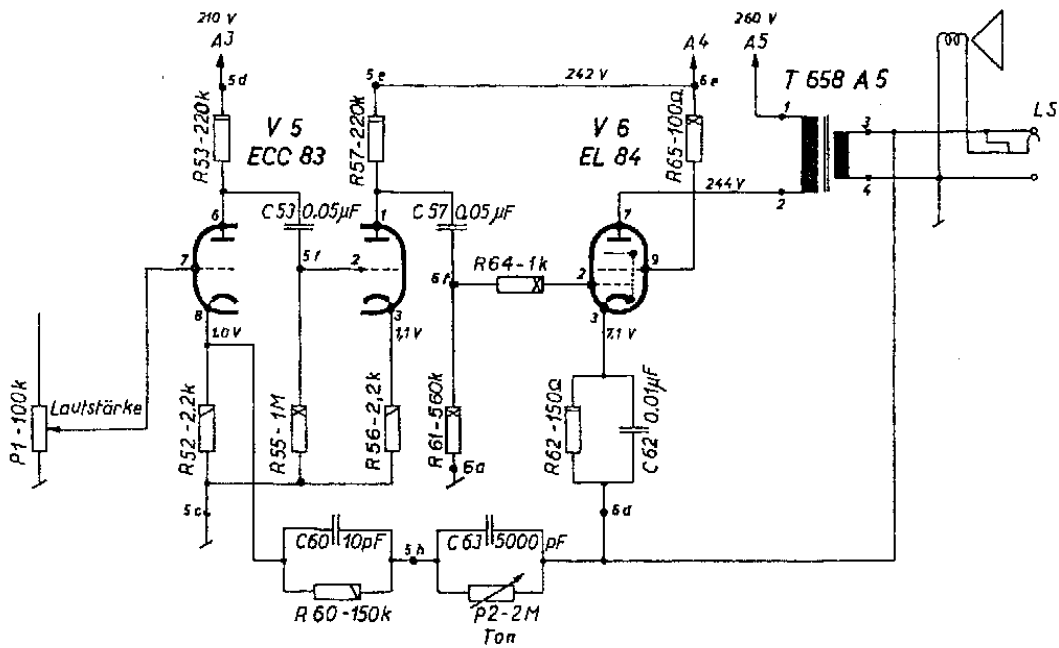
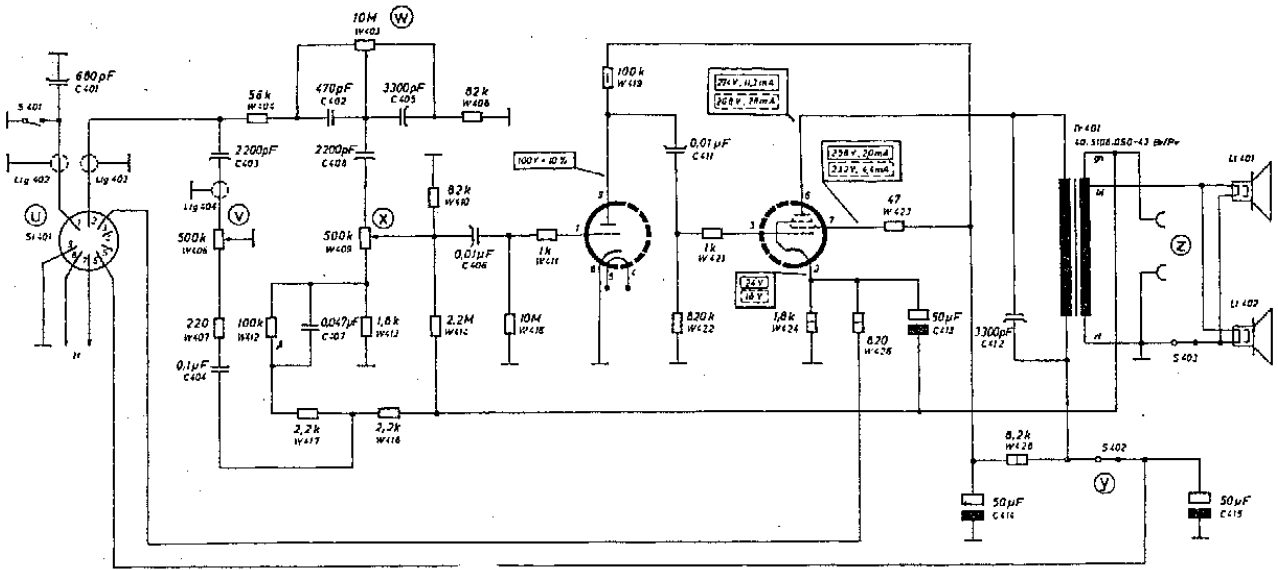


# Appendix

- **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**

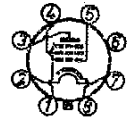
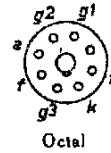


Two diagrams showing typical SE-amplifiers from the late fifties.

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.

|  |  |   |  |  |
|--|--|---|--|--|
| <b>EL 34</b><br>Class A final<br>amplifier   |  | $V_a = 250 \text{ V}$<br>$V_{g2} = 265 \text{ V}$<br>$V_{g1} = -13.5 \text{ V}$<br>$V_{g3} = 0 \text{ V}$ | $I_a = 100$<br>$I_{g2} = 15$   | $S = 11 \text{ mA/V}$<br>$R_i = 15 \text{ k}\Omega$<br>$R_a = 2 \text{ k}\Omega$<br>$W_o = 11 \text{ W}$<br>$W_a = 25 \text{ W}$ |
|  | <b>EL 34</b><br>Output<br>pentode<br>Class AB<br>push-pull<br>amplifier<br>Class B<br>push-pull<br>amplifier | $V_f = 6.3 \text{ V}$<br>$I_f = 1.5 \text{ A}$  | $V_b = 375 \text{ V}$<br>$R_{g2}^{(1)} = 470 \Omega$<br>$R_k = 130 \Omega$<br>$V_{g3} = 0 \text{ V}$                     | $I_{a \min} = 2 \times 75$<br>$I_{a \max} = 2 \times 95$<br>$I_{g2 \min} = 2 \times 11.5$<br>$I_{g2 \max} = 2 \times 22.5$       |
| $V_b = 425 \text{ V}$<br>$R_{g2}^{(1)} = 1 \text{ k}\Omega$<br>$V_{g1} = -38 \text{ V}$<br>$V_{g3} = 0 \text{ V}$                    |  |   | $I_{a \min} = 2 \times 30$<br>$I_{a \max} = 2 \times 120$<br>$I_{g2 \min} = 2 \times 4.4$<br>$I_{g2 \max} = 2 \times 25$ | $R_{aa} = 3.4 \text{ k}\Omega$<br>$W_o = 55 \text{ W}$   |
| $V_{ba} = 800 \text{ V}$<br>$V_{bg2} = 400 \text{ V}$<br>$V_{g1} = -39 \text{ V}$<br>$R_{g2} = 750 \Omega$<br>$V_{g3} = 0 \text{ V}$ |  |   | $I_{a \min} = 2 \times 25$<br>$I_{a \max} = 2 \times 91$<br>$I_{g2 \min} = 2 \times 3$<br>$I_{g2 \max} = 2 \times 19$    | $R_{aa} = 11 \text{ k}\Omega$<br>$W_o = 100 \text{ W}$   |



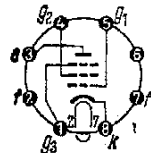
Octal

**EL 34**  
**6 CA 7**

Endpentode

Verwendung  
für Kraftverstärker

Power Pentode  
for Power Amplifier



Oktaal

Kolben Nr. 23  
Bulb No. 23

| Allgemeine Daten<br>General Data   | Kenn- und Betriebsdaten<br>Characteristics and Typical Operation   |  | Grenzdaten<br>Maximum Ratings   |
|--|--|--|---|
| <b>Helzung</b><br>Heating<br><br>$U_f = 6.3 \text{ V}$<br>$I_f = 1.5 \text{ A}$<br>Indirekt<br>indirect<br><br><b>Kapazitäten</b><br>Capacitances<br>$C_{eing} = 15.5 \text{ pF}$<br>$C_{ausg} = 7.2 \text{ pF}$<br>$C_{ag1} < 1.0 \text{ pF}$<br>$C_{g1f} < 1.0 \text{ pF}$<br>$C_{kf} = 11 \text{ pF}$ | <b>Betriebsdaten</b><br>Typical Operation<br><br><b>Eintakt A</b><br>Class A<br>$U_b = 265$ 265 V<br>$U_a = 250$ 250 V<br>$R_{g2} = 2$ 0 k $\Omega$<br>$U_{g3} = 0$ 0 V<br>$U_{g1} = -14.5$ -13.5 V<br>$I_a = 70$ 100 mA<br>$I_{g2} = 10$ 14.9 mA<br>$S = 9.0$ 11 mA/V<br>$R_i = 18$ 15 k $\Omega$<br>$R_a = 3.0$ 2.0 k $\Omega$<br>$U_{g1 \sim} = 9.3$ 8.7 V <sub>eff</sub><br>$N_{\sim} = 8$ 11 W<br>$k = 10$ 10 %<br>$U_{g1 \sim} N_{\sim} (= 50 \text{ mW})$<br>= 0.65                      0.5 V <sub>eff</sub><br>$\mu_{g1g1} = 11$ 11 |  | $U_{a \text{ kalt}} = 2000 \text{ V}$<br>$U_a = 800 \text{ V}$<br>$Q_a (U_{g1 \sim} = 0)$<br>= 25 W<br>$Q_a (U_{g1 \sim} > 0)$<br>= 27.5 W<br>$U_{g2 \text{ kalt}} = 800 \text{ V}$<br>$U_{g2} = 425 \text{ V}$<br>$Q_{g2} = 8 \text{ W}$<br>$I_k = 150 \text{ mA}$<br>$R_{g1} = 0.7 \text{ M}\Omega^*$<br>$R_{g1} = 0.5 \text{ M}\Omega^{**}$<br>$U_{fk} = 100 \text{ V}$<br>$R_{fk} = 20 \text{ k}\Omega$ |
|  |  |  | * Kl. A und AB<br>** Kl. B  |

Data of the EL34 taken 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<br>(each unit) |       |          |
|-------------------------------------|-------|----------|
| Anode current                       | $I_a$ | 1.2 mA   |
| Transconductance                    | $S$   | 1.6 mA/V |
| Amplification factor                | $\mu$ | 100 -    |

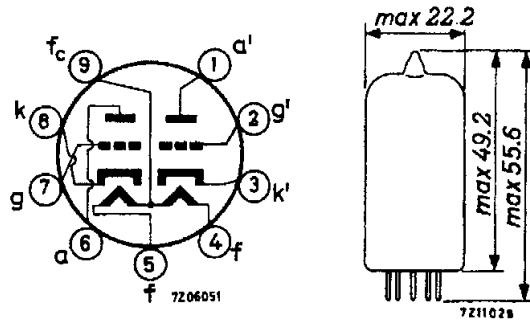
**HEATING:** Indirect by A.C. or D.C.; series or parallel supply

|                |       |              |          |
|----------------|-------|--------------|----------|
| 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**

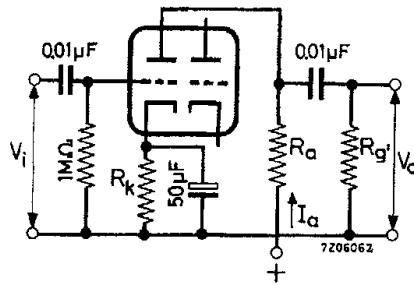
|                          |              |              |
|--------------------------|--------------|--------------|
| Grid to all except anode | $C_{g(a)}$   | 1.6 pF       |
|                          | $C_{g'(a')}$ | 1.6 pF       |
| Anode to all except grid | $C_{a(g)}$   | 0.33 pF      |
|                          | $C_{a'(g')}$ | 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 | $\mu$ | 100  | 100  | -          |
| Internal resistance  | $R_i$ | 80   | 62.5 | k $\Omega$ |

**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   | k $\Omega$       |
| Grid resistor next stage             | $R_{g'}$  | 150  | 150  | 150  | 150  | 150  | k $\Omega$       |
| Cathode resistor                     | $R_k$     | 1500 | 1200 | 1000 | 820  | 680  | $\Omega$         |
| 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 ( $I_g = 0.3 \mu A$ ) | $V_o$     | 18   | 23   | 26   | 33   | 37   | V <sub>RMS</sub> |
| 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  | k $\Omega$       |
| Grid resistor next stage             | $R_{g'}$  | 330  | 330  | 330  | 330  | 330  | k $\Omega$       |
| Cathode resistor                     | $R_k$     | 1800 | 1500 | 1200 | 1000 | 820  | $\Omega$         |
| 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 ( $I_g = 0.3 \mu A$ ) | $V_o$     | 20   | 26   | 30   | 36   | 38   | V <sub>RMS</sub> |
| 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  | k $\Omega$       |
| Grid resistor next stage             | $R_{g'}$  | 680  | 680  | 680  | 680  | 680  | k $\Omega$       |
| Cathode resistor                     | $R_k$     | 3.3  | 2.7  | 2.2  | 1.5  | 1.2  | k $\Omega$       |
| 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 ( $I_g = 0.3 \mu A$ ) | $V_o$     | 24   | 28   | 36   | 37   | 38   | V <sub>RMS</sub> |
| Total distortion                     | $d_{tot}$ | 4.6  | 3.4  | 2.6  | 1.6  | 1.1  | %                |

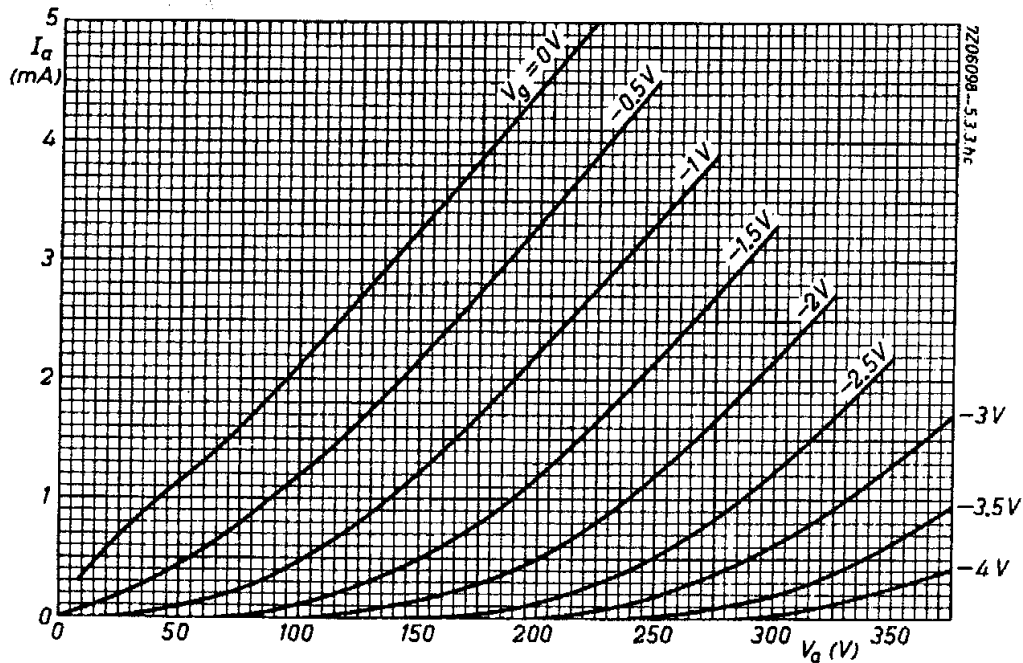
**LIMITING VALUES** (Design centre rating system)

|   |          |                     |
|---|----------|---------------------|
| Anode voltage   | $V_{a0}$ | 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 M $\Omega$   |
| Cathode to heater voltage   | $V_{kf}$ | max. 180 V          |
| Cathode to heater circuit<br>resistance in phase splitting circuits | $R_{kf}$ | max. 150 k $\Omega$ |

**REMARK**

Microphony and hum

This tube can be used without special precautions against microphony in equipment in which the input voltage  $V_i \geq 5$  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,  $R_g \leq 0.5$  M $\Omega$  and the cathode resistor is sufficiently decoupled.



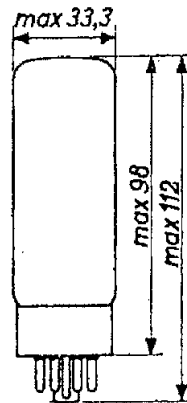
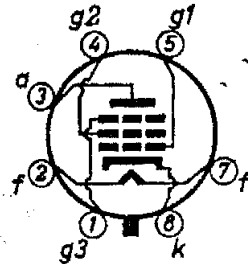
# PHILIPS

# EL 34

OUTPUT PENTODE  
PENTHODE DE SORTIE  
ENDPENTODE

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

Dimensions in mm  
Dimensions en mm  
Abmessungen in mm



Base  
Culot OCTAL  
Sockel

Socket  
Support 5903/13  
Fassung

Capacitances  
Capacités  
Kapazitäten

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

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.

2.2.1958

938 2856

1.



**EL 34****PHILIPS**

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

|   |   |       |       |                  |
|---|---|-------|-------|------------------|
| V <sub>b</sub>                          | = | 265   | 265   | V                |
| V <sub>a</sub>                          | = | 250   | 250   | V                |
| R <sub>g2</sub>                         | = | 2     | 0     | kΩ               |
| V <sub>g3</sub>                         | = | 0     | 0     | V                |
| V <sub>g1</sub>                         | = | -14,5 | -13,5 | V                |
| I <sub>a</sub>                          | = | 70    | 100   | mA               |
| I <sub>g2</sub>                         | = | 10    | 14,9  | mA               |
| S                                       | = | 9,0   | 11    | mA/V             |
| μ <sub>g2g1</sub>                       | = | 11    | 11    |                  |
| R <sub>i</sub>                          | = | 18    | 15    | kΩ               |
| R <sub>a</sub>                          | = | 3,0   | 2,0   | kΩ               |
| V <sub>i</sub>                          | = | 9,3   | 8,7   | V <sub>eff</sub> |
| W <sub>o</sub>                          | = | 8     | 11    | W                |
| d <sub>tot</sub>                        | = | 10    | 10    | %                |
| V <sub>i</sub> (W <sub>o</sub> = 50 mW) | = | 0,65  | 0,5   | V <sub>eff</sub> |

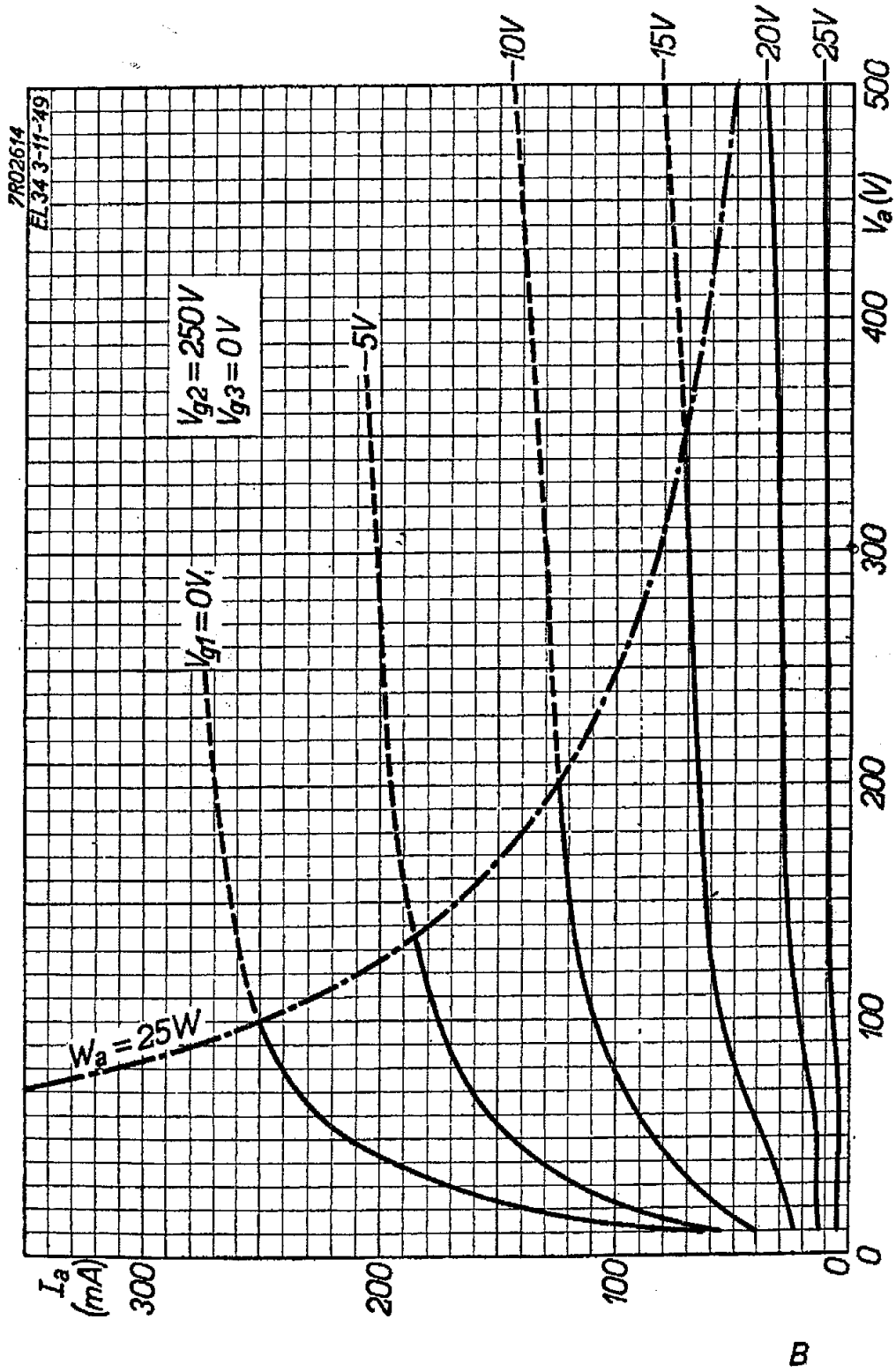
Operating characteristics class B  
 Caractéristiques d'utilisation classe B  
 Betriebsdaten Klasse B

|                  |   |       |       |       |       |                 |      |                  |
|------------------|---|-------|-------|-------|-------|-----------------|------|------------------|
| R <sub>g2</sub>  | = | 1000  |       | 470   |       | Ω <sup>1)</sup> |      |                  |
| V <sub>g1</sub>  | = | -38   |       | -32   |       | V               |      |                  |
| V <sub>g3</sub>  | = | 0     |       | 0     |       | V               |      |                  |
| V <sub>i</sub>   | = | 0     | 27    | 27    | 0     | 22,7            | 22,7 | V <sub>eff</sub> |
| R <sub>aa</sub>  | = | -     | 3,4   | 4,0   | -     | 2,8             | 3,8  | kΩ               |
| V <sub>b</sub>   | = | 425   | 425   | 400   | 375   | 375             | 350  | V                |
| V <sub>a</sub>   | = | 420   | 400   | 375   | 370   | 350             | 325  | V                |
| I <sub>a</sub>   | = | 2x30  | 2x120 | 2x100 | 2x35  | 2x120           | 2x93 | mA               |
| I <sub>g2</sub>  | = | 2x4,4 | 2x25  | 2x25  | 2x4,7 | 2x25            | 2x25 | mA               |
| W <sub>o</sub>   | = | 0     | 55    | 45    | 0     | 44              | 36   | W                |
| d <sub>tot</sub> | = | -     | 5     | 6     | -     | 5               | 6    | %                |

<sup>1)</sup> Common screen grid resistor; non decoupled  
 Résistance de grille-écran commune; ne pas découplée  
 Gemeinsamer Schirmgitterwiderstand; nicht entkoppelt

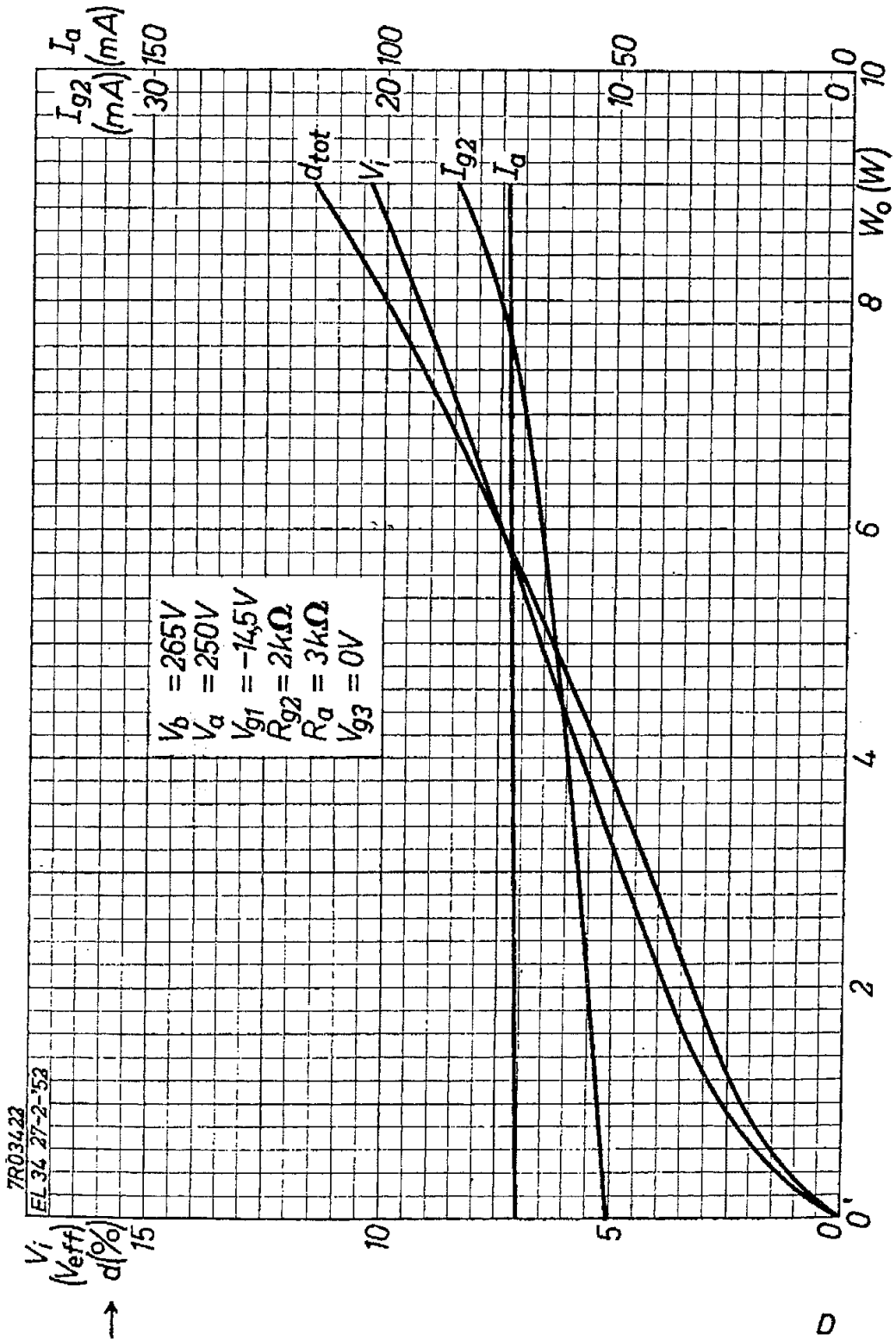
**EL 34**

**PHILIPS**



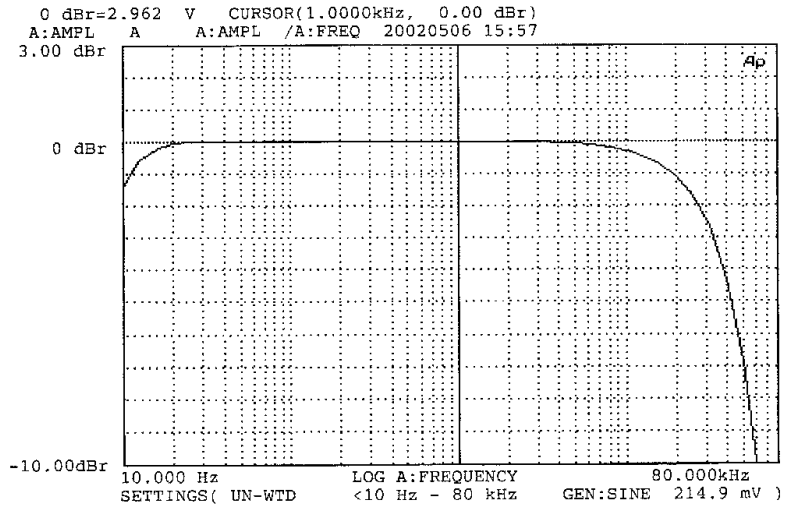
**EL 34**

**PHILIPS**



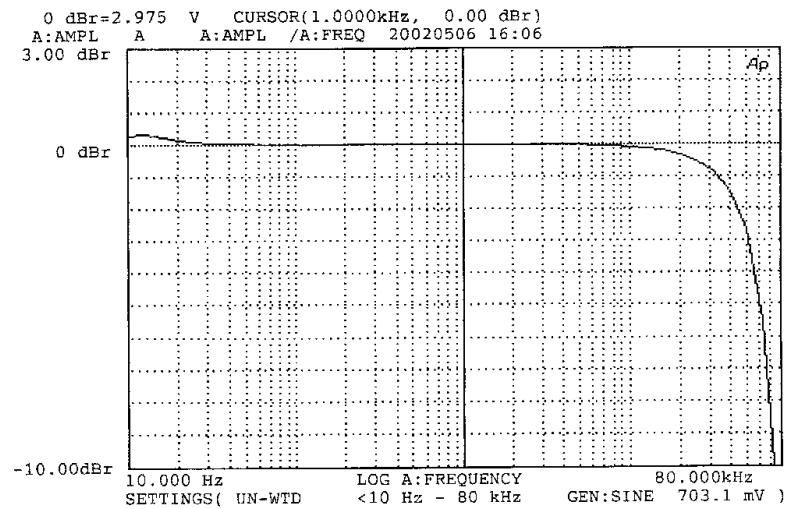
Performance of the standard single-end pentode output stage according to recommendations from the table. Note that distortion,  $d$ , exceeds 10% at 8W

1W  
no NFB



| AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL   | A   | Ap |
|-----------|-------|-----|-----------|-------|-----|-----------|--------|-----|----|
| 10.000 Hz | -1.39 | dBr | 250.00 Hz | 0.00  | dBr | 6.3000kHz | -0.13  | dBr |    |
| 12.500 Hz | -0.58 | dBr | 315.00 Hz | 0.00  | dBr | 8.0000kHz | -0.20  | dBr |    |
| 16.000 Hz | -0.19 | dBr | 400.00 Hz | 0.00  | dBr | 10.000kHz | -0.31  | dBr |    |
| 20.000 Hz | -0.06 | dBr | 500.00 Hz | 0.00  | dBr | 12.500kHz | -0.46  | dBr |    |
| 25.000 Hz | -0.01 | dBr | 630.00 Hz | 0.00  | dBr | 16.000kHz | -0.73  | dBr |    |
| 31.500 Hz | 0.00  | dBr | 800.00 Hz | 0.00  | dBr | 20.000kHz | -1.11  | dBr |    |
| 40.000 Hz | 0.00  | dBr | 1.0000kHz | 0.00  | dBr | 25.000kHz | -1.69  | dBr |    |
| 50.000 Hz | 0.00  | dBr | 1.2500kHz | 0.00  | dBr | 31.500kHz | -2.69  | dBr |    |
| 63.000 Hz | 0.00  | dBr | 1.6000kHz | 0.00  | dBr | 40.000kHz | -4.32  | dBr |    |
| 80.000 Hz | 0.00  | dBr | 2.0000kHz | -0.01 | dBr | 50.000kHz | -6.82  | dBr |    |
| 100.00 Hz | 0.00  | dBr | 2.5000kHz | -0.02 | dBr | 63.000kHz | -11.27 | dBr |    |
| 125.00 Hz | 0.00  | dBr | 3.1500kHz | -0.03 | dBr | 80.000kHz | -19.84 | dBr |    |
| 160.00 Hz | 0.00  | dBr | 4.0000kHz | -0.05 | dBr |           |        |     |    |
| 200.00 Hz | 0.00  | dBr | 5.0000kHz | -0.08 | dBr |           |        |     |    |

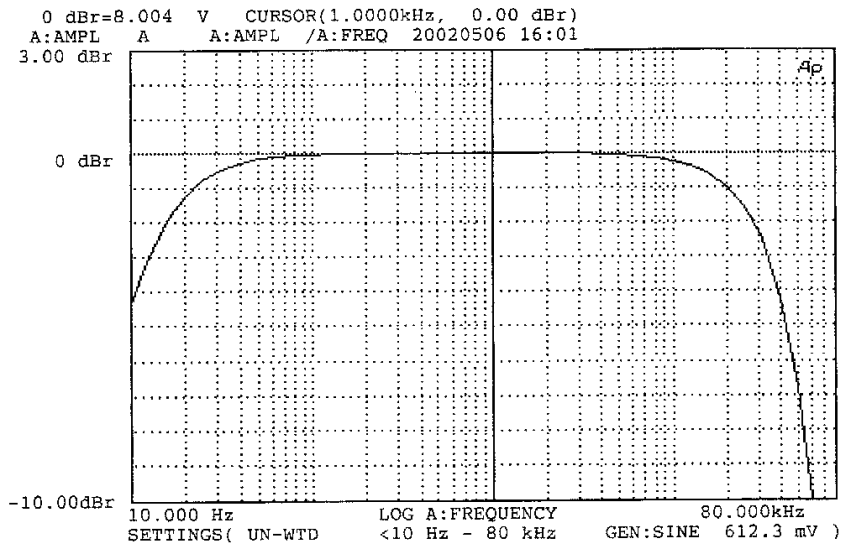
1W  
10 dB of NFB



| AGEN FREQ | AMPL | A   | AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL   | A   | Ap |
|-----------|------|-----|-----------|-------|-----|-----------|--------|-----|----|
| 10.000 Hz | 0.30 | dBr | 250.00 Hz | 0.00  | dBr | 6.3000kHz | -0.04  | dBr |    |
| 12.500 Hz | 0.31 | dBr | 315.00 Hz | 0.00  | dBr | 8.0000kHz | -0.06  | dBr |    |
| 16.000 Hz | 0.22 | dBr | 400.00 Hz | 0.00  | dBr | 10.000kHz | -0.09  | dBr |    |
| 20.000 Hz | 0.14 | dBr | 500.00 Hz | 0.00  | dBr | 12.500kHz | -0.14  | dBr |    |
| 25.000 Hz | 0.09 | dBr | 630.00 Hz | 0.00  | dBr | 16.000kHz | -0.22  | dBr |    |
| 31.500 Hz | 0.05 | dBr | 800.00 Hz | 0.00  | dBr | 20.000kHz | -0.33  | dBr |    |
| 40.000 Hz | 0.03 | dBr | 1.0000kHz | 0.00  | dBr | 25.000kHz | -0.52  | dBr |    |
| 50.000 Hz | 0.02 | dBr | 1.2500kHz | 0.00  | dBr | 31.500kHz | -0.85  | dBr |    |
| 63.000 Hz | 0.01 | dBr | 1.6000kHz | 0.00  | dBr | 40.000kHz | -1.46  | dBr |    |
| 80.000 Hz | 0.00 | dBr | 2.0000kHz | 0.00  | dBr | 50.000kHz | -2.66  | dBr |    |
| 100.00 Hz | 0.00 | dBr | 2.5000kHz | 0.00  | dBr | 63.000kHz | -5.50  | dBr |    |
| 125.00 Hz | 0.00 | dBr | 3.1500kHz | 0.00  | dBr | 80.000kHz | -12.87 | dBr |    |
| 160.00 Hz | 0.00 | dBr | 4.0000kHz | -0.01 | dBr |           |        |     |    |
| 200.00 Hz | 0.00 | dBr | 5.0000kHz | -0.02 | dBr |           |        |     |    |

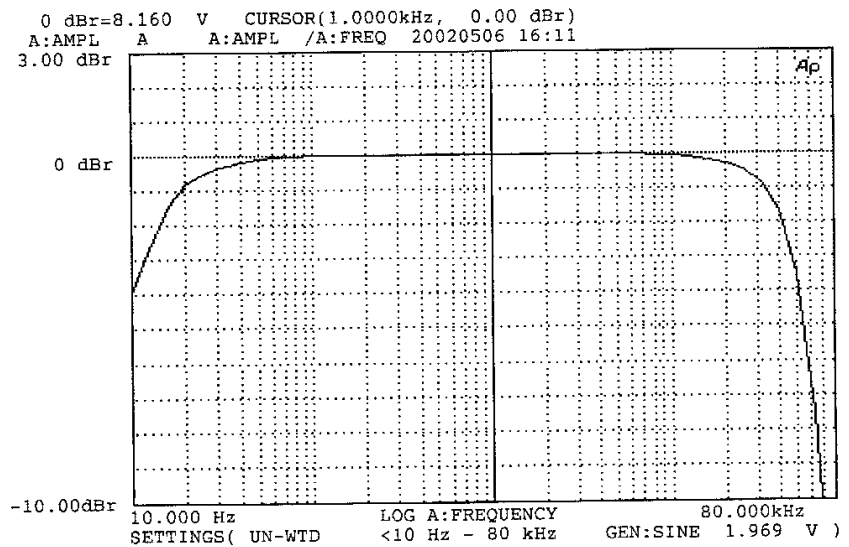
Frequency response at  
1W with and without NFB

8W  
no NFB



| AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL   | A   | Ap |
|-----------|-------|-----|-----------|-------|-----|-----------|--------|-----|----|
| 10.000 Hz | -4.32 | dBr | 250.00 Hz | 0.00  | dBr | 6.3000kHz | -0.10  | dBr |    |
| 12.500 Hz | -2.98 | dBr | 315.00 Hz | 0.00  | dBr | 8.0000kHz | -0.16  | dBr |    |
| 16.000 Hz | -1.85 | dBr | 400.00 Hz | 0.00  | dBr | 10.000kHz | -0.24  | dBr |    |
| 20.000 Hz | -1.22 | dBr | 500.00 Hz | 0.00  | dBr | 12.500kHz | -0.39  | dBr |    |
| 25.000 Hz | -0.78 | dBr | 630.00 Hz | 0.00  | dBr | 16.000kHz | -0.63  | dBr |    |
| 31.500 Hz | -0.47 | dBr | 800.00 Hz | 0.00  | dBr | 20.000kHz | -0.99  | dBr |    |
| 40.000 Hz | -0.28 | dBr | 1.0000kHz | 0.00  | dBr | 25.000kHz | -1.56  | dBr |    |
| 50.000 Hz | -0.17 | dBr | 1.2500kHz | 0.00  | dBr | 31.500kHz | -2.53  | dBr |    |
| 63.000 Hz | -0.10 | dBr | 1.6000kHz | 0.00  | dBr | 40.000kHz | -4.20  | dBr |    |
| 80.000 Hz | -0.06 | dBr | 2.0000kHz | -0.01 | dBr | 50.000kHz | -6.77  | dBr |    |
| 100.00 Hz | -0.04 | dBr | 2.5000kHz | -0.01 | dBr | 63.000kHz | -11.35 | dBr |    |
| 125.00 Hz | -0.02 | dBr | 3.1500kHz | -0.02 | dBr | 80.000kHz | -19.93 | dBr |    |
| 160.00 Hz | -0.01 | dBr | 4.0000kHz | -0.04 | dBr |           |        |     |    |
| 200.00 Hz | -0.01 | dBr | 5.0000kHz | -0.06 | dBr |           |        |     |    |

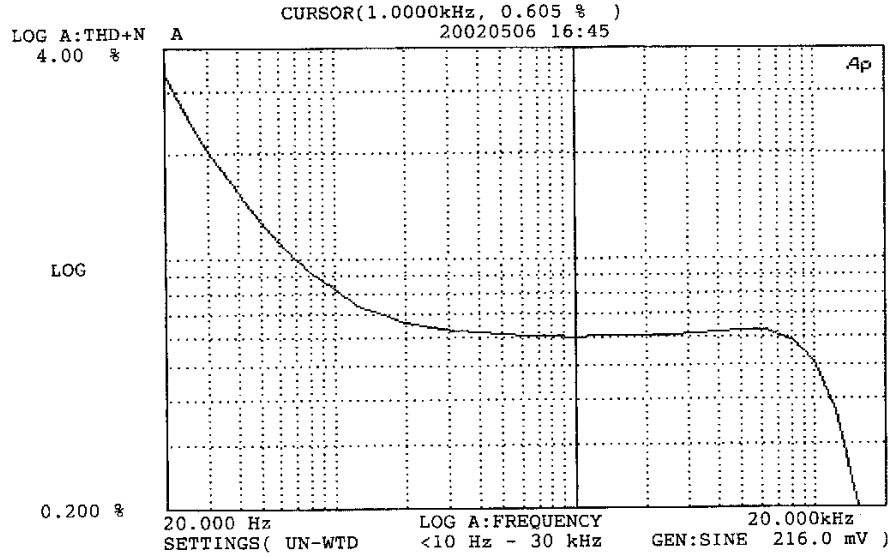
8W  
10dB of  
NFB



| AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL  | A   | AGEN FREQ | AMPL   | A   | Ap |
|-----------|-------|-----|-----------|-------|-----|-----------|--------|-----|----|
| 10.000 Hz | -3.92 | dBr | 250.00 Hz | -0.01 | dBr | 6.3000kHz | -0.03  | dBr |    |
| 12.500 Hz | -2.67 | dBr | 315.00 Hz | 0.00  | dBr | 8.0000kHz | -0.06  | dBr |    |
| 16.000 Hz | -1.41 | dBr | 400.00 Hz | 0.00  | dBr | 10.000kHz | -0.08  | dBr |    |
| 20.000 Hz | -0.79 | dBr | 500.00 Hz | 0.00  | dBr | 12.500kHz | -0.11  | dBr |    |
| 25.000 Hz | -0.53 | dBr | 630.00 Hz | 0.00  | dBr | 16.000kHz | -0.18  | dBr |    |
| 31.500 Hz | -0.35 | dBr | 800.00 Hz | 0.00  | dBr | 20.000kHz | -0.29  | dBr |    |
| 40.000 Hz | -0.20 | dBr | 1.0000kHz | 0.00  | dBr | 25.000kHz | -0.47  | dBr |    |
| 50.000 Hz | -0.13 | dBr | 1.2500kHz | 0.00  | dBr | 31.500kHz | -0.86  | dBr |    |
| 63.000 Hz | -0.07 | dBr | 1.6000kHz | 0.00  | dBr | 40.000kHz | -1.67  | dBr |    |
| 80.000 Hz | -0.04 | dBr | 2.0000kHz | 0.00  | dBr | 50.000kHz | -3.50  | dBr |    |
| 100.00 Hz | -0.03 | dBr | 2.5000kHz | 0.00  | dBr | 63.000kHz | -7.49  | dBr |    |
| 125.00 Hz | -0.02 | dBr | 3.1500kHz | 0.00  | dBr | 80.000kHz | -15.76 | dBr |    |
| 160.00 Hz | -0.01 | dBr | 4.0000kHz | -0.01 | dBr |           |        |     |    |
| 200.00 Hz | -0.01 | dBr | 5.0000kHz | -0.02 | dBr |           |        |     |    |

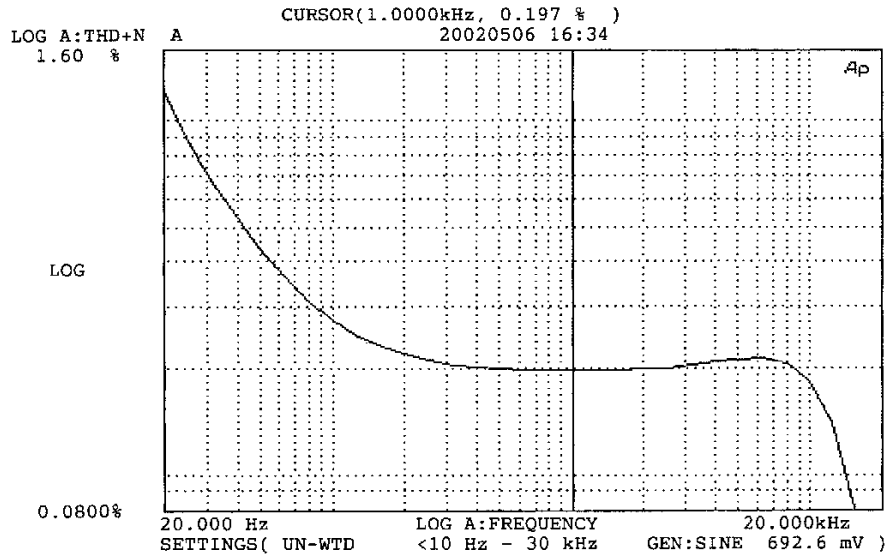
Frequency response  
at 8W with and  
without NFB

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 % |   |           |          |   |    |

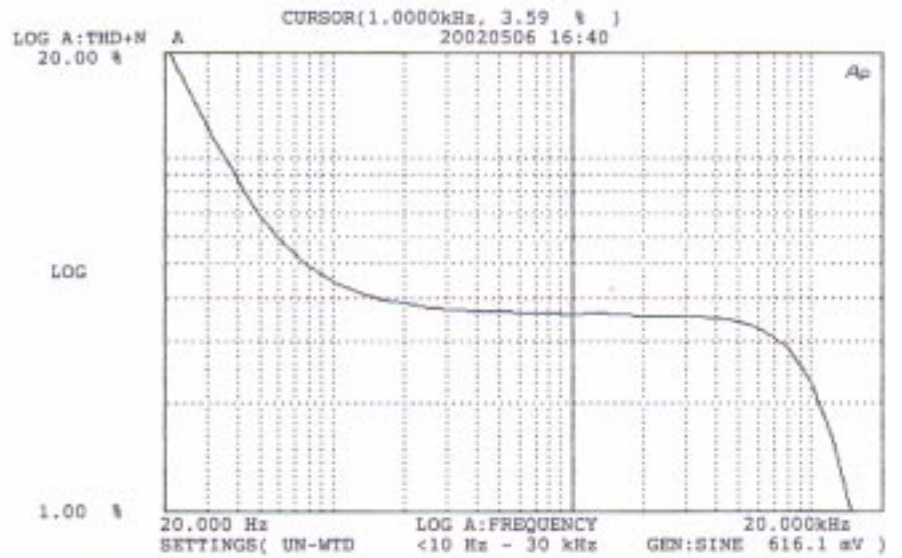
1W  
10dB of NFB



| 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 % |   |           |          |   |    |

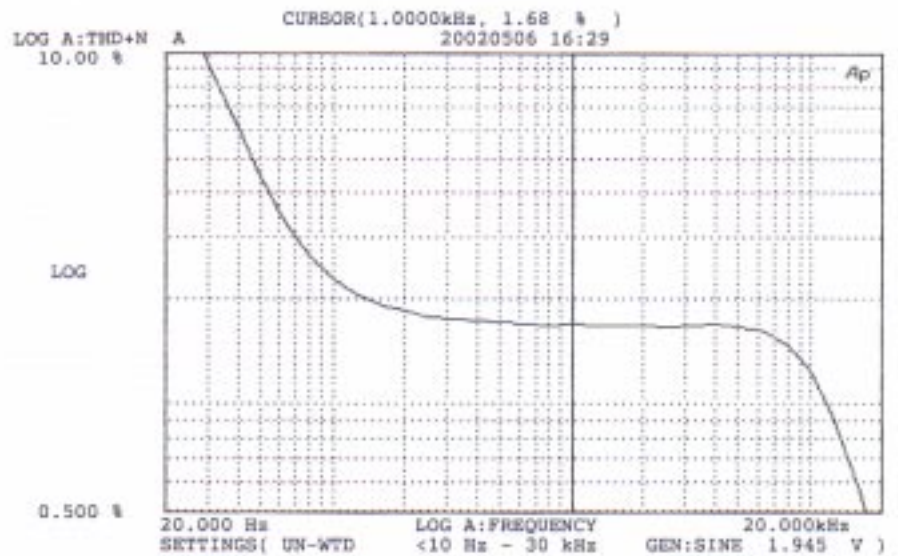
Distortion is frequency  
at 1W with and  
without NFB  
Note: Different  
vertical scales

8W  
no NFB



| AGEN FREQ | THD+N   | A | AGEN FREQ | THD+N  | A | AGEN FREQ | THD+N   | A | Ap |
|-----------|---------|---|-----------|--------|---|-----------|---------|---|----|
| 20.000 Hz | 20.94 % |   | 250.00 Hz | 3.76 % |   | 3.1500kHz | 3.52 %  |   |    |
| 25.000 Hz | 15.72 % |   | 315.00 Hz | 3.70 % |   | 4.0000kHz | 3.50 %  |   |    |
| 31.500 Hz | 11.60 % |   | 400.00 Hz | 3.67 % |   | 5.0000kHz | 3.42 %  |   |    |
| 40.000 Hz | 8.63 %  |   | 500.00 Hz | 3.64 % |   | 6.3000kHz | 3.25 %  |   |    |
| 50.000 Hz | 6.84 %  |   | 630.00 Hz | 3.62 % |   | 8.0000kHz | 2.88 %  |   |    |
| 63.000 Hz | 5.68 %  |   | 800.00 Hz | 3.60 % |   | 10.000kHz | 2.30 %  |   |    |
| 80.000 Hz | 4.93 %  |   | 1.0000kHz | 3.59 % |   | 12.500kHz | 1.58 %  |   |    |
| 100.00 Hz | 4.46 %  |   | 1.2500kHz | 3.60 % |   | 16.000kHz | 0.810 % |   |    |
| 125.00 Hz | 4.18 %  |   | 1.6000kHz | 3.57 % |   | 20.000kHz | 0.340 % |   |    |
| 160.00 Hz | 3.95 %  |   | 2.0000kHz | 3.55 % |   |           |         |   |    |
| 200.00 Hz | 3.84 %  |   | 2.5000kHz | 3.54 % |   |           |         |   |    |

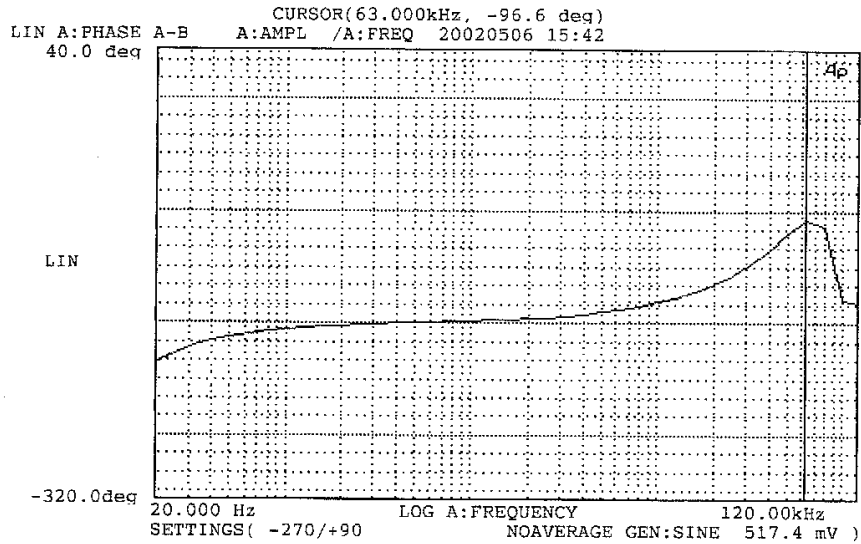
8W  
10dB of NFB



| AGEN FREQ | THD+N   | A | AGEN FREQ | THD+N  | A | AGEN FREQ | THD+N   | A | Ap |
|-----------|---------|---|-----------|--------|---|-----------|---------|---|----|
| 20.000 Hz | 16.46 % |   | 250.00 Hz | 1.78 % |   | 3.1500kHz | 1.68 %  |   |    |
| 25.000 Hz | 12.10 % |   | 315.00 Hz | 1.75 % |   | 4.0000kHz | 1.69 %  |   |    |
| 31.500 Hz | 8.73 %  |   | 400.00 Hz | 1.72 % |   | 5.0000kHz | 1.66 %  |   |    |
| 40.000 Hz | 6.11 %  |   | 500.00 Hz | 1.71 % |   | 6.3000kHz | 1.61 %  |   |    |
| 50.000 Hz | 4.43 %  |   | 630.00 Hz | 1.69 % |   | 8.0000kHz | 1.47 %  |   |    |
| 63.000 Hz | 3.30 %  |   | 800.00 Hz | 1.68 % |   | 10.000kHz | 1.24 %  |   |    |
| 80.000 Hz | 2.64 %  |   | 1.0000kHz | 1.68 % |   | 12.500kHz | 0.934 % |   |    |
| 100.00 Hz | 2.28 %  |   | 1.2500kHz | 1.68 % |   | 16.000kHz | 0.590 % |   |    |
| 125.00 Hz | 2.06 %  |   | 1.6000kHz | 1.67 % |   | 20.000kHz | 0.362 % |   |    |
| 160.00 Hz | 1.91 %  |   | 2.0000kHz | 1.68 % |   |           |         |   |    |
| 200.00 Hz | 1.85 %  |   | 2.5000kHz | 1.66 % |   |           |         |   |    |

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

With 10dB of NFB

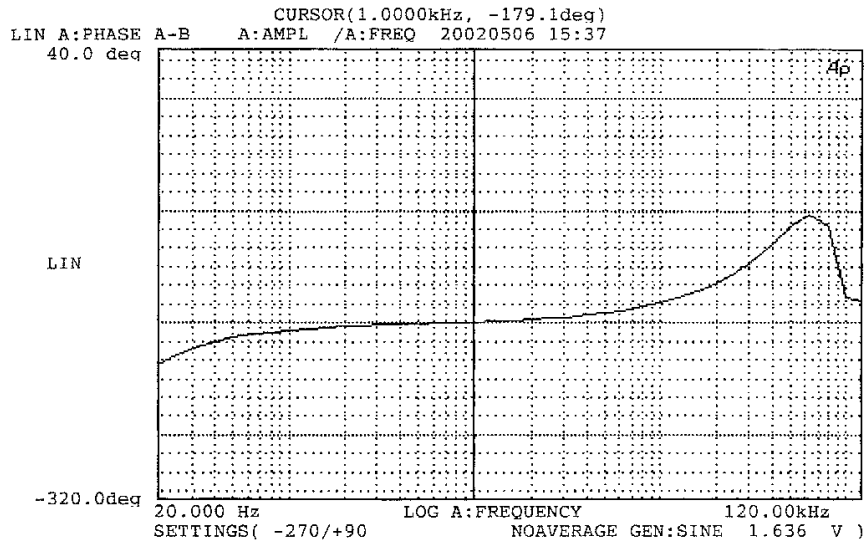


Max shift  
 - 41.2° at 20Hz  
 +83.4° at 63 kHz

| AGEN FREQ | PHASE A-B | AGEN FREQ | PHASE A-B | AGEN FREQ | PHASE A-B Ap |
|-----------|-----------|-----------|-----------|-----------|--------------|
| 20.000 Hz | -212.4deg | 500.00 Hz | -179.6deg | 12.500kHz | -159.4deg    |
| 25.000 Hz | -204.3deg | 630.00 Hz | -179.1deg | 16.000kHz | -154.4deg    |
| 31.500 Hz | -198.4deg | 800.00 Hz | -178.7deg | 20.000kHz | -148.7deg    |
| 40.000 Hz | -194.1deg | 1.0000kHz | -178.1deg | 25.000kHz | -141.6deg    |
| 50.000 Hz | -191.0deg | 1.2500kHz | -177.6deg | 31.500kHz | -132.2deg    |
| 63.000 Hz | -188.4deg | 1.6000kHz | -177.0deg | 40.000kHz | -120.0deg    |
| 80.000 Hz | -186.4deg | 2.0000kHz | -176.2deg | 50.000kHz | -107.7deg    |
| 100.00 Hz | -184.9deg | 2.5000kHz | -175.3deg | 63.000kHz | -96.6 deg    |
| 125.00 Hz | -183.7deg | 3.1500kHz | -174.1deg | 80.000kHz | -101.8deg    |
| 160.00 Hz | -182.6deg | 4.0000kHz | -172.6deg | 100.00kHz | -161.6deg    |
| 200.00 Hz | -181.7deg | 5.0000kHz | -170.9deg | 120.00kHz | -164.3deg    |
| 250.00 Hz | -181.1deg | 6.3000kHz | -168.7deg |           |              |
| 315.00 Hz | -180.5deg | 8.0000kHz | -166.1deg |           |              |
| 400.00 Hz | -180.0deg | 10.000kHz | -163.0deg |           |              |

No NFB

Max shift  
 - 43.2° at 20Hz  
 +86.5° at 63 kHz



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

| AGEN FREQ | PHASE A-B | AGEN FREQ | PHASE A-B | AGEN FREQ | PHASE A-B Ap |
|-----------|-----------|-----------|-----------|-----------|--------------|
| 20.000 Hz | -213.2deg | 500.00 Hz | -180.5deg | 12.500kHz | -160.0deg    |
| 25.000 Hz | -205.8deg | 630.00 Hz | -180.1deg | 16.000kHz | -154.4deg    |
| 31.500 Hz | -199.9deg | 800.00 Hz | -179.6deg | 20.000kHz | -147.9deg    |
| 40.000 Hz | -195.3deg | 1.0000kHz | -179.1deg | 25.000kHz | -140.2deg    |
| 50.000 Hz | -192.1deg | 1.2500kHz | -178.6deg | 31.500kHz | -130.4deg    |
| 63.000 Hz | -189.5deg | 1.6000kHz | -177.9deg | 40.000kHz | -117.0deg    |
| 80.000 Hz | -187.4deg | 2.0000kHz | -177.1deg | 50.000kHz | -102.4deg    |
| 100.00 Hz | -185.9deg | 2.5000kHz | -176.3deg | 63.000kHz | -93.5 deg    |
| 125.00 Hz | -184.7deg | 3.1500kHz | -175.1deg | 80.000kHz | -101.8deg    |
| 160.00 Hz | -183.6deg | 4.0000kHz | -173.7deg | 100.00kHz | -159.9deg    |
| 200.00 Hz | -182.8deg | 5.0000kHz | -172.0deg | 120.00kHz | -163.1deg    |
| 250.00 Hz | -182.1deg | 6.3000kHz | -169.9deg |           |              |
| 315.00 Hz | -181.5deg | 8.0000kHz | -167.2deg |           |              |
| 400.00 Hz | -181.0deg | 10.000kHz | -164.0deg |           |              |





