TDA1514A Hi-Fi Power Amplifiers

AN8911

Report No. NBA/AN8911; Author: D. Udo

SUMMARY

The TDA1514A is a monolithic, low distortion power amplifier intended to be used for several hi-fi applications such as radio and TV sets, amplifier for compact disc, tape recorders, etcetera.

A single circuit can deliver up to 40W output power in a load of 8Ω with a phase shift lower than 30°.

Applications with 2 times TDA1514A in BTL configuration deliver up to 95W in a load of 8Ω at ±Vp = 24V. Amplifiers with a single TDA1514A have to be used preferably with symmetrical power supplies, but application information is given for use with an asymmetrical power supply.

A special feature of this IC is the Mute facility. The IC has several internal protection circuits to survive misloading conditions.

INTRODUCTION

The TDA1514A integrated operational amplifier in the 9-leads single-in-line plastic power package SOT131A is intended for use as class-B hi-fi power amplifier. Some specific data on this IC is given in Table 1.

The TDA1514A is designed for use with a symmetrical power supply, but application with an asymmetrical power supply, with 8Ω and 4Ω load and with and without bootstrap.

Also information about 2 times TDA1514A in BTL is given.

An important feature of this IC is the Mute and Stand-by facility which makes it possible to switch off the circuit for stand-by purposes or to avoid switching clicks.

Table 1.

Supply Voltage Range	±10V to ±30V		
Maximum Output Current (repetitive peak)	8A		
Minimum Available Output Peak Current	6.4A		
Maximum Crystal Temperature	150°C		
Thermal Resistance Rth_{vj-mb}	< 1K/W		
Quiescent Current	58mA		
Input Impedance at Pin 1	> 1MΩ		
Output Impedance	25mΩ		
Signal-to-noise Ratio related to Po = 50mW (Rs = 2kΩ)	86dB		
Slew Rate	14V/μs		
	R1 = 4Ω	**R1 = 8Ω**	**BTL R1 = 8Ω**
Output Power THD = -60dB or 0.1%			
±Vp = 24V	52W		95W
±Vp = 27.5V		40W	
Output Power THD = -20dB or 10%			
±Vp = 24V	65W		
±Vp = 27.5V		51W	

INTERNAL CIRCUIT DESCRIPTION

The internal block diagram of the TDA1514A is shown in Figure 1. The input stage is a differential amplifier with a very low bias current at pin 1, because of base current compensation.

A second differential amplifier is used for muting. At muting the input stage is switched off and the mute stage is switched on. The mute stage is connected to pin 8 (reference voltage) and pin 9 (feedback pin). Because the DC levels of the input (pin 1) and pin 8 are equal, there is no difference in the DC output voltage during switching of the input amplifier to the mute amplifier.

The output stage is a quasi complementary stage with NPN power transistors. The open loop gain is typically 85dB and the frequency behavior of the open loop gain is determined by the miller capacitor CM.

The amplifier has a number of internal circuit blocks for SOAR and thermal protection. The internal pin connection diagram is shown in Figure 2.

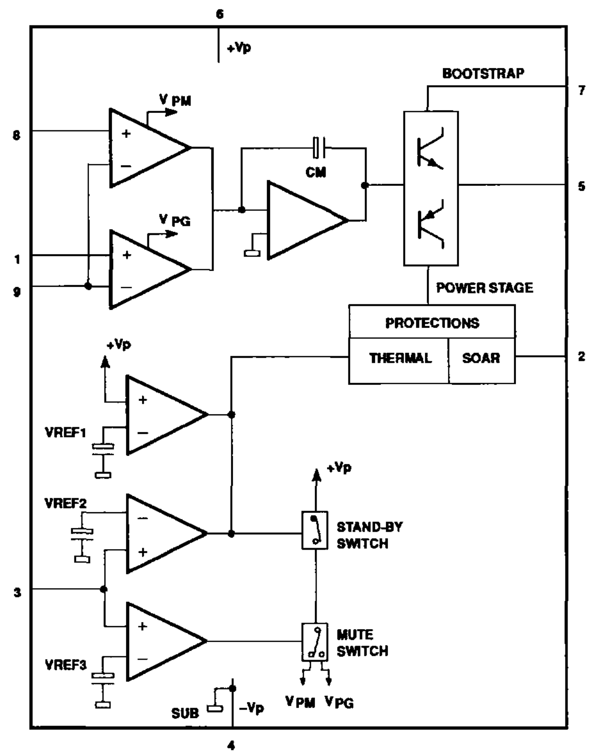


Figure 1. Internal Circuit Block Diagram

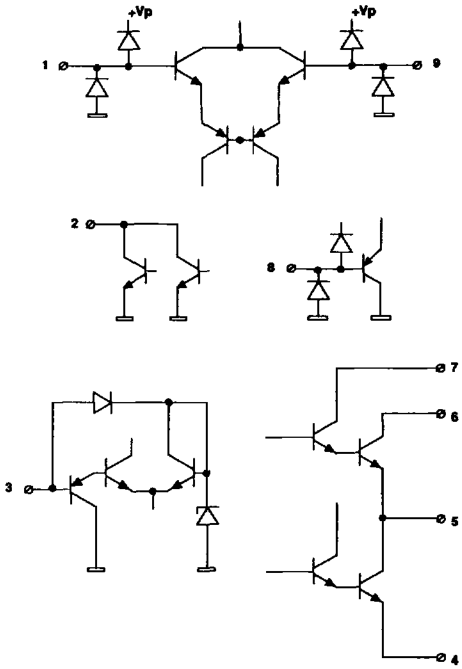
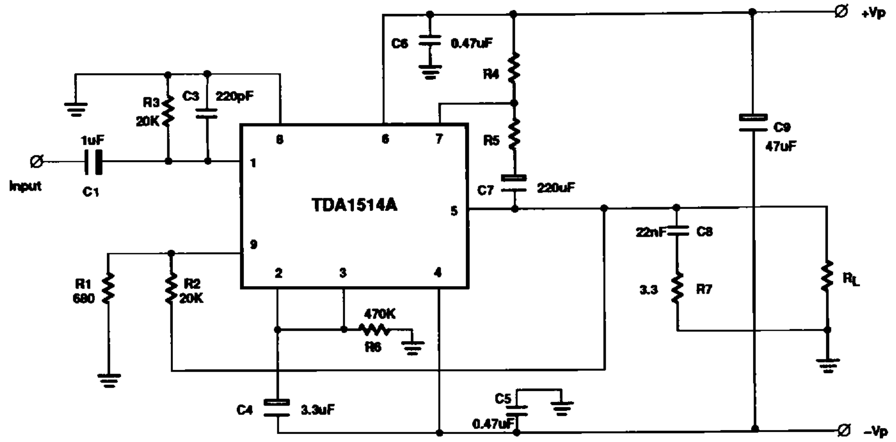


Figure 2. Internal Pin Connection Diagram



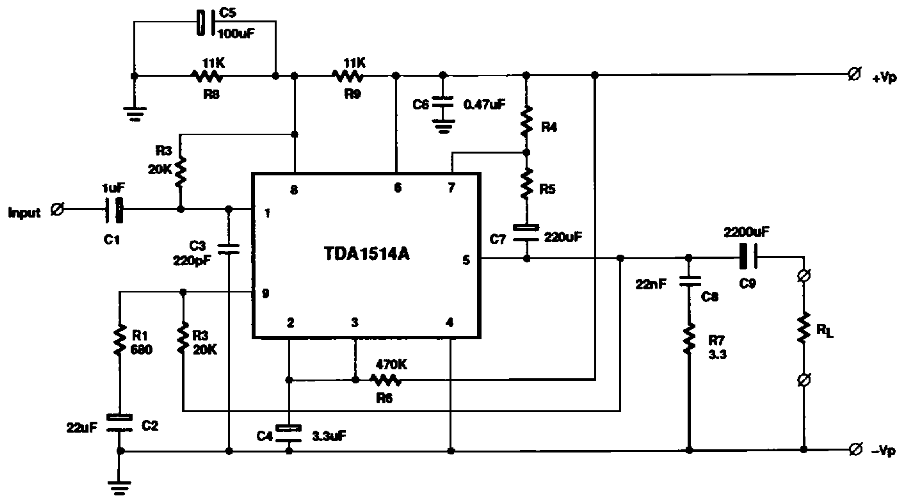
NOTES:

With $R_L = 4\Omega$:	R4 = 47Ω and R5 = 82Ω
With $R_L = 8\Omega$:	R4 = 82Ω and R5 = 150Ω

Without Bootstrap

R4, R5 and C7 have to be omitted and pin 6 to pin 7 connected, in applications without bootstrap, decreasing the output power with about 3W for 8Ω load and about 4W for a 4Ω load.

Figure 3. Circuit Diagram with Symmetrical Power Supply



NOTES:

With $R_L = 4\Omega$:	R4 = 47Ω and R5 = 82Ω
With $R_L = 8\Omega$:	R4 = 82Ω and R5 = 150Ω

Without Bootstrap

R4, R5 and C7 have to be omitted and pin 6 to pin 7 connected, in applications without bootstrap, decreasing the output power with about 3W for 8Ω load and about 4W for a 4Ω load.

Figure 4. Circuit Diagram with Asymmetrical Power Supply

APPLICATION AND PERFORMANCE

Application Circuits

The circuit diagram of the TDA1514A amplifier operating from a symmetrical power supply is shown in Figure 3 and from an asymmetrical power supply in Figure 4. The print layouts and the component layouts are shown in Figures 5, 6, 7 and 8. The bootstrap resistors in Figure 3 and 4, which are different for R1 = 8Ω and R1 = 4Ω, should be 1W types because of the dissipation.

The typical output power in 8Ω load and ±Vp = 27.5V is with bootstrap 40W and without bootstrap 37W. The typical output power in 4Ω load and ±Vp = 24V is with bootstrap 52W and without bootstrap 49W.

In the typical symmetrical application the bootstrap circuit is with R4, R5 and C7. The combination R4, R5 is used as a bleeder network to limit the bootstrap voltage at pin 7. The absolute maximum rating for this voltage at pin 7 is 70V with respect to pin 4. Without R5 this voltage can go up to 90V (at maximum supply voltage).

Bootstrapping is also possible with a separate voltage to pin 7. The output power with an 8Ω load and ±Vp = 27.5V is 40W and with 4Ω load and ±Vp = 24V is 52W.

The closed loop gain of 29.6dB is fixed by the resistors R1 and R2. The gain can be changed between 20 and 46dB by R1 and R2. Without a feedback capacitor in series with R1, the DC and AC feedback is the same. But when offset is too high, the use of a feedback capacitor is advised. To keep the offset voltage low, it is advised to limit the maximum value of R2 to 100kΩ.

In Figure 9 there is a proposal for a switch mode power supply for 2 times TDA1514A and a DC input voltage of 12 to 14V (car applications).

Figure 10 shows the circuit diagram of 2 times TDA1514A in BTL. Power output is 95W with an 8Ω resistive load and up to 90W in a complex load with a maximum phase shift of 30°. Figures 11 and 12 show the print layout and component layout.

Mute and Stand-by

The TDA1514A has a mute and stand-by facility.

With a certain voltage level between pin 3 and pin 4 the state of the TDA1514A can be chosen. If this potential is between 6 and 7V the TDA1514A is in the operating state. If this potential is between 2 and 4.5V the TDA1514A is in the mute state. This means that the circuit is not operating but the DC settings remain the same as in the operating state. The output impedance will be kept low. With this potential between 0 and 0.9V the TDA1514A is in the stand-by state. The quiescent current is dropping down to typical 18mA.

In Figure 15 Ip and Vo are given as a function of the voltage between pin 3 and pin 4 with a constant input voltage of 100mV.

The TDA1514A is also in the stand-by state with the supply voltage between ±5V and ±7V. This can be used for SMPS applications with a stand-by mode. The mute time is determined by R6 and C4 (see Figure 3).

Calculation of the mute time can be done with:

$$t\ \text{mute} = \frac{C4 * Vm * R6}{1/2\ Vp}$$

in which:

Vp = *total* supply voltage (max. 60V)
Vm = mute voltage (6V)
R6 = resistor between pin 3 & 8
C4 = mute capacitor between pin 3 & 4

In our application circuit the calculation of the mute time is:

$$t\ \text{mute} = \frac{3.3 * 10^{-6} * 6 * 470 * 10^{3}}{27.5} = 338\text{ms}$$

The maximum value of resistor R6 has to be 620kΩ, otherwise the mute circuit will be activated at higher temperatures.

Complex Loads

Driving complex loads with the TDA1514A can cause, in certain conditions, some problems. When phase shifts higher than 30° are reached, the SOAR protection circuit is activated at certain driving levels. When the SOAR protection circuit is activated, the amplifier is switched in the mute state. The SOAR protection curves (see Figures 13 and 14) are showing than these problems are depending to the values of Vp, R1 and phase shift of the load. The curves in the SOAR protection figures are calculated for a maximum phase shift of 30°.

Short Circuit Behavior

A good HF decoupling of the supply line is very important for the short circuit behavior (C5 and C6 as close as possible to the IC pins).

Short circuit tests are made in the application circuit of Figure 3 with a stabilized supply voltage of ±27.5V and driven with a 1kHz sine wave until clipping. With these tests the TDA1514A can withstand short circuiting for a 10-minute period.

Short circuit tests with a Switch Mode Power Supply, mostly used in TV receivers, no ICs were damaged during the 10-minute test time.

Switch-on and -off Behavior

Tests are made with a practical power supply in the standard application circuit. Results of these tests are, that there is a small switch-on and switch-off click during switching with a long time interval. At repeated switch-on and switch-off there is only a small switch-on click.

The use of a feedback capacitor has an impact on the switch-on and -off behavior. With a feedback capacitor the switch-on and -off behavior is somewhat worse.

Switch-on and -off behavior can be improved by using the mute facility. Switching-on and -off with the amplifier in the mute or stand-by state gives no click at all.

The practical power supply consists of a transformer, a bridge rectifier and two electrolitic capacitors of 4700µF (for + and -Vp).

Heatsink Calculation

With a symmetrical power supply of ±27.5V and an 8Ω load, the worst case power dissipation is 23W (see also Figure 24).

Calculation of the heatsink:

$$R_{th(vj-a)} = \frac{T_{j\,max} - T_{a\,max}}{P_{tot}} = \frac{(150-45)^{o}C}{23} = 4.5K/W$$

The thermal resistance of the heatsink becomes:

$$\begin{aligned} Rth_{(h-a)} &= Rth_{(vj-a)} - Rth_{(vj-case)} - Rth_{(case-h)} \\ &= (4.5-1-0.2)K/W \\ &= 3.3K/W \end{aligned}$$

This can be realized with a 5cm extruded heatsink (type KL-134 of Seifert).

Because the substrate of the IC is directly soldered on the copper block of the encapsulation, this copper block and so the external heatsink, when no mica washer is used, is connected to the lowest potential in the circuit (-Vp). For symmetrical power supplies the heatsink can be connected to ground potential when a mica washer is used for electrical isolation. In that case $Rth_{(mb-h)}$ will become higher.

MEASUREMENTS

Quiescent Current Consumption

The quiescent current consumption versus supply voltage is given in Figure 16.

Total Harmonic Distortion

The total harmonic distortion versus frequency at Po = 20W is given in Figure 17 for ±Vp = 27.5V and R1 = 8Ω and in Figure 25 for R1 = 8Ω and an asymmetrical power supply of 55V. The total harmonic distortion versus frequency at Po = 25W is given in Figure 30 for ±Vp = 24V and R1 = 4Ω. The total harmonic distortion versus frequency at Po = 50W for 2 times TDA1514A in BTL is given in Figure 39 for ±Vp = 24V and R1 = 8Ω.

The total harmonic distortion versus output power at f = 1kHz is given in Figure 18 for ±Vp = 27.5V and R1 = 8Ω and in Figure 31 for R1 = 4Ω and ±Vp = 24V. In Figure 26 the total harmonic distortion versus output power at f = 1kHz for an asymmetrical power supply of 55V and R1 = 8Ω is given and in Figure 38 for Vp = 48V and R1 = 8Ω.

For 2 times TDA1514A in BTL the total harmonic distortion versus output power is given in Figure 40 for ±Vp = 24V, f = 1kHz and R1 = 8Ω.

Power Bandwidth

The power bandwidth for THD = -60dB is given in Figure 19 for ±Vp = 27.5V and R1 = 8Ω and in Figure 32 for ±Vp = 24V and R1 = 4Ω. In Figure 27 the power bandwidth is given for an asymmetrical supply voltage of 55V and R1 = 8Ω. The power bandwidth for 2 times TDA1514A in BTL is given in Figure 41 for ±Vp = 24V and R1 = 8Ω.

Intermodulation Distortion

IM distortion versus output power is given in Figure 20 for ±Vp = 27.5V and R1 = 8Ω and in Figure 33 for ±Vp = 24V and R1 = 4Ω.

Frequency Response

In Figure 21 the frequency response is given for ±Vp = 27.5V and R1 = 8Ω. The reference level (0dB) is at 10dB below Po max (= 4W) at f = 1kHz. In Figure 34 the frequency response is given for ±Vp = 24V and R1 = 4Ω. The reference level (0dB) is at 10dB below Po max (= 5W) at f = 1kHz. For an asymmetrical supply voltage of 55V and R1 = 8Ω the frequency response is given in Figure 28. The reference level (0dB) is at 10dB below Po max (= 4W) at f = 1kHz.

The low frequency behavior depends on the coupling capacitor C1 and for the application with asymmetrical power supply also on the coupling capacitor C9 to the loudspeaker.

In Figure 42 the frequency response is given for 2 times TDA1514A in BTL at ±Vp = 24V and R1 = 8Ω. The reference level (0dB) is at 10dB below Po max (= 10W).

Output Power

The output power versus supply voltage for a single TDA1514A with and without bootstrap is given in Figure 22 measured with R1 = 8Ω at THD = -60dB and f = 1kHz and in Figure 35 measured with R1 = 4Ω at THD = -60dB and f = 1kHz. The output power with an asymmetrical supply voltage is given in Figure 29 measured with R1 = 8Ω and R1 = 4Ω at THD = -60dB and f = 1kHz. For 2 times TDA1514A in BTL the output power versus supply voltage is given in Figure 43 measured with R1 = 16Ω, 8Ω and 4Ω at THD = -60dB and f = 1kHz.

Power Dissipation

The power dissipation of the TDA1514A as a function of the output power, measured at ±Vp = 27.5V, f = 1kHz and R1 = 8Ω is given in Figure 23 and measured at ±Vp = 24V, f = 1kHz and R1 = 4Ω is given in Figure 36.

The worst case power dissipation versus supply voltage, in both cases, is shown in Figures 24 and 37.

Supply Voltage Ripple Rejection

The supply voltage ripple rejection is measured in the operating state, in the mute state and in the stand-by state.

Figure 44 shows the ripple rejection as a function of frequency with the ripple on +Vp and Figure 45 the ripple rejection with the ripple on -Vp. With the ripple on +Vp the ripple rejection is low in the stand-by mode because of the network for bootstrapping (between pin6 and pin 5). Without bootstrapping this ripple rejection is much better.

Because the ripple rejection is dependent of the input resistance, we have measured the ripple rejection as a function of the input resistance. The results of this measurement, with ripple voltage on -Vp line, are in Figure 46.

Input and Output Impedance

The input impedance of the TDA1514A at pin 1 is greater than 1MΩ. The input impedance in the used application circuit is 20kΩ, determined by the external input resistor.

The output impedance at pin 5 is typical 25mΩ at f = 1kHz.

Gain

The input sensitivity for Po = 20W in R1 = 8Ω is 418mV. The closed loop gain measured at f = 1kHz is 29.6dB. The closed loop gain can be varied by resistors R1 and R2 between 20 and 46dB.

Noise

The weighted signal to noise ratio at Po = 50mW and Rs = 2kΩ is 86dB measured according to IEC 179 (A-curve). The unweighted noise (f = 20Hz–20kHz) is 83dB. Measured according to CCIR 468 peak value (also new DIN 45405 standard) this S/N ratio is 73dB.

Slew Rate

The slew rate of the amplifier is 14V/µs.

CRITICAL POINTS

To reach the very good distortion levels, a correct print layout design is important. The connection of the following components is critical. The HF decoupling capacitors on the supply lines (C5, C6 in Figure 3) must be mounted as close as possible to the TDA1514A.

Care must be taken by choosing the right grounding. The input grounding of R1, R3 and C3 must be together and then with a single track as short as possible to pin 8. The capacitors C5 and C6 must be grounded as close as possible to pin 8. Resistor R6 is grounded close to pin 8 and R7 is grounded close to the output grounding.

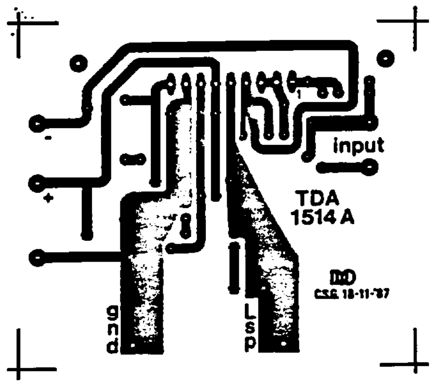


Figure 5. Print Layout TDA1514A – Symmetrical Power Supply

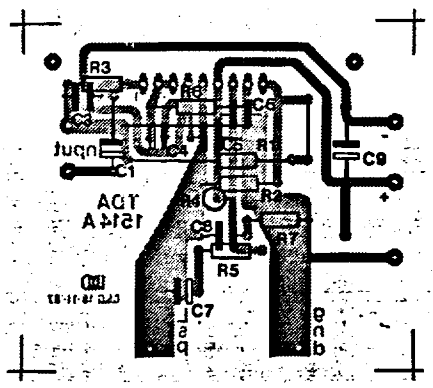


Figure 6. Component Layout TDA1514A – Symmetrical Power Supply

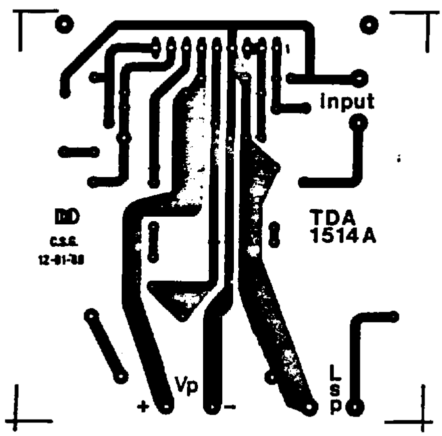


Figure 7. Print Layout TDA1514A – Asymmetrical Power Supply

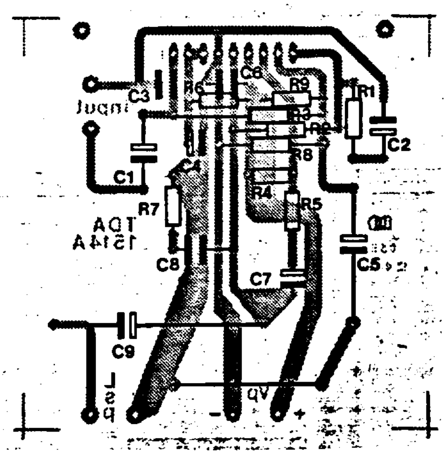
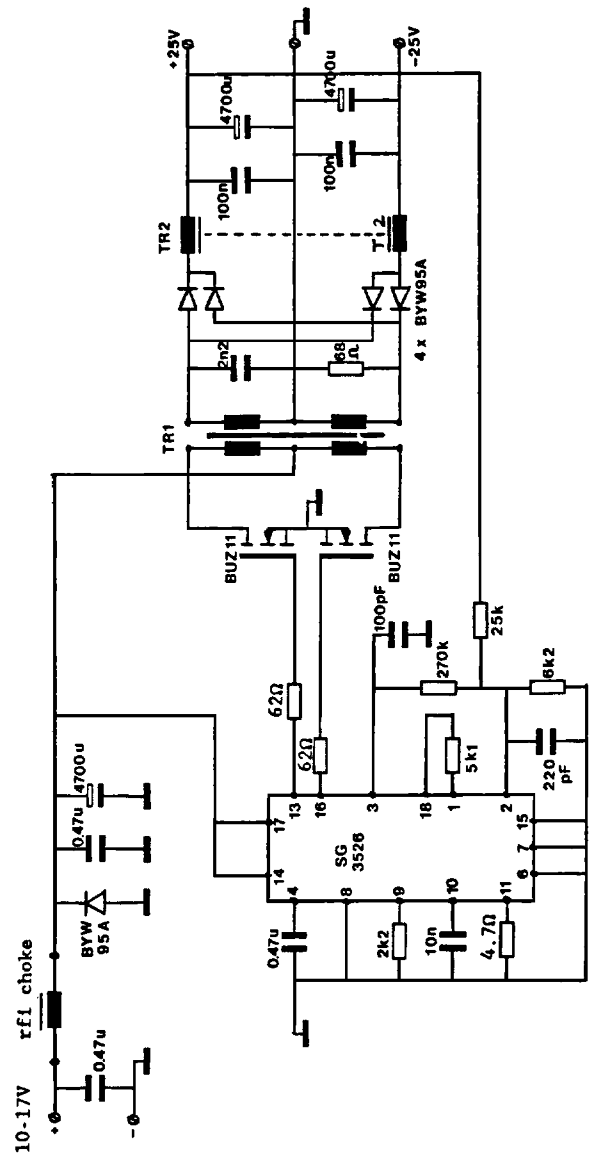


Figure 8. Component Layout TDA1514A – Asymmetrical Power Supply



TR1 ringcore 3C85	25x15x10	nr.4330 030 35000	primary 2x9 turns bifilair. secondary 2x30 turns bifilair.
TR2 ringcore 2P65	26.5x14.9x7	nr.4330 030 60200	2x40 turns bifilair.

Figure 9. Switch-Mode Power Supply (Proposal)

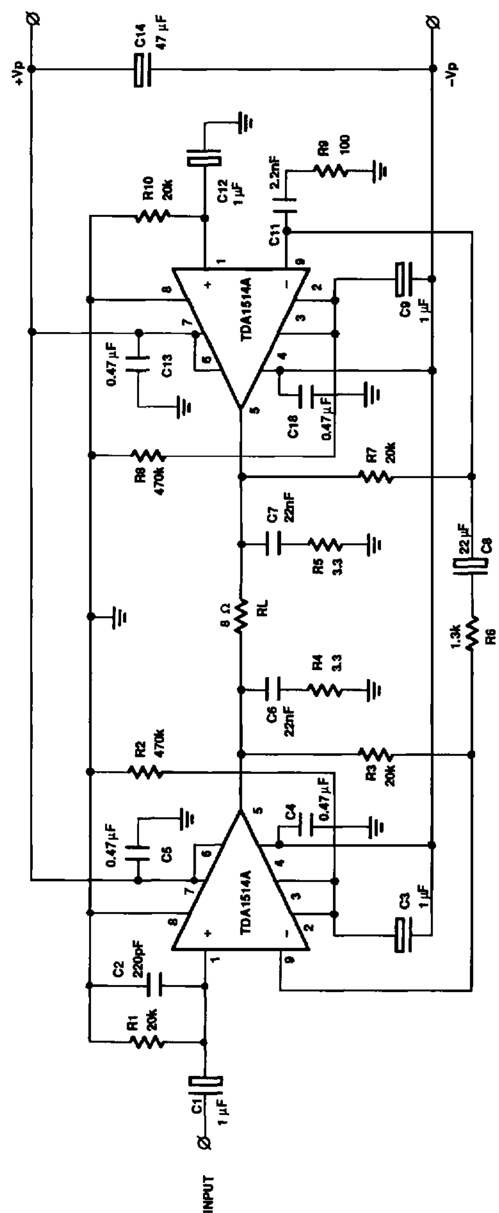


Figure 10. Circuit Diagram BTL Amplifier with TDA1514A

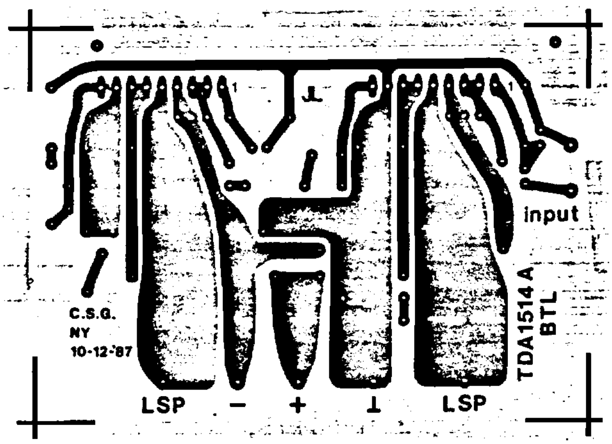


Figure 11. Print Layout TDA1514A – BTL

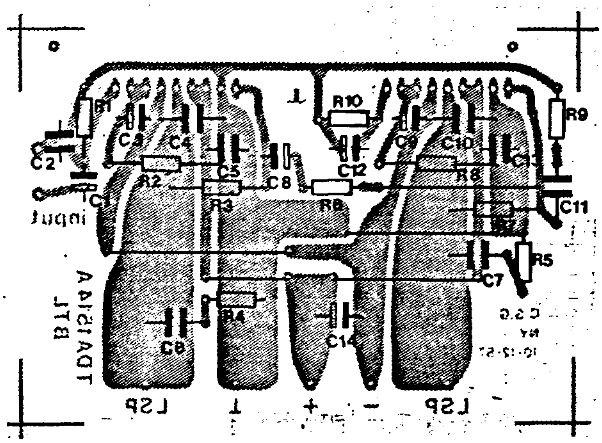


Figure 12. Component Layout TDA1514A – BTL

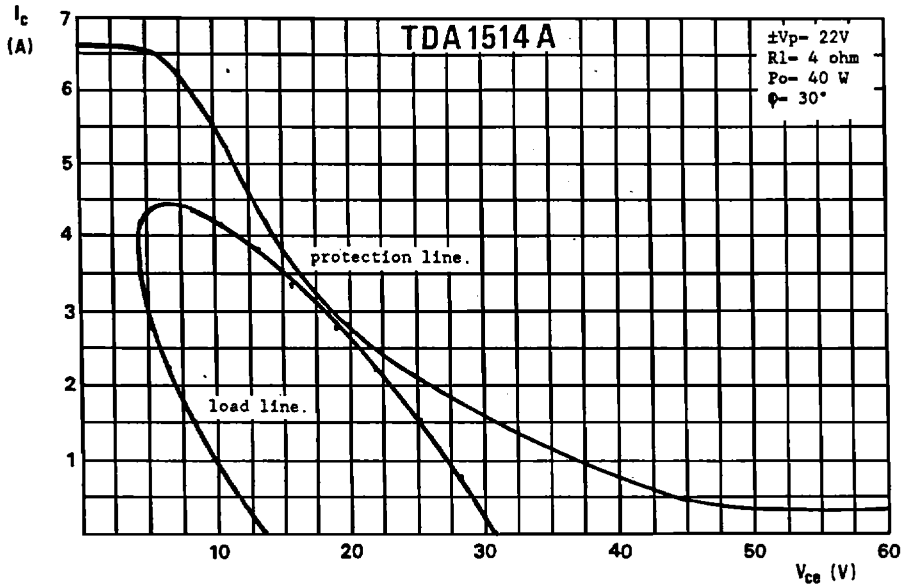


Figure 13. SOAR Curves

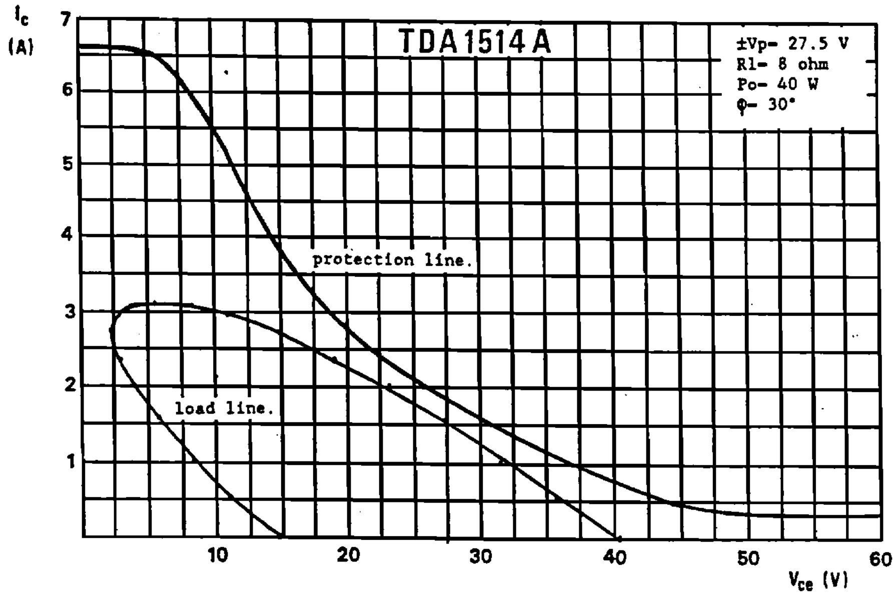


Figure 14. SOAR Curves

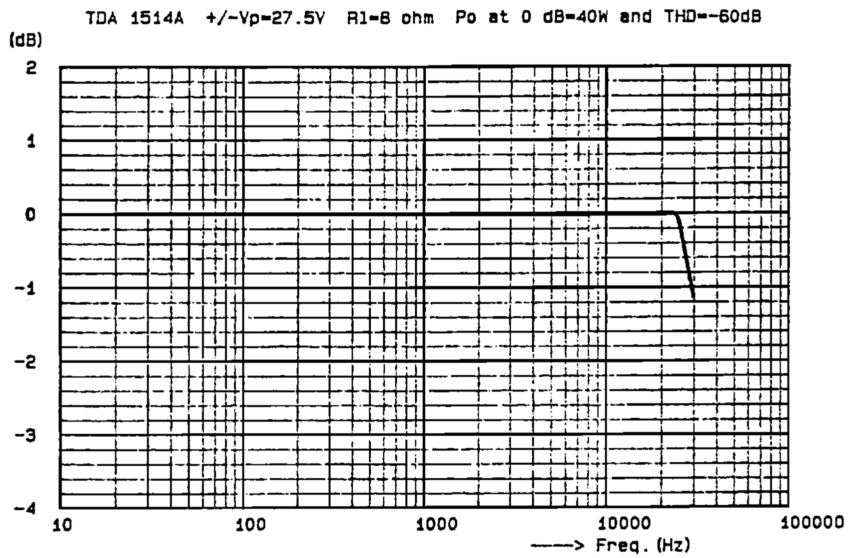


Figure 19. Power Bandwidth

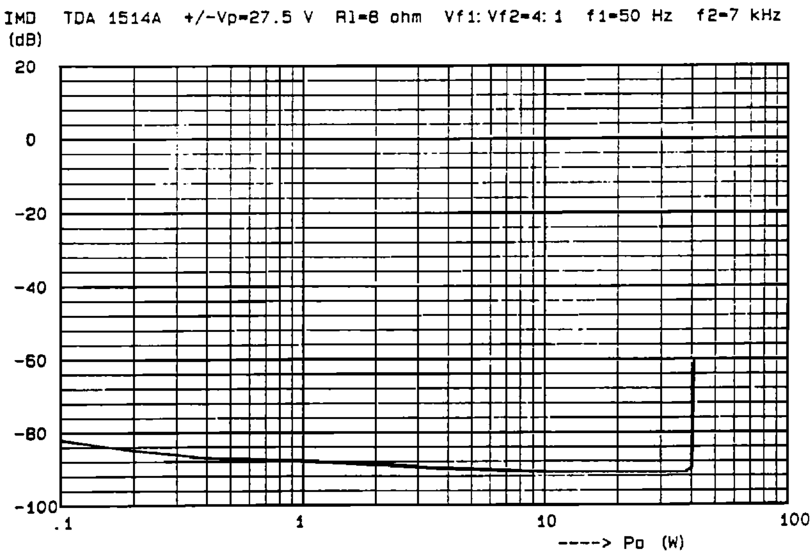


Figure 20. IMD vs. Output Power

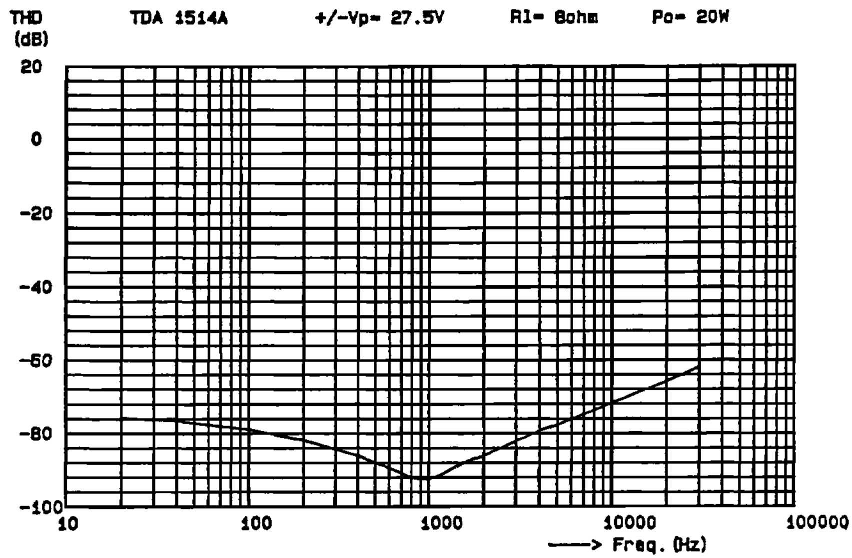


Figure 17. THD vs. Frequency

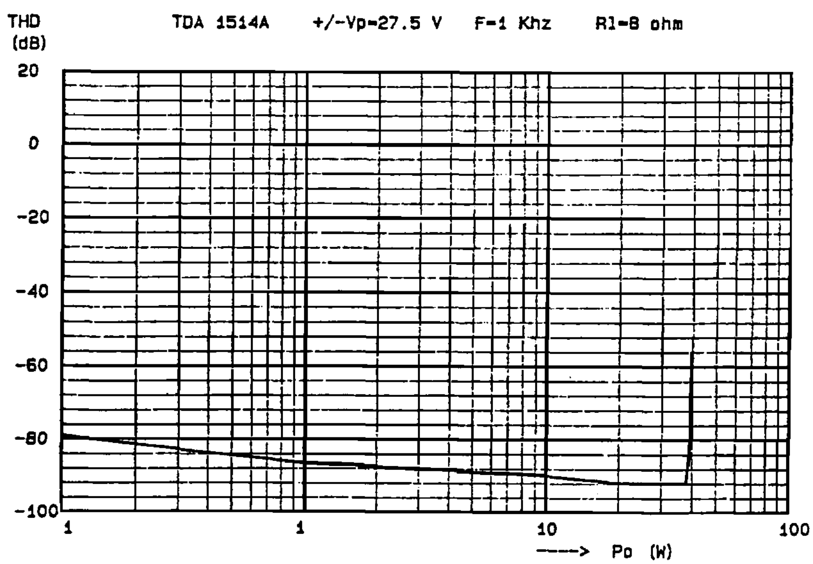


Figure 18. THD vs. Output Power

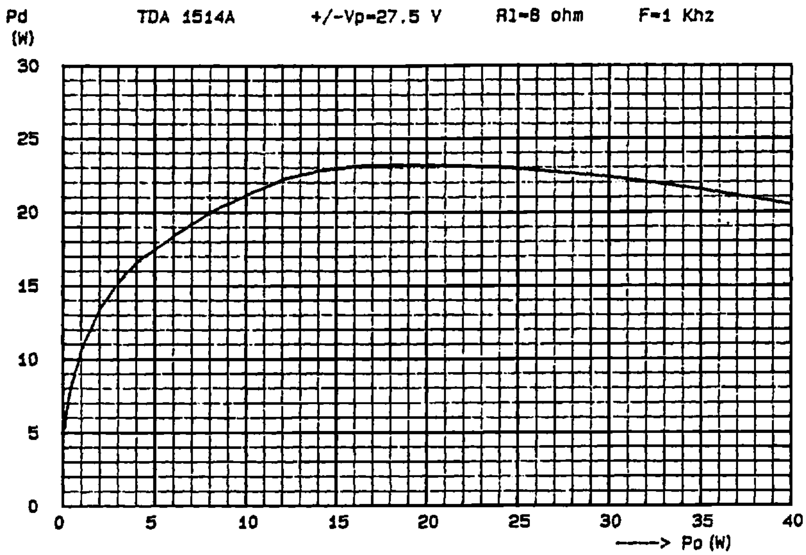


Figure 23. Power Dissipation vs. Output Power

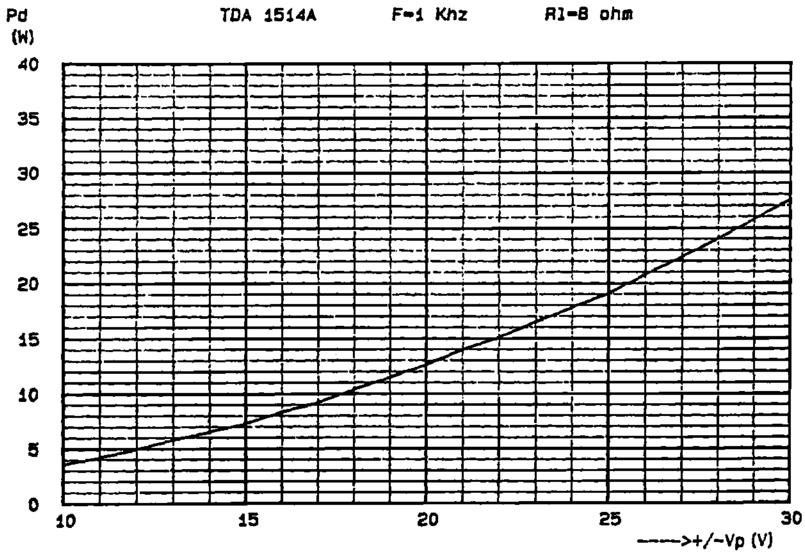


Figure 24. Worst Case Power Dissipation vs. Supply Voltage

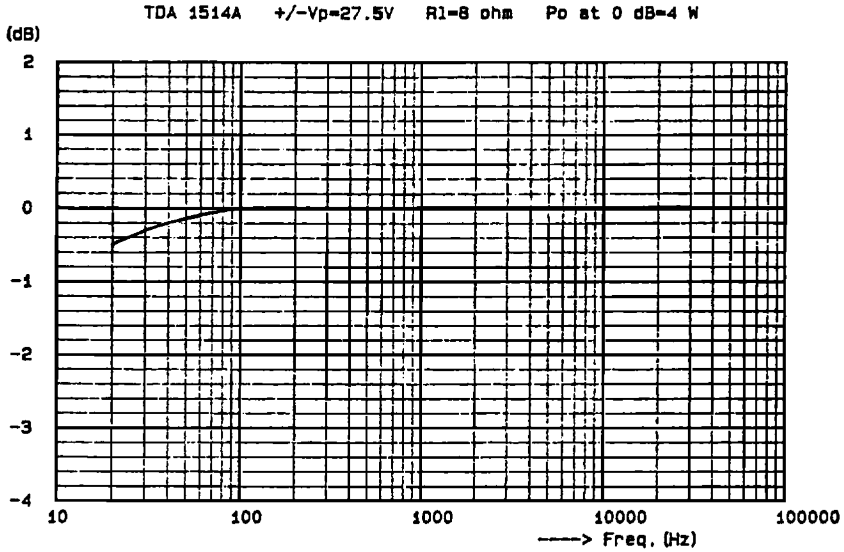


Figure 21. Frequency Response at Po = 4W

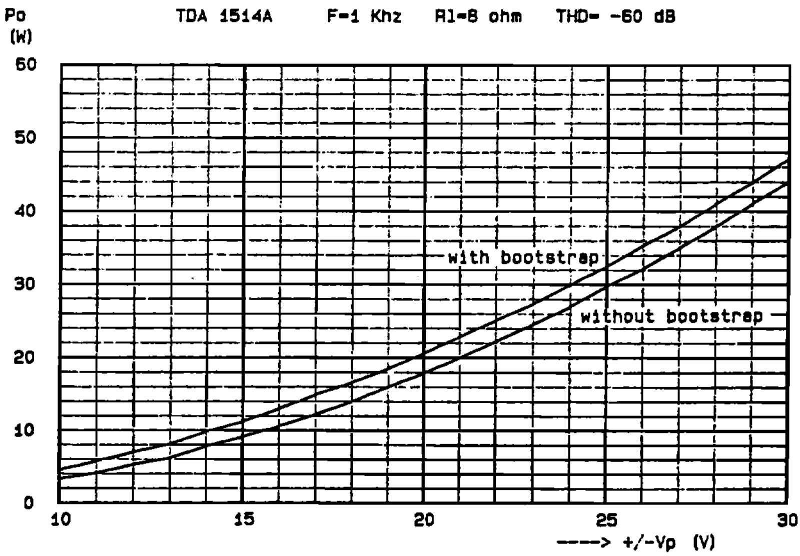


Figure 22. Output Power vs. Supply Voltage

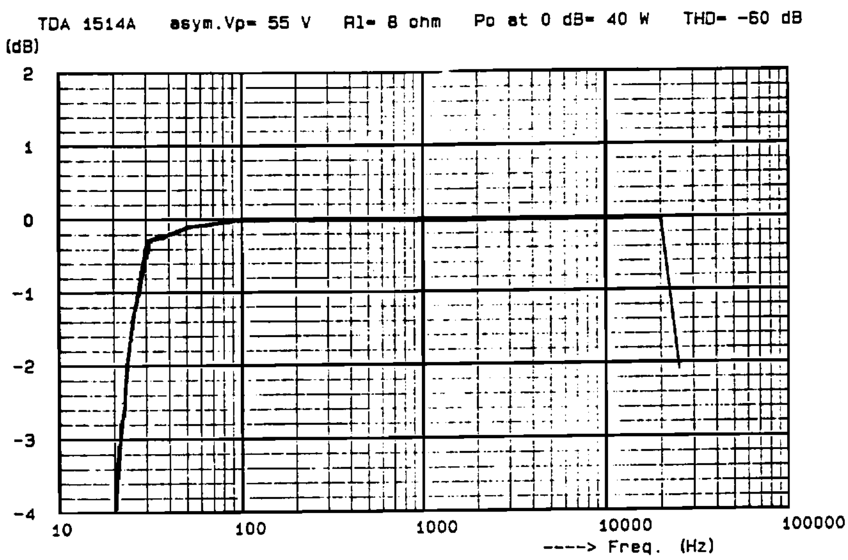


Figure 27. Power Bandwidth

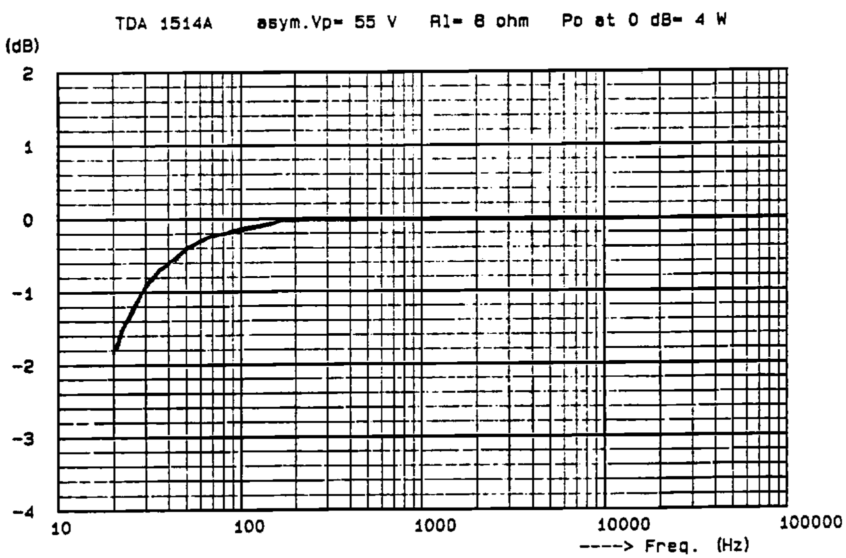


Figure 28. Frequency Response at Po = 4W

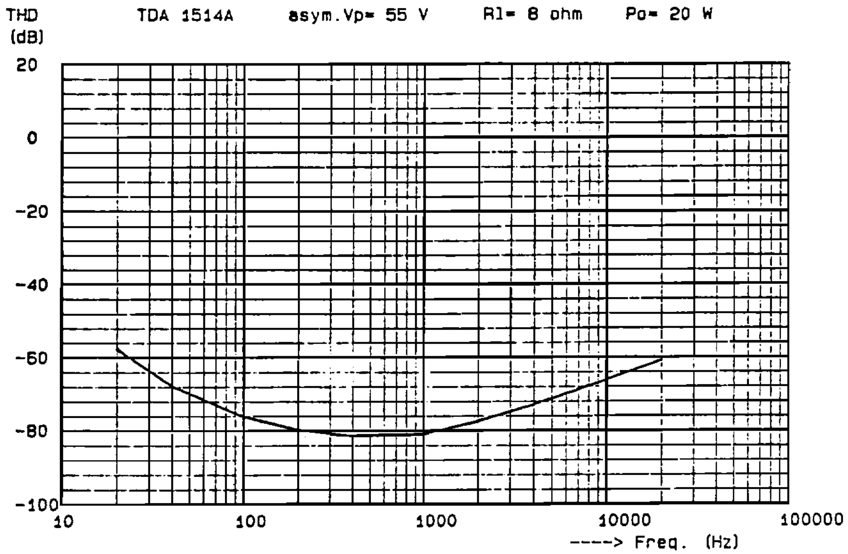


Figure 25. THD vs. Frequency

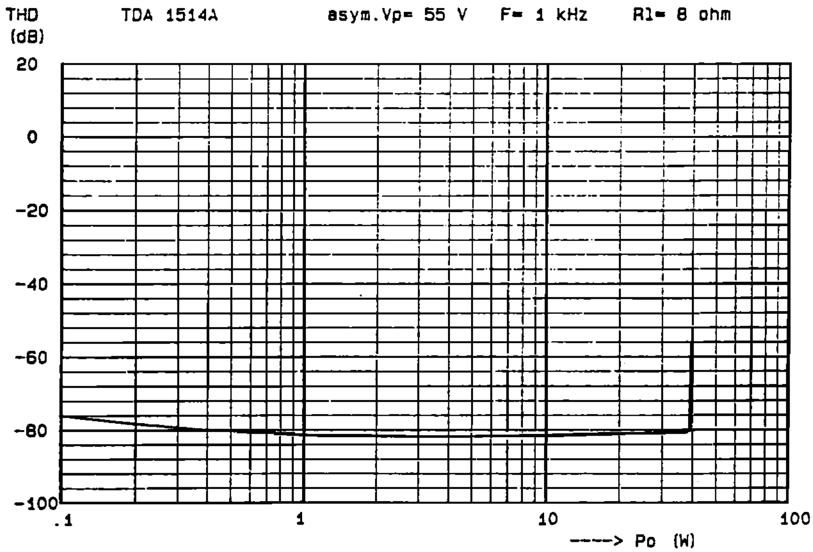


Figure 26. THD vs. Output Power

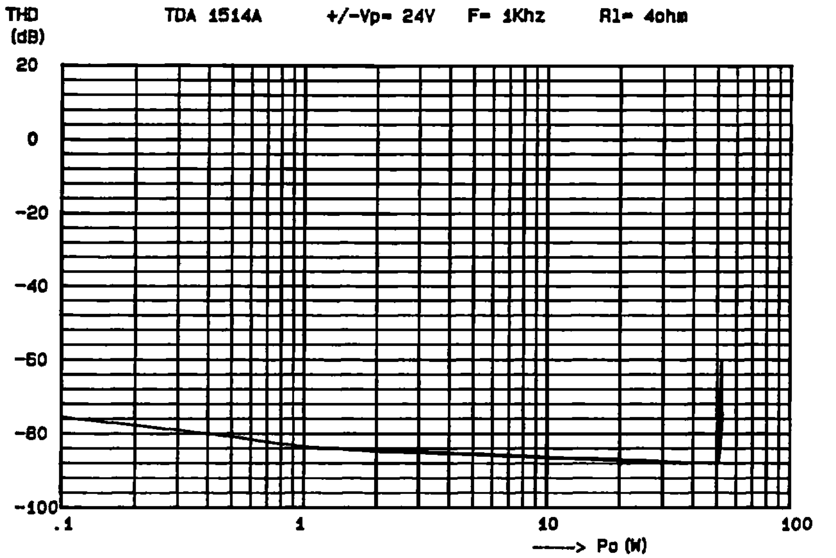


Figure 31. THD vs. Output Power

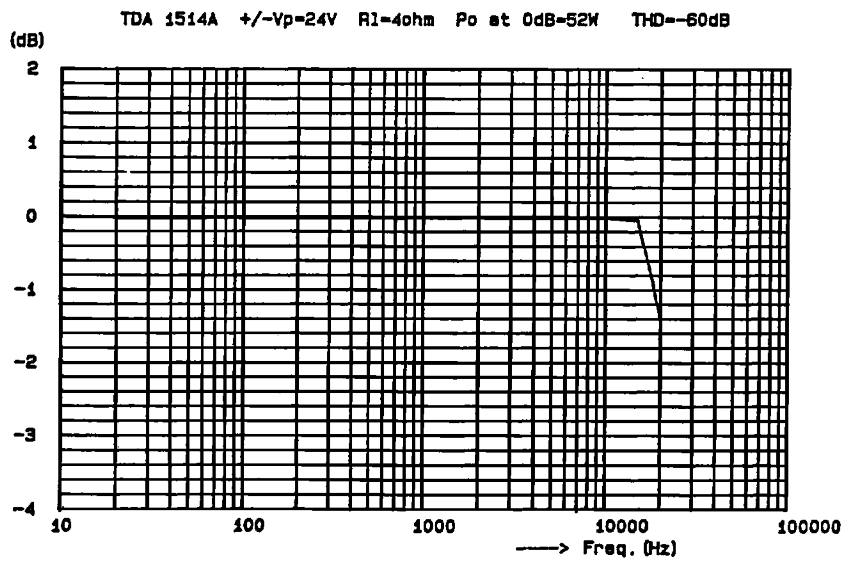


Figure 32. Power Bandwidth

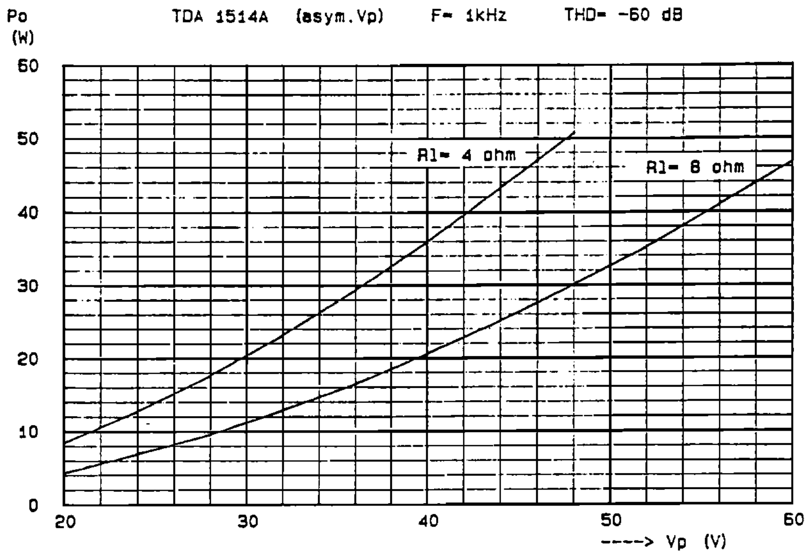


Figure 29. Output Power vs. Supply Voltage

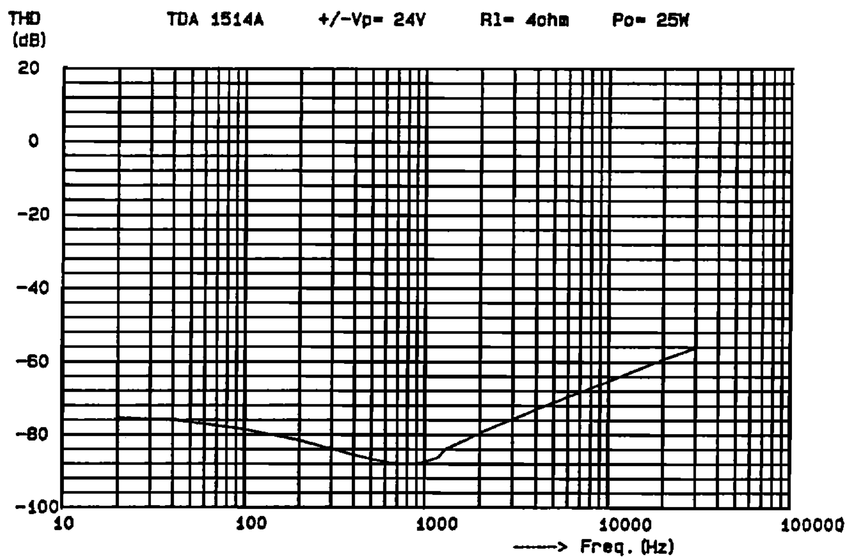


Figure 30. THD vs. Frequency

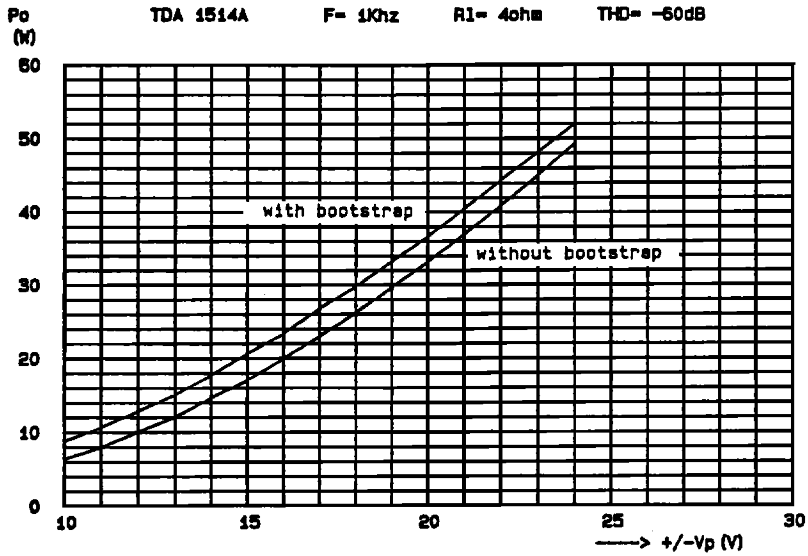


Figure 35. Output Power vs. Supply Voltage

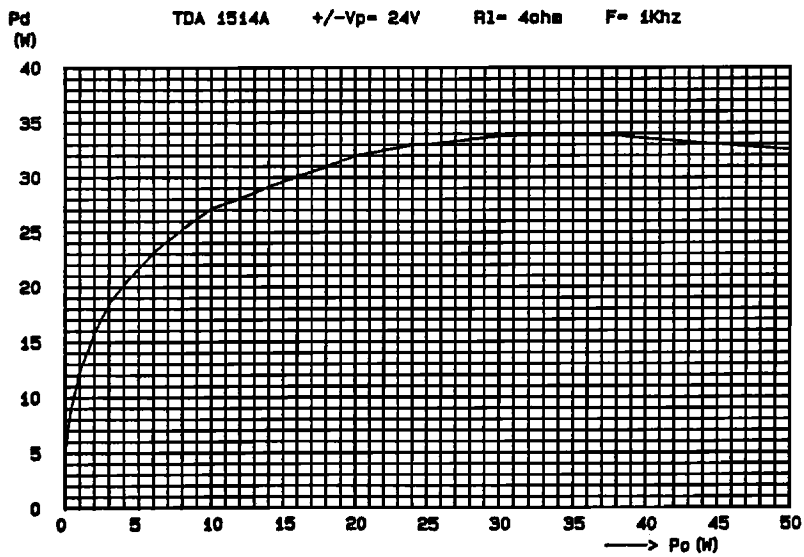


Figure 36. Power Dissipation vs. Output Power

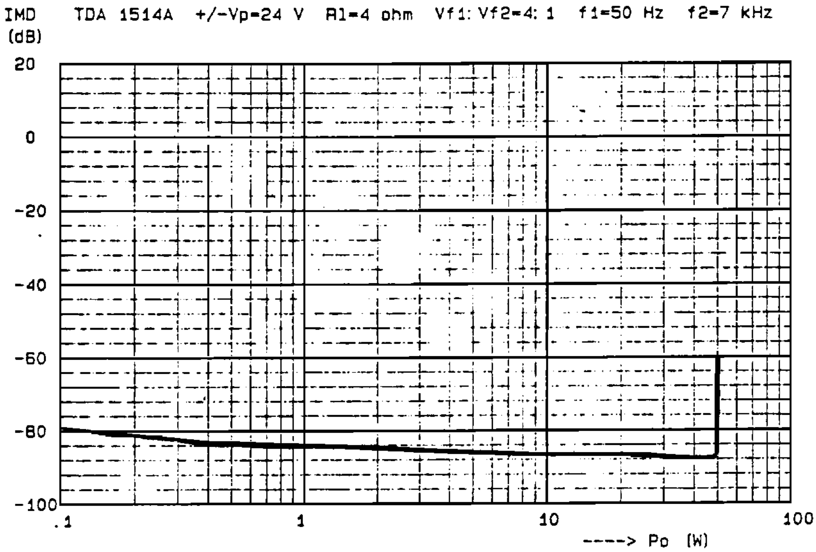


Figure 33. IMD vs. Output Power

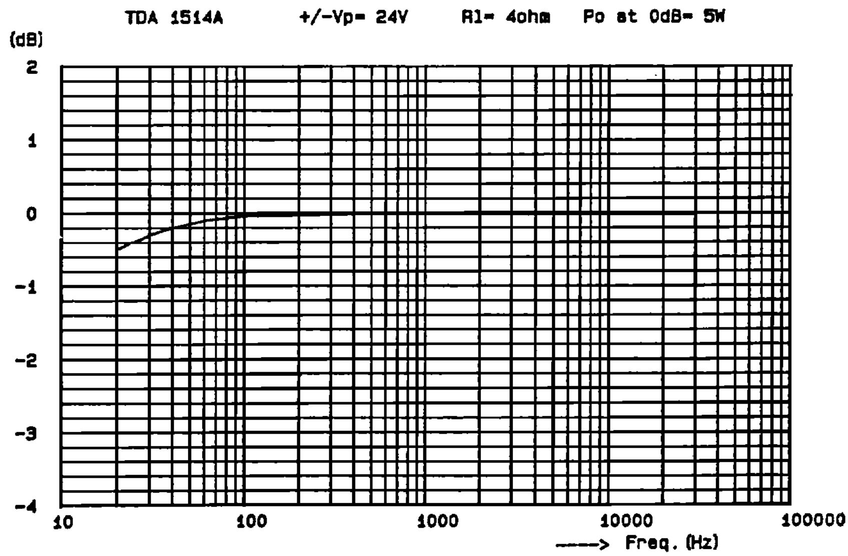


Figure 34. Frequency Response at Po = 5W

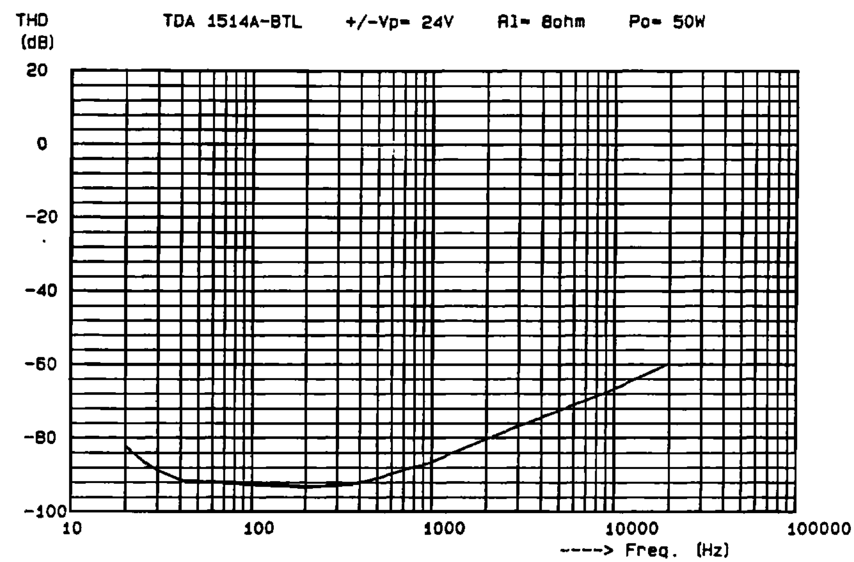


Figure 39. THD vs. Frequency

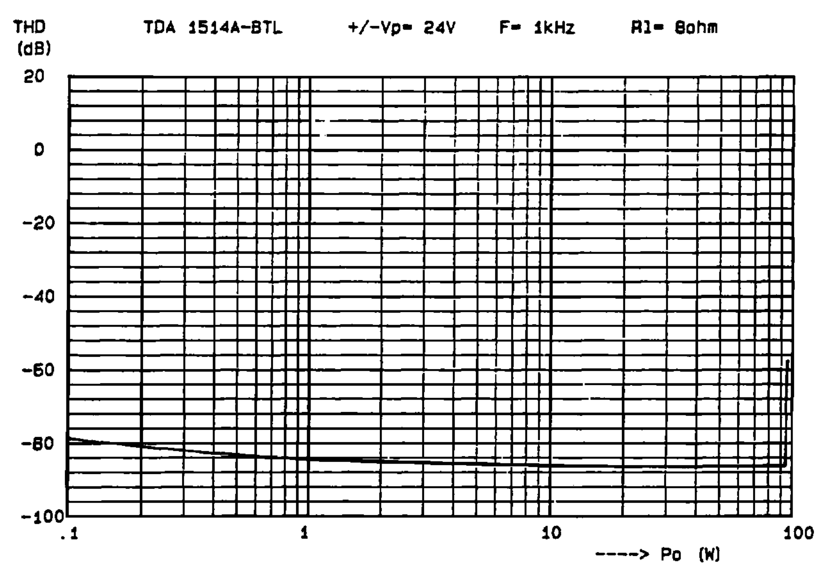


Figure 40. THD vs. Output Power

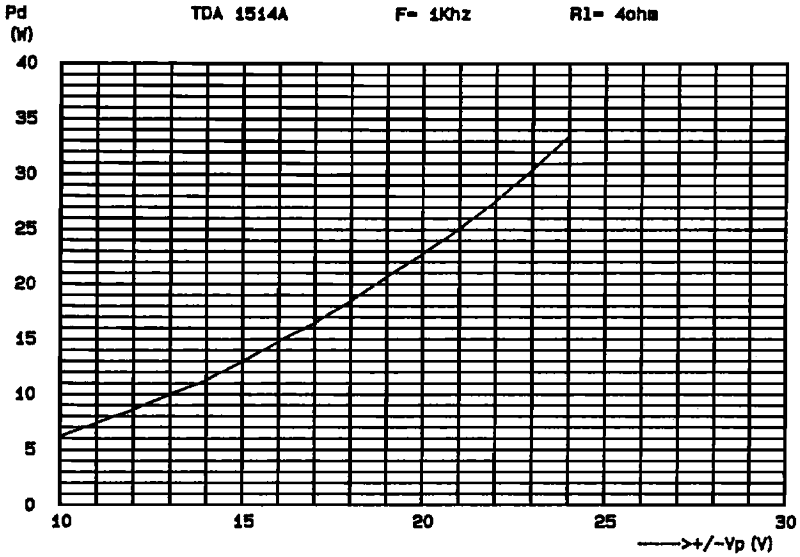


Figure 37. Worst Case Power Dissipation vs. Supply Voltage

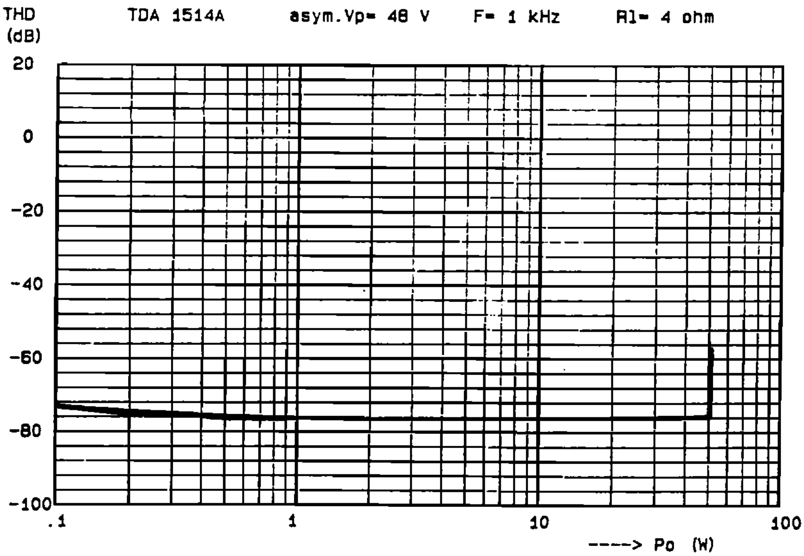


Figure 38. THD vs. Output Power

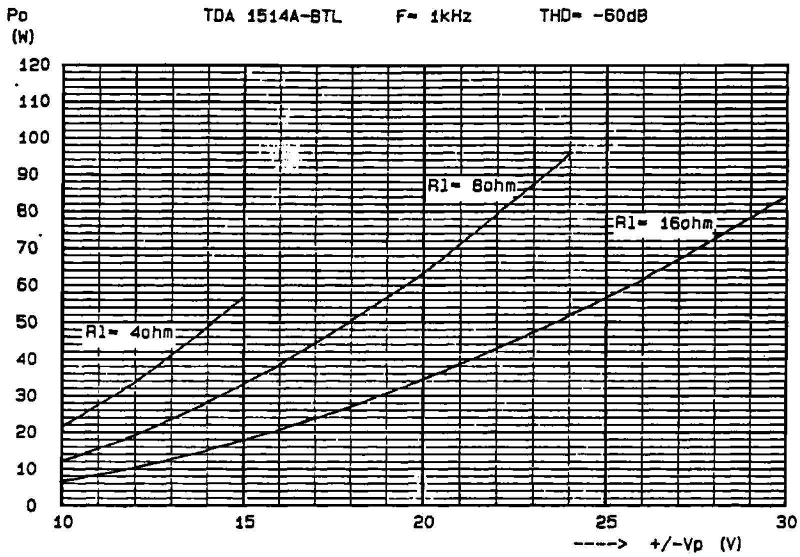


Figure 43. Output Power vs. Supply Voltage

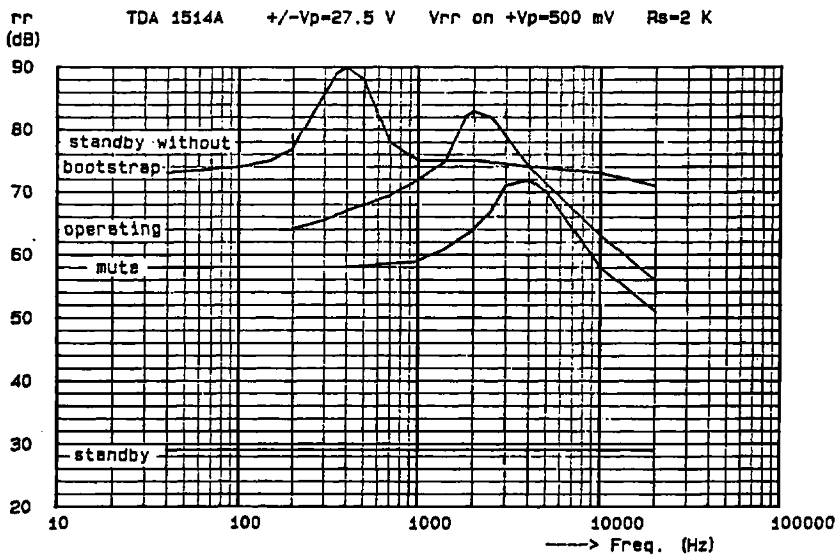


Figure 44. Ripple Rejection vs. Frequency

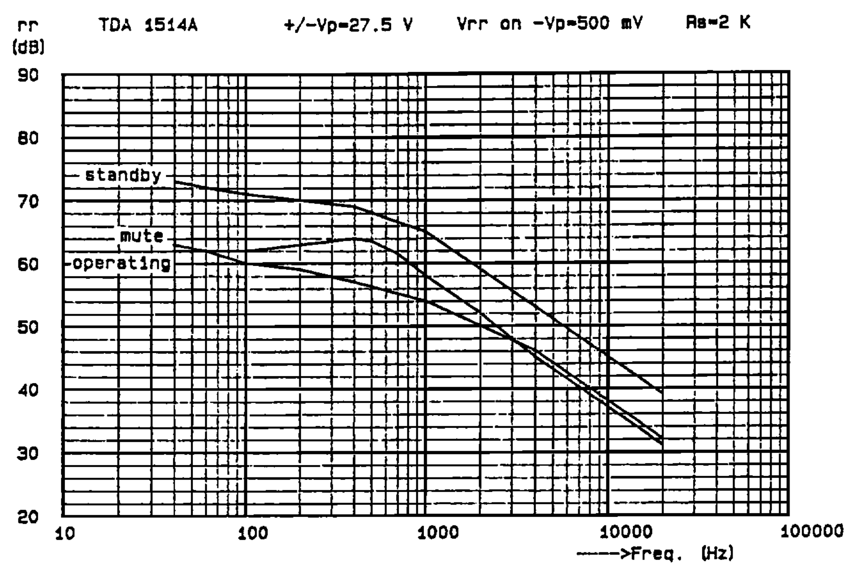


Figure 45. Ripple Rejection vs. Frequency

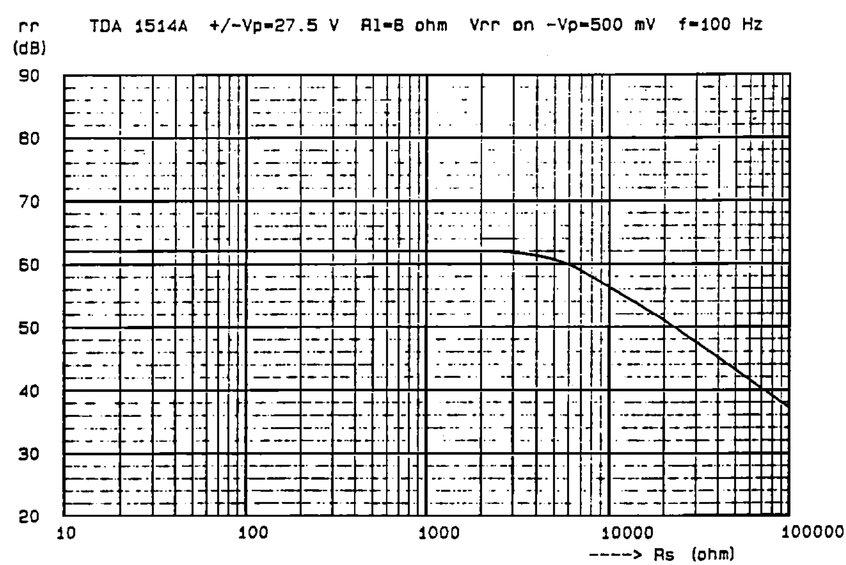


Figure 46. Ripple Rejection vs. Source Resistor