0,7 MΩ*
C_{ag_1} < 1,0 pF	R_i = 18	15 kΩ	R_{g_1} = 0,5 MΩ**
C_{g_1f} < 1,0 pF	R_a = 3,0	2,0 kΩ	U_{fk} = 100 V
C_{kf} = 11 pF	$U_{g_1\sim}$ = 9,3	8,7 V_{eff}	R_{fk} = 20 kΩ
	$N_\sim$ = 8	11 W	* Kl. A und AB
	k = 10	10 %	** Kl. B
	$U_{g_1\sim}$ $N_\sim$ (= 50 mW)		
	= 0,65	0,5 V_{eff}	
	$\mu_{g_2g_1}$ = 11	11	

Data of the EL34 taken form from the Philips pocket-book 1958 and the Siemens pocket book 1964, the only data available to me at that time. The next pages from Philips gives a little more detailed information of the valves.

While numerous application notes from various valve manufacturers on optimising push-pull stages exist, no such are to the best of knowledge given for SE-stages.

A.F. DOUBLE TRIODE

Double triode intended for use as A.F. amplifier.

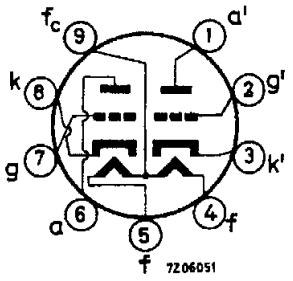
QUICK REFERENCE DATA (each unit)			
Anode current	I_a	1.2	mA
Transconductance	S	1.6	mA/V
Amplification factor	μ	100	–

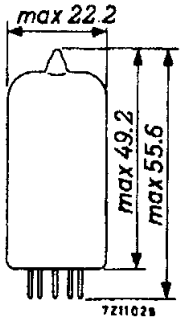
HEATING: Indirect by A.C. or D.C.; series or parallel supply

Heater voltage	V_f	6.3	12.6	V
Heater current	I_f	300	150	mA
		pins 9-(4+5)	pins 4-5	

DIMENSIONS AND CONNECTIONS Dimensions in mm

Base: Noval





REMARK

With V_f applied to pins 9 and 4+5 and the centre tap of the heater transformer connected to earth, the triode section connected to pins 6, 7 and 8 is the more favourable section of the tube with respect to hum.

CAPACITANCES

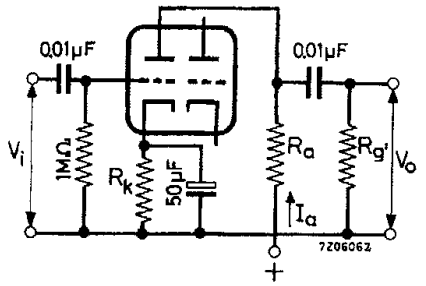
Grid to all except anode	$C_{g(a)}$	1.6	pF
	$C_{g'(a')}$	1.6	pF
Anode to all except grid	$C_{a(g)}$	0.33	pF
	$C_{a'(g')}$	0.23	pF
Anode to grid	C_{ag}	1.6	pF
	$C_{a'g'}$	1.6	pF
Grid to heater	C_{gf}	max. 0.15	pF
	$C_{g'f}$	max. 0.15	pF
Anode to anode	$C_{aa'}$	max. 1.2	pF
Anode to grid other unit	$C_{ag'}$	max. 0.11	pF
Grid to anode other unit	$C_{ga'}$	max. 0.1	pF
Grid to grid	$C_{gg'}$	max. 0.01	pF

TYPICAL CHARACTERISTICS

Anode voltage	V_a	100	250	V
Grid voltage	V_g	−1.0	−2.0	V
Anode current	I_a	0.5	1.2	mA
Transconductance	S	1.25	1.6	mA/V
Amplification factor	μ	100	100	–
Internal resistance	R_i	80	62.5	kΩ

OPERATING CHARACTERISTICS

As A.F. amplifier, one unit



Supply voltage	V_b	200	250	300	350	400	V
Anode resistor	R_a	47	47	47	47	47	kΩ
Grid resistor next stage	$R_{g'}$	150	150	150	150	150	kΩ
Cathode resistor	R_k	1500	1200	1000	820	680	Ω
Anode current	I_a	0.86	1.18	1.55	1.98	2.45	mA
Voltage gain	V_o/V_i	34	37.5	40	42.5	44	-
Output voltage (I_g = 0.3 μA)	V_o	18	23	26	33	37	V_{RMS}
Total distortion	d_{tot}	8.5	7.0	5.0	4.4	3.6	%
Supply voltage	V_b	200	250	300	350	400	V
Anode resistor	R_a	100	100	100	100	100	kΩ
Grid resistor next stage	$R_{g'}$	330	330	330	330	330	kΩ
Cathode resistor	R_k	1800	1500	1200	1000	820	Ω
Anode current	I_a	0.65	0.86	1.11	1.40	1.72	mA
Voltage gain	V_o/V_i	50	54.5	57	61	63	-
Output voltage (I_g = 0.3 μA)	V_o	20	26	30	36	38	V_{RMS}
Total distortion	d_{tot}	4.8	3.9	2.7	2.2	1.7	%
Supply voltage	V_b	200	250	300	350	400	V
Anode resistor	R_a	220	220	220	220	220	kΩ
Grid resistor next stage	$R_{g'}$	680	680	680	680	680	kΩ
Cathode resistor	R_k	3.3	2.7	2.2	1.5	1.2	kΩ
Anode current	I_a	0.36	0.48	0.63	0.85	1.02	mA
Voltage gain	V_o/V_i	56	66.5	72	75.5	76.5	-
Output voltage (I_g = 0.3 μA)	V_o	24	28	36	37	38	V_{RMS}
Total distortion	d_{tot}	4.6	3.4	2.6	1.6	1.1	%

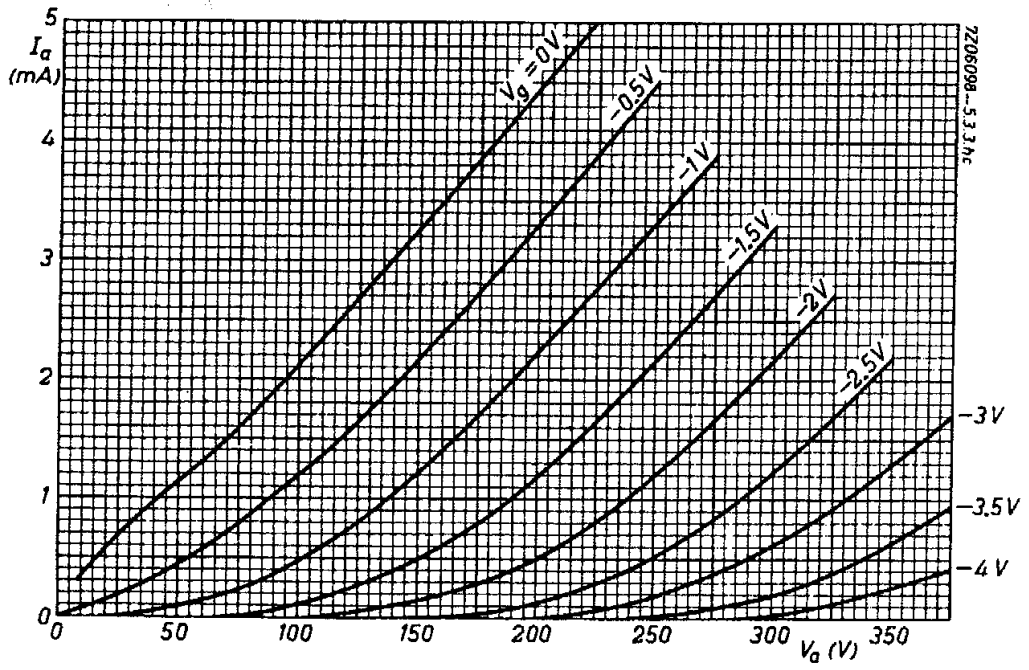
LIMITING VALUES (Design centre rating system)

Anode voltage	V_{a_o}	max. 550	V
	V_a	max. 300	V
Anode dissipation	W_a	max. 1	W
Cathode current	I_k	max. 8	mA
Grid voltage	$-V_g$	max. 50	V
Grid resistor (automatic bias)	R_g	max. 2	MΩ
Cathode to heater voltage	V_{kf}	max. 180	V
Cathode to heater circuit resistance in phase splitting circuits	R_{kf}	max. 150	kΩ

REMARK

Microphony and hum

This tube can be used without special precautions against microphony in equipment in which the input voltage $V_i \geqq 5$ mV for an output of 50 mW (or 50 mV for an output of 5 W) provided the average acceleration of the tube is not greater than indicated in the section "Microphonic effect" of the "Application directions". In this case the disturbance level for hum and noise will be better than −60 dB when the centre tap of the heater has been earthed, $R_g \leqq 0.5$ MΩ and the cathode resistor is sufficiently decoupled.



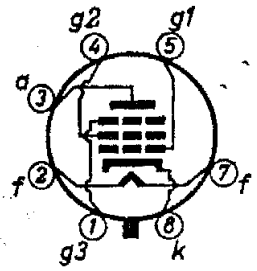
PHILIPS

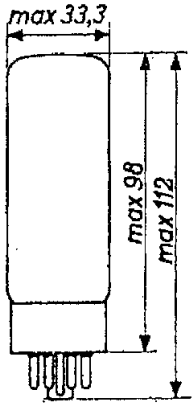
EL 34

OUTPUT PENTODE
PENTHODE DE SORTIE
ENDPENTODE

Heating:	indirect by A.C. or D.C.; parallel supply	V_f = 6,3 V
Chauffage:	indirect par C.A. ou C.C.; alimentation en parallèle	I_f = 1,5 A
Heizung:	indirekt durch Wechsel- oder Gleichstrom; Parallelspeisung	

Dimensions in mm
Dimensions en mm
Abmessungen in mm





Base
Culot OCTAL
Sockel

Socket
Support 5903/13
Fassung

Capacitances
Capacités
Kapazitäten

C_{g1}	=	15,2 pF
C_a	=	8,4 pF
C_{ag1}	<	1,1 pF
C_{g1f}	<	1,0 pF
C_{kf}	=	10 pF

Remark When using a sinusoidal input signal care should be taken not to exceed the maximum admissible W_{g2}.

Observation En cas d'un signal d'entrée sinusoïdal il faut faire attention à ne pas dépasser la valeur maximum admissible de W_{g2}.

Bemerkung Bei Verwendung eines sinusförmigen Eingangssignales muss darauf geachtet werden dass der maximal zulässige Wert von W_{g2} nicht überschritten wird.

EL 34 PHILIPS

Operating characteristics class A
Caractéristiques d'utilisation classe A
Betriebsdaten Klasse A

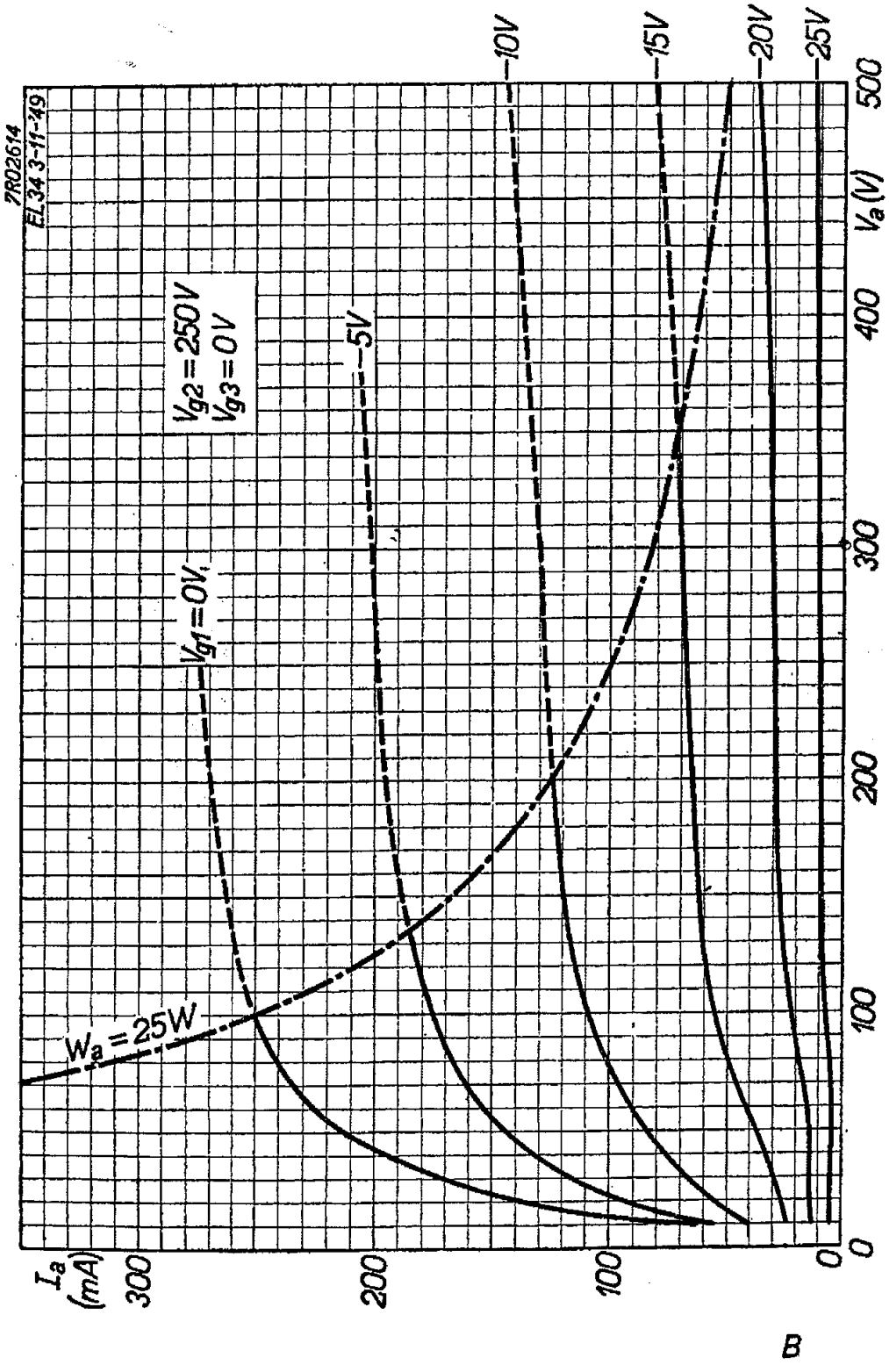
V_b	= 265	265	V
V_a	= 250	250	V
R_{g2}	= 2	0	kΩ
V_{g3}	= 0	0	V
V_{g1}	= -14,5	-13,5	V
I_a	= 70	100	mA
I_{g2}	= 10	14,9	mA
S	= 9,0	11	mA/V
μ_{g2g1}	= 11	11	
R_i	= 18	15	kΩ
R_a	= 3,0	2,0	kΩ
V_i	= 9,3	8,7	V_{eff}
W_o	= 8	11	W
d_{tot}	= 10	10	%
V_i (W_o = 50 mW)	= 0,65	0,5	V_{eff}

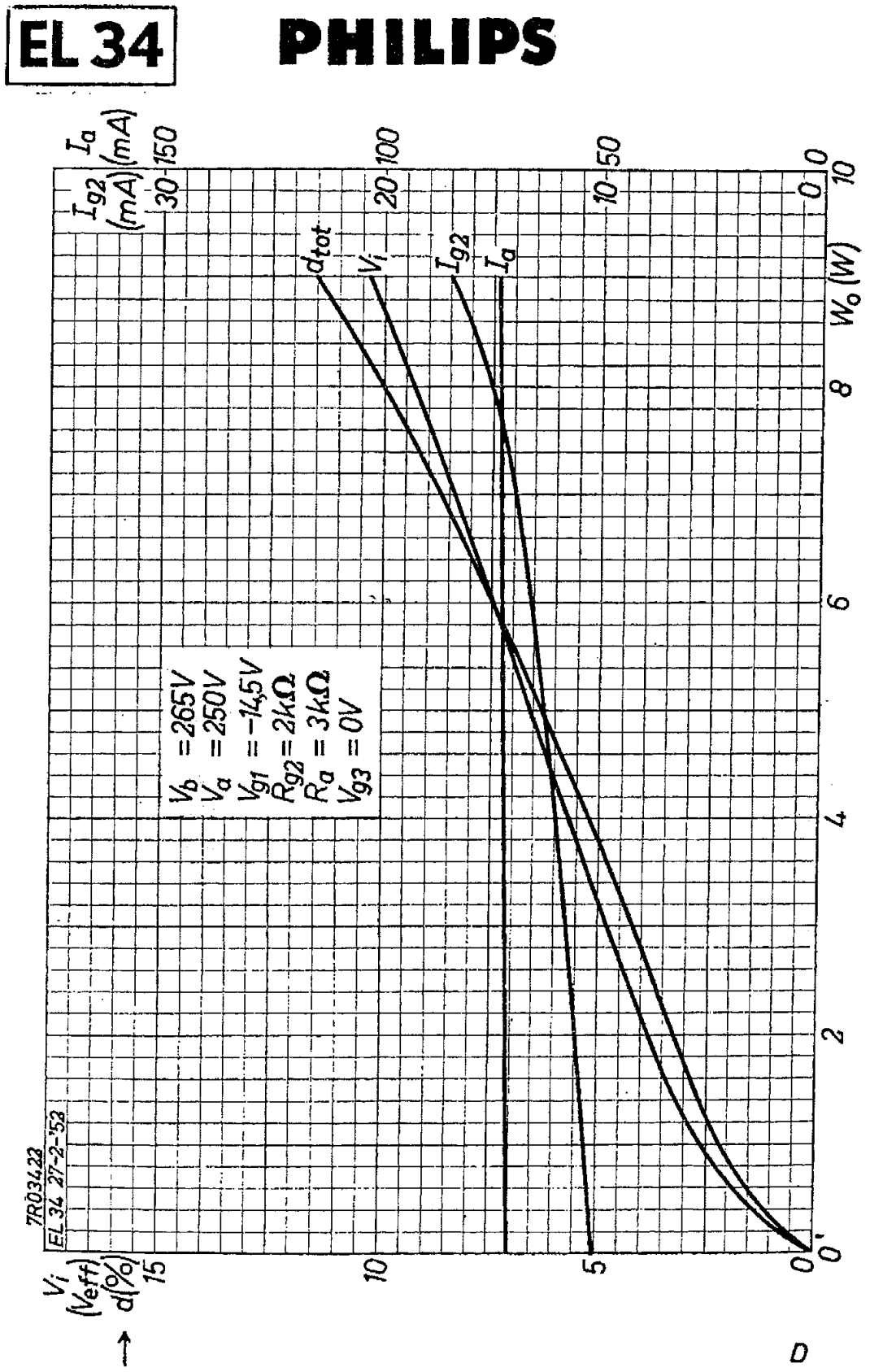
Operating characteristics class B
Caractéristiques d'utilisation classe B
Betriebsdaten Klasse B

R_{g2}	=	1000			470		Ω [1]
V_{g1}	=	-38			-32		V
V_{g3}	=	0			0		V
V_i	=	0	27	27	0	22,7	22,7	V_{eff}
R_{aa}	=	-	3,4	4,0	-	2,8	3,8	kΩ
V_b	=	425	425	400	375	375	350	V
V_a	=	420	400	375	370	350	325	V
I_a	=	2x30	2x120	2x100	2x35	2x120	2x93	mA
I_{g2}	=	2x4,4	2x25	2x25	2x4,7	2x25	2x25	mA
W_o	=	0	55	45	0	44	36	W
d_{tot}	=	-	5	6	-	5	6	%

[1]) Common screen grid resistor; non decoupled
Résistance de grille-écran commune; ne pas découplée
Gemeinsamer Schirmgitterwiderstand; nicht entkoppelt

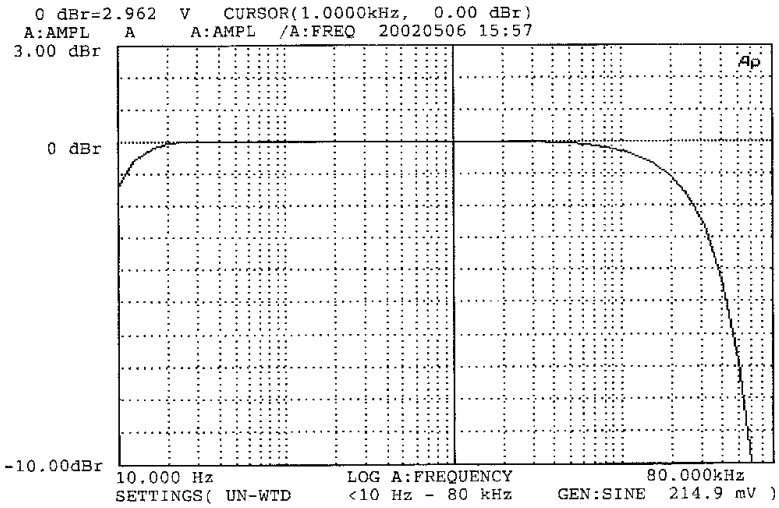
EL 34 PHILIPS





Performance of the standard single-end pentode output stage according to recommendations from the table. Note that distortion, d, exceeds 10% at 8W

1W
no NFB

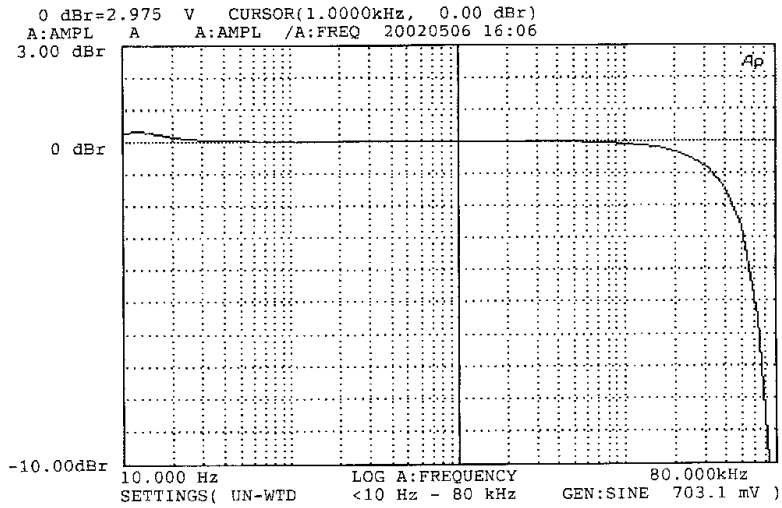


AGEN FREQ	AMPL	A
10.000 Hz	-1.39	dBr
12.500 Hz	-0.58	dBr
16.000 Hz	-0.19	dBr
20.000 Hz	-0.06	dBr
25.000 Hz	-0.01	dBr
31.500 Hz	0.00	dBr
40.000 Hz	0.00	dBr
50.000 Hz	0.00	dBr
63.000 Hz	0.00	dBr
80.000 Hz	0.00	dBr
100.00 Hz	0.00	dBr
125.00 Hz	0.00	dBr
160.00 Hz	0.00	dBr
200.00 Hz	0.00	dBr

AGEN FREQ	AMPL	A
250.00 Hz	0.00	dBr
315.00 Hz	0.00	dBr
400.00 Hz	0.00	dBr
500.00 Hz	0.00	dBr
630.00 Hz	0.00	dBr
800.00 Hz	0.00	dBr
1.0000kHz	0.00	dBr
1.2500kHz	0.00	dBr
1.6000kHz	0.00	dBr
2.0000kHz	-0.01	dBr
2.5000kHz	-0.02	dBr
3.1500kHz	-0.03	dBr
4.0000kHz	-0.05	dBr
5.0000kHz	-0.08	dBr

AGEN FREQ	AMPL	A	Ap
6.3000kHz	-0.13	dBr	
8.0000kHz	-0.20	dBr	
10.000kHz	-0.31	dBr	
12.500kHz	-0.46	dBr	
16.000kHz	-0.73	dBr	
20.000kHz	-1.11	dBr	
25.000kHz	-1.69	dBr	
31.500kHz	-2.69	dBr	
40.000kHz	-4.32	dBr	
50.000kHz	-6.82	dBr	
63.000kHz	-11.27	dBr	
80.000kHz	-19.84	dBr	

1W
10 dB of NFB



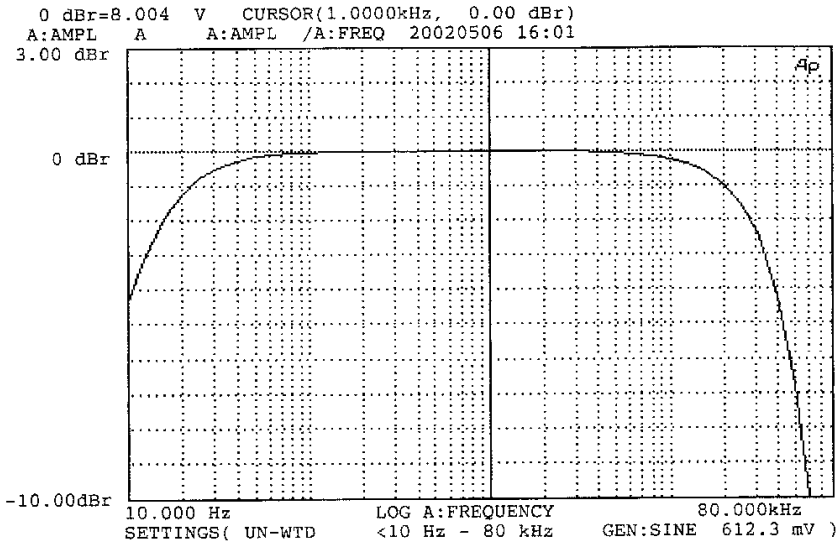
AGEN FREQ	AMPL	A
10.000 Hz	0.30	dBr
12.500 Hz	0.31	dBr
16.000 Hz	0.22	dBr
20.000 Hz	0.14	dBr
25.000 Hz	0.09	dBr
31.500 Hz	0.05	dBr
40.000 Hz	0.03	dBr
50.000 Hz	0.02	dBr
63.000 Hz	0.01	dBr
80.000 Hz	0.00	dBr
100.00 Hz	0.00	dBr
125.00 Hz	0.00	dBr
160.00 Hz	0.00	dBr
200.00 Hz	0.00	dBr

AGEN FREQ	AMPL	A
250.00 Hz	0.00	dBr
315.00 Hz	0.00	dBr
400.00 Hz	0.00	dBr
500.00 Hz	0.00	dBr
630.00 Hz	0.00	dBr
800.00 Hz	0.00	dBr
1.0000kHz	0.00	dBr
1.2500kHz	0.00	dBr
1.6000kHz	0.00	dBr
2.0000kHz	0.00	dBr
2.5000kHz	0.00	dBr
3.1500kHz	0.00	dBr
4.0000kHz	-0.01	dBr
5.0000kHz	-0.02	dBr

AGEN FREQ	AMPL	A	Ap
6.3000kHz	-0.04	dBr	
8.0000kHz	-0.06	dBr	
10.000kHz	-0.09	dBr	
12.500kHz	-0.14	dBr	
16.000kHz	-0.22	dBr	
20.000kHz	-0.33	dBr	
25.000kHz	-0.52	dBr	
31.500kHz	-0.85	dBr	
40.000kHz	-1.46	dBr	
50.000kHz	-2.66	dBr	
63.000kHz	-5.50	dBr	
80.000kHz	-12.87	dBr	

Frequency response at
1W with and without NFB

8W
no NFB

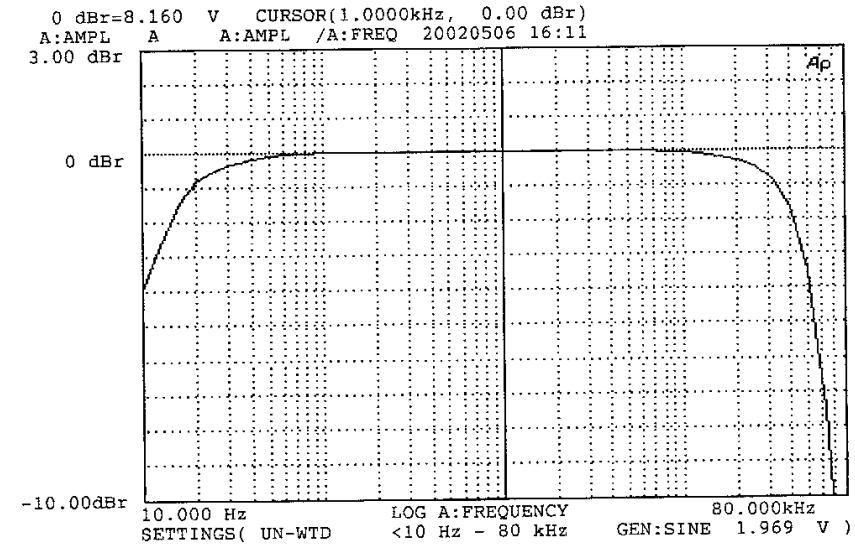


AGEN FREQ	AMPL	A
10.000 Hz	-4.32	dBr
12.500 Hz	-2.98	dBr
16.000 Hz	-1.85	dBr
20.000 Hz	-1.22	dBr
25.000 Hz	-0.78	dBr
31.500 Hz	-0.47	dBr
40.000 Hz	-0.28	dBr
50.000 Hz	-0.17	dBr
63.000 Hz	-0.10	dBr
80.000 Hz	-0.06	dBr
100.00 Hz	-0.04	dBr
125.00 Hz	-0.02	dBr
160.00 Hz	-0.01	dBr
200.00 Hz	-0.01	dBr

AGEN FREQ	AMPL	A
250.00 Hz	0.00	dBr
315.00 Hz	0.00	dBr
400.00 Hz	0.00	dBr
500.00 Hz	0.00	dBr
630.00 Hz	0.00	dBr
800.00 Hz	0.00	dBr
1.0000kHz	0.00	dBr
1.2500kHz	0.00	dBr
1.6000kHz	0.00	dBr
2.0000kHz	-0.01	dBr
2.5000kHz	-0.01	dBr
3.1500kHz	-0.02	dBr
4.0000kHz	-0.04	dBr
5.0000kHz	-0.06	dBr

AGEN FREQ	AMPL	A	Ap
6.3000kHz	-0.10	dBr	
8.0000kHz	-0.16	dBr	
10.000kHz	-0.24	dBr	
12.500kHz	-0.39	dBr	
16.000kHz	-0.63	dBr	
20.000kHz	-0.99	dBr	
25.000kHz	-1.56	dBr	
31.500kHz	-2.53	dBr	
40.000kHz	-4.20	dBr	
50.000kHz	-6.77	dBr	
63.000kHz	-11.35	dBr	
80.000kHz	-19.93	dBr	

8W
10dB of
NFB



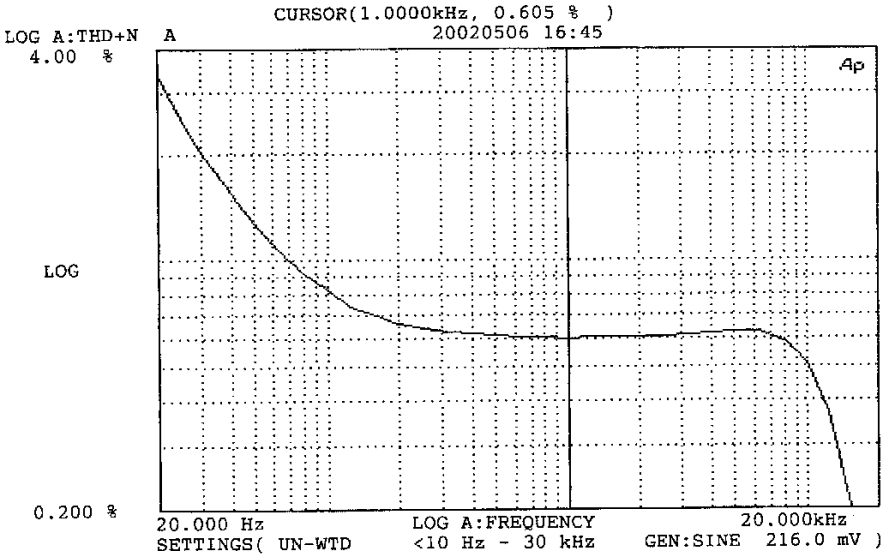
Frequency response at 8W with and without NFB

AGEN FREQ	AMPL	A
10.000 Hz	-3.92	dBr
12.500 Hz	-2.67	dBr
16.000 Hz	-1.41	dBr
20.000 Hz	-0.79	dBr
25.000 Hz	-0.53	dBr
31.500 Hz	-0.35	dBr
40.000 Hz	-0.20	dBr
50.000 Hz	-0.13	dBr
63.000 Hz	-0.07	dBr
80.000 Hz	-0.04	dBr
100.00 Hz	-0.03	dBr
125.00 Hz	-0.02	dBr
160.00 Hz	-0.01	dBr
200.00 Hz	-0.01	dBr

AGEN FREQ	AMPL	A
250.00 Hz	-0.01	dBr
315.00 Hz	0.00	dBr
400.00 Hz	0.00	dBr
500.00 Hz	0.00	dBr
630.00 Hz	0.00	dBr
800.00 Hz	0.00	dBr
1.0000kHz	0.00	dBr
1.2500kHz	0.00	dBr
1.6000kHz	0.00	dBr
2.0000kHz	0.00	dBr
2.5000kHz	0.00	dBr
3.1500kHz	0.00	dBr
4.0000kHz	-0.01	dBr
5.0000kHz	-0.02	dBr

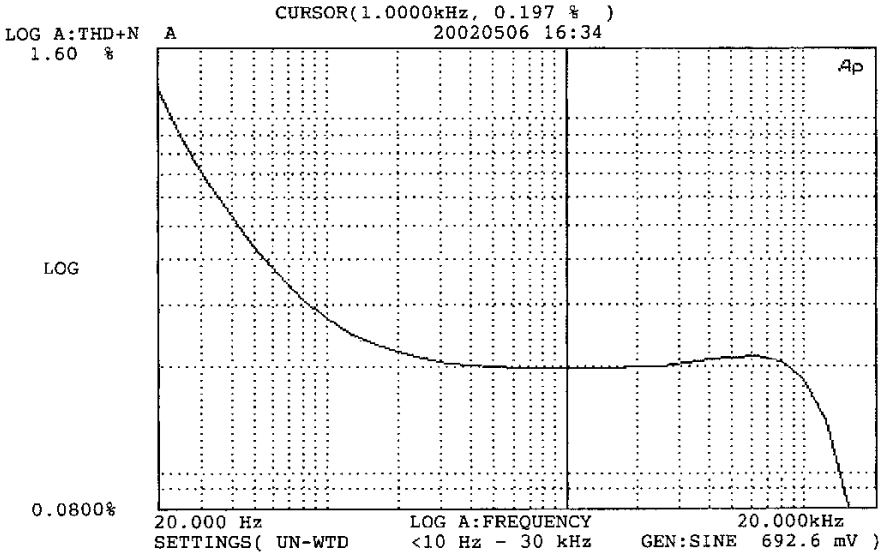
AGEN FREQ	AMPL	A	Ap
6.3000kHz	-0.03	dBr	
8.0000kHz	-0.06	dBr	
10.000kHz	-0.08	dBr	
12.500kHz	-0.11	dBr	
16.000kHz	-0.18	dBr	
20.000kHz	-0.29	dBr	
25.000kHz	-0.47	dBr	
31.500kHz	-0.86	dBr	
40.000kHz	-1.67	dBr	
50.000kHz	-3.50	dBr	
63.000kHz	-7.49	dBr	
80.000kHz	-15.76	dBr	

1W
no NFB



AGEN FREQ	THD+N	A	AGEN FREQ	THD+N	A	AGEN FREQ	THD+N	A	Ap
20.000 Hz	3.36	%	250.00 Hz	0.641	%	3.1500kHz	0.615	%	
25.000 Hz	2.54	%	315.00 Hz	0.628	%	4.0000kHz	0.622	%	
31.500 Hz	1.95	%	400.00 Hz	0.621	%	5.0000kHz	0.630	%	
40.000 Hz	1.54	%	500.00 Hz	0.612	%	6.3000kHz	0.627	%	
50.000 Hz	1.27	%	630.00 Hz	0.609	%	8.0000kHz	0.590	%	
63.000 Hz	1.07	%	800.00 Hz	0.606	%	10.000kHz	0.508	%	
80.000 Hz	0.921	%	1.0000kHz	0.605	%	12.500kHz	0.367	%	
100.00 Hz	0.824	%	1.2500kHz	0.605	%	16.000kHz	0.175	%	
125.00 Hz	0.744	%	1.6000kHz	0.606	%	20.000kHz	0.0742	%	
160.00 Hz	0.697	%	2.0000kHz	0.608	%				
200.00 Hz	0.666	%	2.5000kHz	0.609	%				

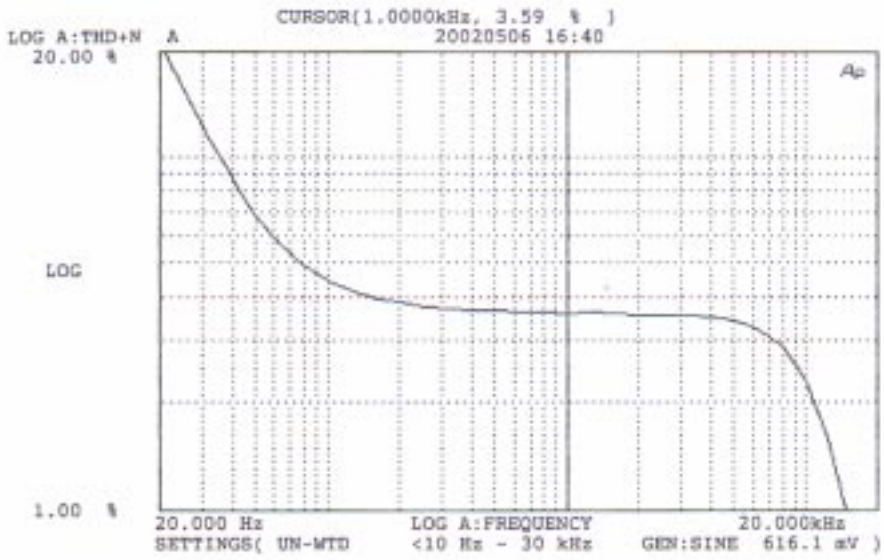
1W
10dB of NFB



Distortion is frequency at 1W with and without NFB
Note: Different vertical scales

AGEN FREQ	THD+N	A	AGEN FREQ	THD+N	A	AGEN FREQ	THD+N	A	Ap
20.000 Hz	1.22	%	250.00 Hz	0.211	%	3.1500kHz	0.203	%	
25.000 Hz	0.899	%	315.00 Hz	0.205	%	4.0000kHz	0.207	%	
31.500 Hz	0.682	%	400.00 Hz	0.202	%	5.0000kHz	0.212	%	
40.000 Hz	0.533	%	500.00 Hz	0.199	%	6.3000kHz	0.214	%	
50.000 Hz	0.435	%	630.00 Hz	0.198	%	8.0000kHz	0.206	%	
63.000 Hz	0.363	%	800.00 Hz	0.197	%	10.000kHz	0.184	%	
80.000 Hz	0.310	%	1.0000kHz	0.197	%	12.500kHz	0.140	%	
100.00 Hz	0.274	%	1.2500kHz	0.197	%	16.000kHz	0.0723	%	
125.00 Hz	0.249	%	1.6000kHz	0.197	%	20.000kHz	0.0319	%	
160.00 Hz	0.230	%	2.0000kHz	0.199	%				
200.00 Hz	0.219	%	2.5000kHz	0.200	%				

8W
no NFB

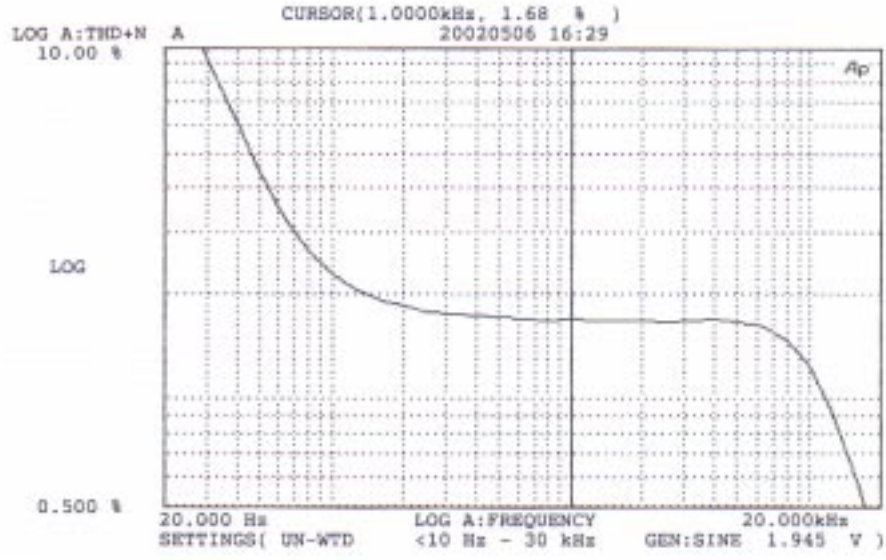


AGEN FREQ	THD+N	A
20.000 Hz	20.94	%
25.000 Hz	15.72	%
31.500 Hz	11.60	%
40.000 Hz	8.63	%
50.000 Hz	6.84	%
63.000 Hz	5.68	%
80.000 Hz	4.93	%
100.00 Hz	4.46	%
125.00 Hz	4.18	%
160.00 Hz	3.95	%
200.00 Hz	3.84	%

AGEN FREQ	THD+N	A
250.00 Hz	3.76	%
315.00 Hz	3.70	%
400.00 Hz	3.67	%
500.00 Hz	3.64	%
630.00 Hz	3.62	%
800.00 Hz	3.60	%
1.0000kHz	3.59	%
1.2500kHz	3.60	%
1.6000kHz	3.57	%
2.0000kHz	3.55	%
2.5000kHz	3.54	%

AGEN FREQ	THD+N	A	Ap
3.1500kHz	3.52	%	
4.0000kHz	3.50	%	
5.0000kHz	3.42	%	
6.3000kHz	3.25	%	
8.0000kHz	2.88	%	
10.000kHz	2.30	%	
12.500kHz	1.58	%	
16.000kHz	0.810	%	
20.000kHz	0.340	%	

8W
10dB of NFB



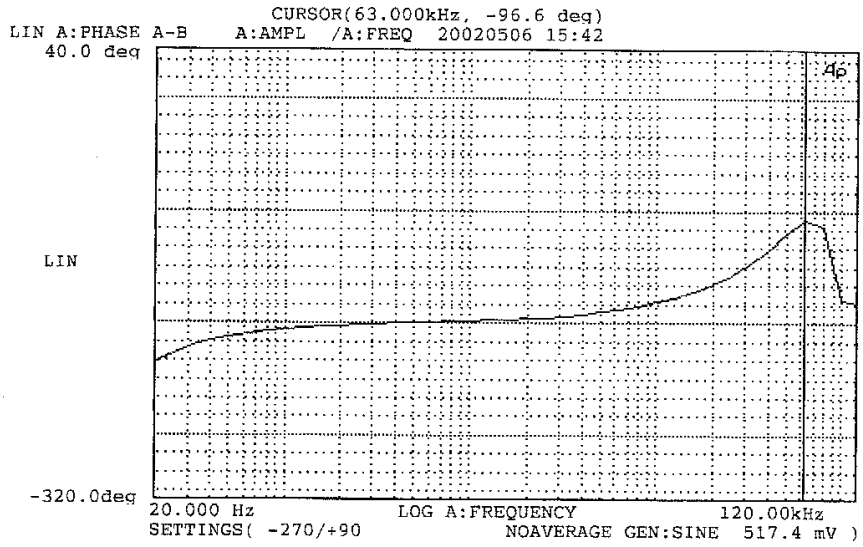
Distortion is frequency at 8W with and without NFB
Note = Different vertical scales

AGEN FREQ	THD+N	A
20.000 Hz	16.46	%
25.000 Hz	12.10	%
31.500 Hz	8.73	%
40.000 Hz	6.11	%
50.000 Hz	4.43	%
63.000 Hz	3.30	%
80.000 Hz	2.64	%
100.00 Hz	2.28	%
125.00 Hz	2.06	%
160.00 Hz	1.91	%
200.00 Hz	1.85	%

AGEN FREQ	THD+N	A
250.00 Hz	1.78	%
315.00 Hz	1.75	%
400.00 Hz	1.72	%
500.00 Hz	1.71	%
630.00 Hz	1.69	%
800.00 Hz	1.68	%
1.0000kHz	1.68	%
1.2500kHz	1.68	%
1.6000kHz	1.67	%
2.0000kHz	1.68	%
2.5000kHz	1.66	%

AGEN FREQ	THD+N	A	Ap
3.1500kHz	1.68	%	
4.0000kHz	1.69	%	
5.0000kHz	1.66	%	
6.3000kHz	1.61	%	
8.0000kHz	1.47	%	
10.000kHz	1.24	%	
12.500kHz	0.934	%	
16.000kHz	0.590	%	
20.000kHz	0.362	%	

With 10dB of NFB



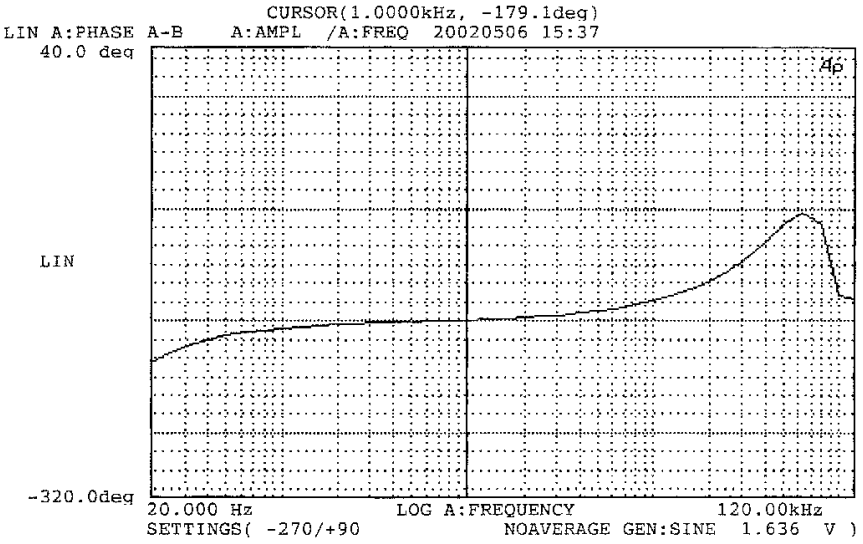
Max shift
- 41.2^0 at 20Hz
+83.4^0 at 63 kHz

AGEN FREQ	PHASE A-B
20.000 Hz	-212.4deg
25.000 Hz	-204.3deg
31.500 Hz	-198.4deg
40.000 Hz	-194.1deg
50.000 Hz	-191.0deg
63.000 Hz	-188.4deg
80.000 Hz	-186.4deg
100.00 Hz	-184.9deg
125.00 Hz	-183.7deg
160.00 Hz	-182.6deg
200.00 Hz	-181.7deg
250.00 Hz	-181.1deg
315.00 Hz	-180.5deg
400.00 Hz	-180.0deg

AGEN FREQ	PHASE A-B
500.00 Hz	-179.6deg
630.00 Hz	-179.1deg
800.00 Hz	-178.7deg
1.0000kHz	-178.1deg
1.2500kHz	-177.6deg
1.6000kHz	-177.0deg
2.0000kHz	-176.2deg
2.5000kHz	-175.3deg
3.1500kHz	-174.1deg
4.0000kHz	-172.6deg
5.0000kHz	-170.9deg
6.3000kHz	-168.7deg
8.0000kHz	-166.1deg
10.000kHz	-163.0deg

AGEN FREQ	PHASE A-B Ap
12.500kHz	-159.4deg
16.000kHz	-154.4deg
20.000kHz	-148.7deg
25.000kHz	-141.6deg
31.500kHz	-132.2deg
40.000kHz	-120.0deg
50.000kHz	-107.7deg
63.000kHz	-96.6 deg
80.000kHz	-101.8deg
100.00kHz	-161.6deg
120.00kHz	-164.3deg

No NFB



Max shift
- 43.2^0 at 20Hz
+86.5^0 at 63 kHz

Phase shift from grid of driver to output i.e. within the feedbach loop.
Since the amplifier inverts -180^0 represents no phase shift of unwanted character.

AGEN FREQ	PHASE A-B
20.000 Hz	-213.2deg
25.000 Hz	-205.8deg
31.500 Hz	-199.9deg
40.000 Hz	-195.3deg
50.000 Hz	-192.1deg
63.000 Hz	-189.5deg
80.000 Hz	-187.4deg
100.00 Hz	-185.9deg
125.00 Hz	-184.7deg
160.00 Hz	-183.6deg
200.00 Hz	-182.8deg
250.00 Hz	-182.1deg
315.00 Hz	-181.5deg
400.00 Hz	-181.0deg

AGEN FREQ	PHASE A-B
500.00 Hz	-180.5deg
630.00 Hz	-180.1deg
800.00 Hz	-179.6deg
1.0000kHz	-179.1deg
1.2500kHz	-178.6deg
1.6000kHz	-177.9deg
2.0000kHz	-177.1deg
2.5000kHz	-176.3deg
3.1500kHz	-175.1deg
4.0000kHz	-173.7deg
5.0000kHz	-172.0deg
6.3000kHz	-169.9deg
8.0000kHz	-167.2deg
10.000kHz	-164.0deg

AGEN FREQ	PHASE A-B Ap
12.500kHz	-160.0deg
16.000kHz	-154.4deg
20.000kHz	-147.9deg
25.000kHz	-140.2deg
31.500kHz	-130.4deg
40.000kHz	-117.0deg
50.000kHz	-102.4deg
63.000kHz	-93.5 deg
80.000kHz	-101.8deg
100.00kHz	-159.9deg
120.00kHz	-163.1deg