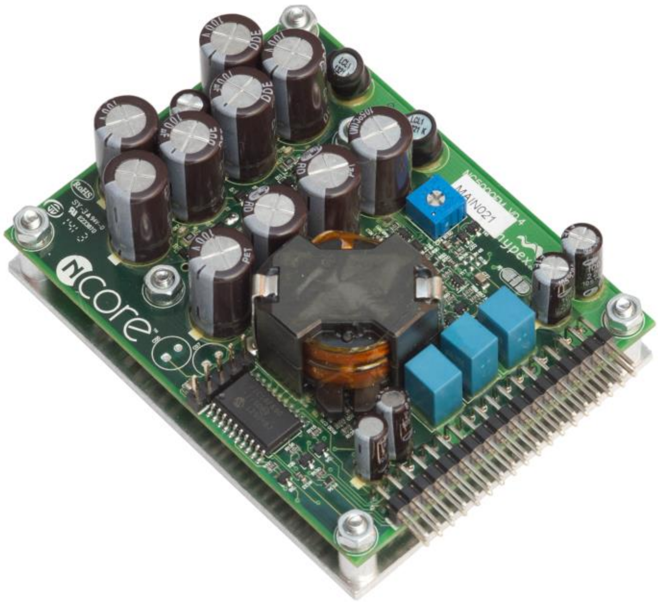
Hypex Electronics BV
Kattegat 8
9723 JP Groningen, The Netherlands
+31 50 526 4993
sales@hypex.nl
www.hypex.nl

audio power by hypex ®

NC500OEM Definitive performance class D amp



Highlights

- Extremely low distortion and noise over frequency and power range
- Extremely low output impedance
- Very high power density
- Neutral and transparent reproduction: "Neither dirt nor fairy dust"

Features

- Conservatively rated
- Differential audio input
- 2 Ω capable
- Extensive, microprocessor-controlled error protection

Applications

- Top-end stereo and multichannel amps
- Active speakers

Description

The NC500 OEM amplifier module is an extremely high-quality audio power amplifier module which operates in class D. Not only does it offer a way for audiophile music reproduction to continue in an ever more energy-conscious world, its measured and sonic performance actually raises the bar for audio amplifiers of any description. Operation is based on a non-hysteresis 5th order self-oscillating control loop taking feedback only at the speaker output.

Contents

1 Performance data

Power supply = SMPS1200A700, Load=4**Ω**, MBW=20kHz, Source imp=40**Ω**, unless otherwise noted

Item	Symbol	Min	Typ	Max	Unit	Notes
Rated Output Power	P_R		550		W	THD=1%, Load=2Ω
			700		W	THD=1%, Load=4Ω
			400		W	THD=1%, Load=8Ω
Distortion	THD+N, IMD [1]		0.001	0.005	%	20Hz<f<20kHz [1], 4Ω Pout<P_R/2
Output noise	U_N		9	10	µV	Unwtd
Signal-to-noise ratio (unweighted, add 2 dB for A-weighted)	SNR	134	135		dB	Re P_R,
		109	110			Re 2.8Vrms
Output Impedance	Z_{OUT}		1.5	2	mΩ	f<16kHz
				5	mΩ	f=20kHz
Power Bandwidth	PBW	35			kHz	[2]
Frequency Response		0		50	kHz	+0/-3dB. All loads.
Voltage Gain	A_V	11.9	12.4	12.9	dB	
Output Offset Voltage	$\lvert V_{OO} \rvert$			50	mV	
Supply Ripple Rejection	PSRR	75	85		dB	Either rail, f<1kHz.
Efficiency	η		93		%	Full power
Idle Losses	P_0		6.3	7	W	
Current Limit		25	26	28	A	Hiccup mode after 200ms limiting

Note 1: At higher audio frequencies there are not enough harmonics left in the audio band to make a meaningful THD measurement. High frequency distortion is therefore determined using a 18.5kHz+19.5kHz 1:1 two-tone IMD test.
Note 2: Dielectric losses in the output capacitor limit long term (>30s) full-power bandwidth to 5kHz.

2 Audio Input Characteristics

Item	Symbol	Min	Typ	Max	Unit	Notes
DM Input Impedance	$Z_{IN,DM}$		1.8		kΩ	Per input [1]
CM Rejection Ratio	CMRR	50	65		dB	All frequencies

Note 1: See 8.3.

3 Control I/O Characteristics

Item	Symbol	Min	Typ	Max	Unit	Notes
Pull-up	R_{WPU}		27		kΩ	nAMPON, OPTION, To 3.3V
Logical high input voltage	V_{IH}	2.65		3.6	V	nAMPON, SCL, SDA
Logical low input voltage	V_{IL}	-0.3		0.5	V	nAMPON, SCL, SDA
Logical low output voltage	V_{OL}			0.4	V	nFATAL, SCCPIND, SDA, CLIP I_{OL}=1mA

4 Absolute maximum ratings

Correct operation at these limits is not guaranteed. Operation beyond these limits may result in irreversible damage.

Item	Symbol	Rating	Unit	Notes
Power supply voltage	V_B	+/-100	V	See section 10.3
VDR supply voltage	V_{DR}	20	V	See section 10.3
Peak output current	$I_{OUT,P}$	28	A	Guarded by current limit at 26A
Input voltage	V_{IN}	+/-15	V	Either input referred to ground
Input current	I_{IN}	10m	A	Logical inputs and buffer inputs
Collector voltage	V_{OC}	35	V	Open collector outputs when high
Collector current	I_{OC}	2m	A	Open collector outputs when low
Air Temperature	T_{AMB}	65	°C	Lower improves lifetime
Heat-sink temperature	T_{SINK}	90	°C	Thermistor limited. User to select heat sink to insure this condition under most adverse use case

5 Recommended Operating Conditions and Supply Currents

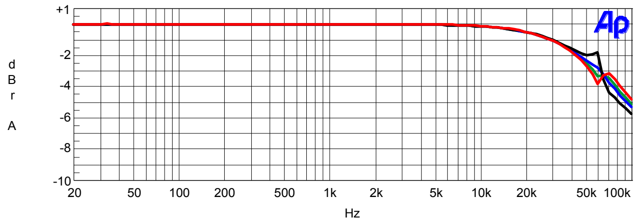
Item	Symbol	Min	Typ	Max	Unit	Notes
Power supply voltage	V_B	35	84	98	V	Available output power depends on supply voltage
Signal stage supply voltage (positive and negative)	V_{SIG}	10.5	15	16	V	
Signal stage supply current	I_{VSIG}		30	35	mA	
External driver supply voltage	V_{DR}	14	15	17	V	Unit protects when allowable range is exceeded
Drive supply current	I_{DR}		70	75	mA	
Load impedance	Z_{LOAD}	1			Ω	
Source impedance	Z_{SRC}			50	Ω	Differentially (25 per leg)
Effective power supply storage capacitance[1)]	C_{SUP}	4700			µF	Per rail, per attached amplifier. 4Ω load presumed.

Note 1: The effective power supply storage capacitance of Hypex SMPS is already in excess of 4700uF. Do not add supplementary capacitance.

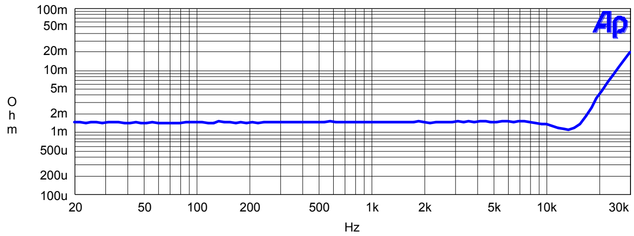
6 Typical performance graphs

Test conditions: one NC500 powered by SMPS1200A700 with 230VAC mains. Measurement bandwidth=20kHz except for small signal tests.

6.1 Small signal tests (all loads)

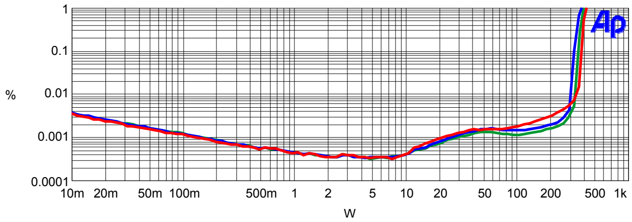


Frequency response into 8 (green), 4 (blue) and 2 (black) ohms and into open circuit (red).

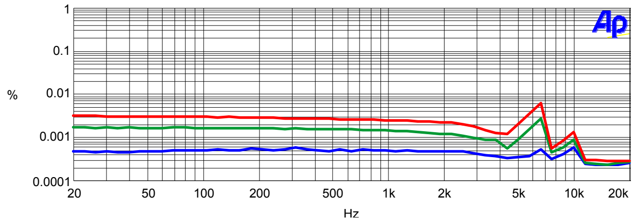


Output impedance, four-wire test at speaker terminals.

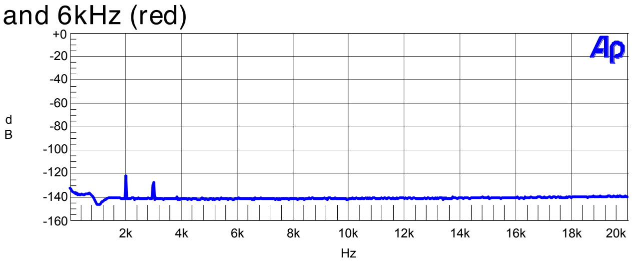
6.2 Large signal tests (8Ω)



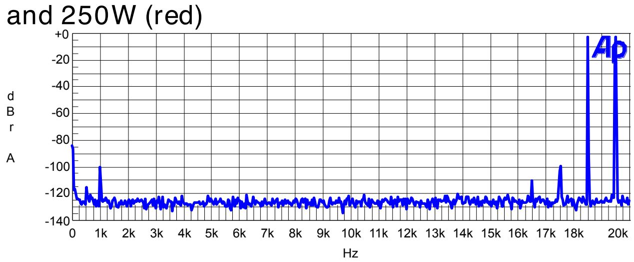
THD+N vs. power at 100Hz (blue), 1kHz (green) and 6kHz (red)



THD vs. frequency at 10W (blue), 100W (green) and 250W (red)

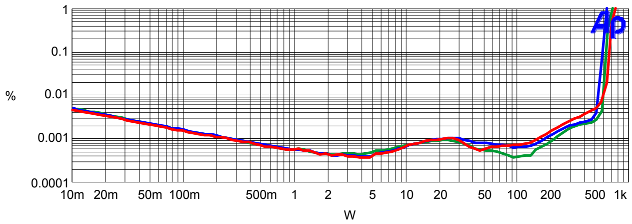


Noise floor and distortion residual at 1W.

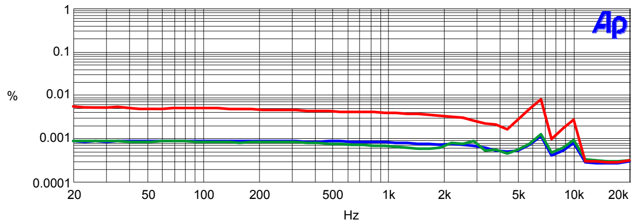


18.5kHz (50W)+19.5kHz (50W) IMD. 0dB=100W

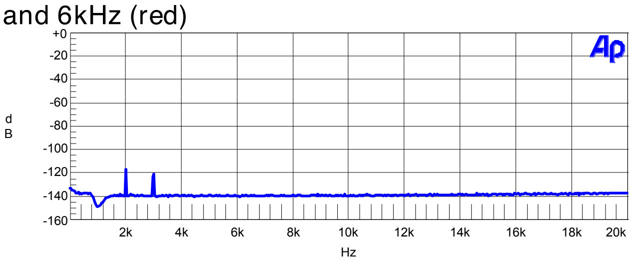
6.3 Large signal tests (4Ω)



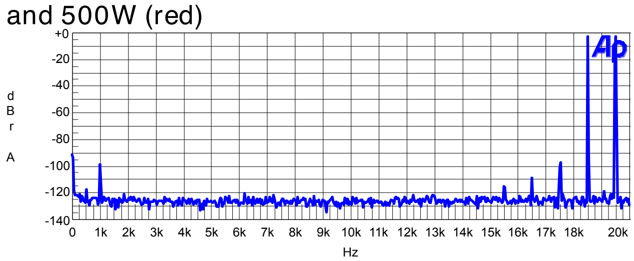
THD+N vs. power at 100Hz (blue), 1kHz (green) and 6kHz (red)



THD vs. frequency at 10W (blue), 100W (green) and 500W (red)

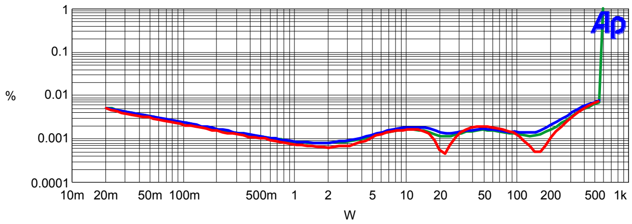


Noise floor and distortion residual at 1W.

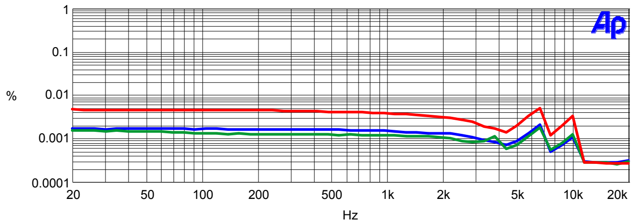


18.5kHz (100W)+19.5kHz (100W) IMD. 0dB=200W

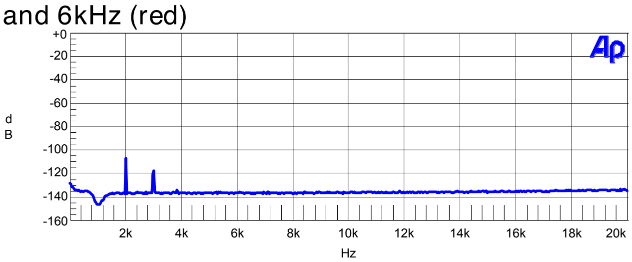
6.4 Large signal tests (2Ω)



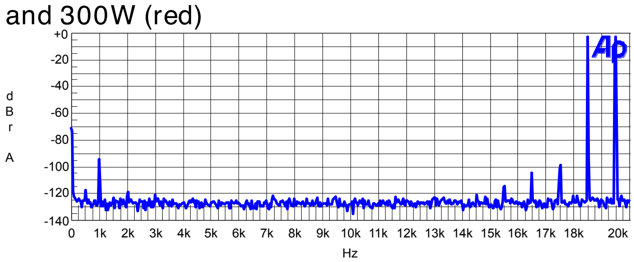
THD+N vs. power at 100Hz (blue), 1kHz (green) and 6kHz (red)



THD vs. frequency at 10W (blue), 100W (green) and 300W (red)



Noise floor and distortion residual at 1W.



18.5kHz (100W)+19.5kHz (100W) IMD. 0dB=200W

7 Frequently asked numbers

The following are neither specifications nor indicators of audio performance but engineering choices which in combination with the specific circuit topology lead to the performance found in section 1. They do not influence sound quality directly. Commonly expressed creeds that an amplifier's suitability for high quality audio can be read from these numbers (f_{SW} in particular) are ill informed.

Item	Symbol	Min	Typ	Max	Unit	Notes
Switching frequency	f_{SW}		450		kHz	Idle, see the white paper.
MOSFET ON resistance	R_{DSON}			100	mΩ	Over tolerance and temperature
Dead time	t_b		100		ns	"Soft" dead time. Effective value depends on load current
Output coil inductance	L		10		μH	Effective output inductance is this number divided by loop gain.
Output coil resistance	R_l		2		mΩ	
Output capacitance	C		2		μF	
Loop gain	A_L	53		60	dB	Loop gain peaks at 15kHz and drops back to 53dB at 20kHz.

8 Connections

J3: Connector type: 2x18 pin horizontal 0.1" pitch header.

Pin	Type	Name	Function
1, 2	Pwr	+HV	unregulated supply
3,4,5, 6,7,8	Pwr	GND	
9, 10	Pwr	-HV	unregulated supply
11	Pwr	V_{DR}	External driver supply connection. A floating unregulated supply must be connected between this pin and –HV.
12	-	Reserved	Do not connect.

13,14, 15,16, 18	Out	OUTC	Cold speaker terminal.
17	In	FBC	Cold feedback terminal (do not leave unconnected, see below)
19	In	FBH	Hot feedback terminal (see below)
20,21, 22,23, 24	Out	OUTH	Hot speaker terminal.
25	Pwr	$-V_{SIG}$	Negative supply for modulator stage.
26	Pwr	$+V_{SIG}$	Positive supply for modulator stage.
27	Pwr	GND	
28	i/o	Iout	Current monitor output, hot (0.1V per Ampere)
29	In	INH	Hot (noninverting) input terminal
30	In	INC	Cold (inverting) input terminal
31	In wpu	OPTION	Control mode and I²C address selection
32	In wpu	nAMPON	HW mode: Amplifier enable control
33	O/C	CLIP	Clip indication Pulled low when amp clips. OR tie with other channels and pull up.
34	O/C	SCCPIND	Overcurrent indication
35	O/C Out	SDA READY	SW mode: Data line of I²C bus HW mode: Operating indicator (active high)
36	In O/C	SCL nFATAL	SW mode: Clock line of I²C bus HW mode: Catastrophic fault indication, inverse of internal FATAL bit.

Note 1: o/c=open collector
Note 2: wpu=weakly pulled up to 3.3V, not to be driven above 3.3V.

8.1 Supply connections

An unregulated split supply of 2x84V is connected to the −HV, GND and +HV pins. The amplifier will operate from 2x35V upward but rated output power is not available at low voltages.
The VDR supply should be connected between −HV and VDR. Any other connection may cause damage or excessive heat output.
All GND pins are directly connected to the same ground plane. A separate GND pin (27) is provided near the small-signal end of the connector for convenience only. No distinction is made between "signal ground" and "power ground" because both inputs and outputs are configured as differential signal pairs that do not rely on GND as a reference potential.

8.2 Speaker and feedback connections

The speaker output is the OUTH/OUTC signal pair. Strictly connect the speaker between OUTH and OUTC. Do not treat OUTC as a ground terminal.
FBH and FBC must be connected to OUTH and OUTC not more than a few cm away from the amplifier. This is done to eliminate the contact resistance of J3 from the output impedance. The points where FBH/FBC take off from OUTH/OUTC may be used to branch off biwired connections. Otherwise, simply connecting all 6 pins 13...18 (and 19...24 likewise) with one wide trace is perfectly acceptable.
Using FBH/FBC to sense remotely (e.g. at the end of a speaker cable) does not work well. Do not leave FBH/FBC unconnected.

8.3 Audio input

The INH/INC inputs form a differential pair. Note that the input impedance is fairly low meaning that minimalist discrete circuits or valve input stages won't work. All op amps commonly used in audio can handle them though. See section 11.2 for suggested circuits and connections.

Do not drive the input with fully floating sources, be it electrically floating ones like line driver IC's intended for driving XLR outputs or transformers. Using a floating source will always result in a common mode component that will exceed the common mode input range and will manifest itself as gross distortion. Make sure to set the outputs of your distortion analyser to grounded, not floating.

9 Operation in Hardware mode

When OPTION (pin 31) is left unconnected, the amplifier is operated in Hardware mode.
Hardware control consists of a single control line, nAMPON. Pulling nAMPON low enables the amplifier as soon as all error conditions have been cleared for at least one second.

9.1 READY

The READY pin is pulled high whenever the amplifier is amplifying audio. When it mutes, for whatever reason, READY goes low. This includes periodic mutes after sustained overcurrent events.

9.2 CLIP

The CLIP indicator pin is active low, open collector, meaning that the CLIP indicator of several channels may be paralleled. An external pull-up resistor should be attached. The CLIP indicator is asserted whenever the amplifier is unable to track the input accurately:

- Normal clipping
- Current limiting
- Signal input during mute

Note that whilst muted the amplifier is clearly unable to track any input other than zero. The application circuit should ignore the CLIP flag when during mute as it is likely that the CLIP indicator will be chattering most of the time.

9.3 SCCPIND

The amplifier has a two-stage overcurrent protection. Short overcurrent events are covered by a cycle-by-cycle limiter which clips the output signal in the current domain. When too many switching cycles are terminated by the cycle-by-cycle limiter, indicating a sustained overload, the amplifier will mute momentarily to allow the output devices to cool down.
SCCPIND is an open-collector, active low output that outputs the cycle-by-cycle pulses.

9.4 nFATAL

nFATAL is an open collector, active low output which is asserted when the amplifier senses a large DC voltage at the output. When a >15V DC potential is detected, the amplifier will first mute because the reason might well be DC at the input. If this fails to restore the output to zero, nFATAL will be pulled low to indicate catastrophic failure.
IMPORTANT: For safety reasons, the application must be able to respond to this line by turning the power supply off.
Do not use output relays. Apart from causing distortion, a relay is not suited to disconnect a heavily inductive load like a loudspeaker. Typical loudspeakers store enough energy to weld the relay shut, maintaining the safety hazard.

10 Operation in Software mode

When OPTION (pin 31) is pulled-down, the amplifier is operated in Software mode. In software mode, pin 36 is configured as SCL and pin 35 as SDA. These lines should be pulled to 3.3V with 4.7k resistors externally. The I2C bus should be operated at the standard 100kHz rate.

10.1 Address selection

The NC500OEM supports up to 16 I2C addresses. Set the address by pulling OPTION to GND through a resistor.

Pull-down resistor at Pin 31	I2C address
0	1011000x
1.8k	1011001x
3.9k	1011010x
6.8k	1011011x
10k	1011100x
12k	1011101x
18k	1011110x
22k	1011111x
27k	1011000x
33k	1011001x
47k	1011010x
56k	1011011x
82k	1011100x
120k	1011101x
180k	1011110x
390k	1011111x

X=r/w bit.

10.2 Registers

10.2.1 Register 0: Status byte 1

Bit	R/W	Function
7	R	FATAL. Shut down power supply immediately when this bit it set. See 9.4.
6	R	FreqError. Indicates direct short very close to the connector.
5	R	OverLoadError. Flags amp is being muted due to sustained overcurrent
4	R	-HV undervoltage. Clears as soon as -HV is above the UVP limit.
3	R	+HV undervoltage. Clears as soon as +HV is above the UVP limit.
2	R	-HV overvoltage. Clears as soon as -HV has returned below the OVP limit.
1	R	+HV overvoltage. Clears as soon as +HV has returned below the OVP limit.
0	R	DC error. Excessive DC content was found at the output.

10.2.2 Register 1: Status byte 2

Bit	R/W	Function
7	R	Always set to 0
6	R	Always set to 1
5		Reserved
4		Reserved
3	R	Overtemperature. Clears as soon as temperature has dropped back to the lower hysteresis limit.
2	R	Amplifier Ready. High when the amplifier is working normally and not muted.
1	R	VDR undervoltage
0	R	VDR overvoltage

10.2.3 Register 2: Command byte

Bit	R/W	Function
0	R/W	AmpEnable, write 1 to enable (unmute) amp, clear to mute

10.2.4 Register 3-7: Measured parameters

Reg	Function
3	+HV, in volts
4	-HV, in volts
5	VDR, in tenths of volts
6	NTC reading, contact for further details
7	Frequency reading in units of 64kHz
8	Product number (5 for NC500)

10.3 Protection limits

Item	Symbol	Rating	Unit	Notes
+/-HV undervoltage		35	V	
+/-HV overvoltage		101	V	
VDR undervoltage		13.5	V	
VDR overvoltage		17.5	V	
Overtemperature		95	°C	
Overtemp, lower hysteresis		85	°C	

11 Application hints

11.1 Thermal considerations

The amount of cooling needed by the NC500OEM varies with usage. Idle dissipation is around 6.3W. Additional power loss scales linearly with output power. A good rule of thumb is $P_{loss}=P_{idle}+0.06*P_{out}$. Please refer to the Thermal Design App Note on the Hypex web site for more details.

11.2 Input Conditioning / Buffering

Unlike in many other Hypex products, no input buffer is present as manufacturers of audiophile equipment tend to bypass it anyway and design their own. The NC500 is practically devoid of any sonic signature so this external buffer is a good way of tuning in a "house sound". For direct connection to external equipment, the recommended input circuit is given in Figure 1. EMC/ESD countermeasures are left out for clarity.

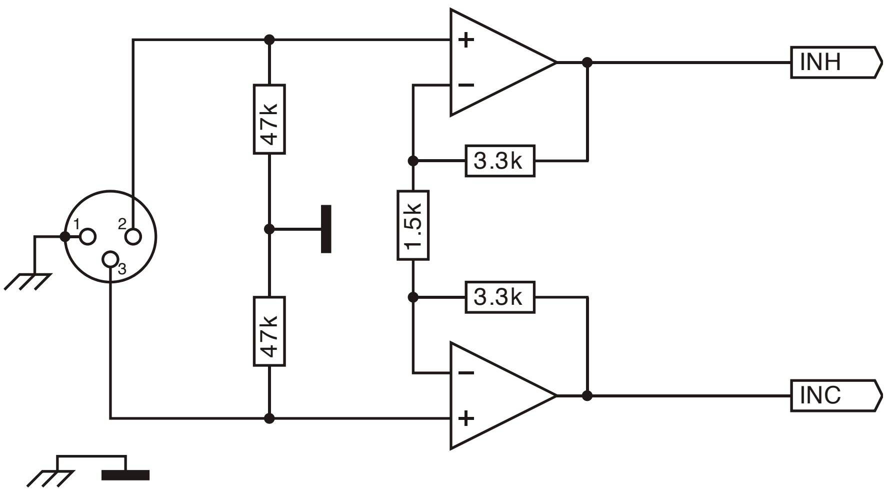


Figure 1: Recommended circuit for XLR inputs

For further clarification of how to connect RCA inputs, please refer to the application note "*Dealing with Legacy Pin-1 Problems*" on the Hypex web site. It and the further reading referenced in it are a good refresher course in the use of balanced signalling.

The impedance of the NC500 input is relatively low and because of the specific configuration, drive currents may become higher than expected. Use the model of Figure 2 to estimate input current:

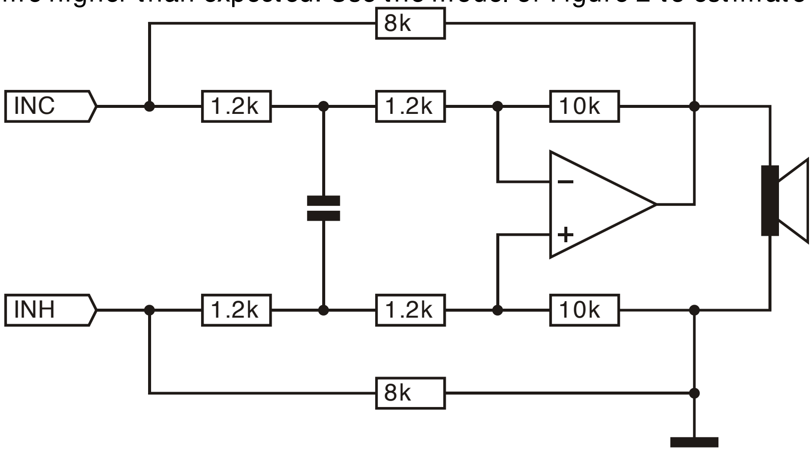


Figure 2: Equivalent model of NC500 for input current estimation

The input is clearly differential. The optimum choice of input circuit depends on the situation. Most audio designers incorrectly assume that it is necessary to drive differential inputs with symmetrical signals. This is entirely unnecessary. For instance, a single op amp suffices to interface most DAC chips with the NC500 as shown in Figure 3. Circuit values depend on the DAC output voltage and the required maximum output from the amplifier.

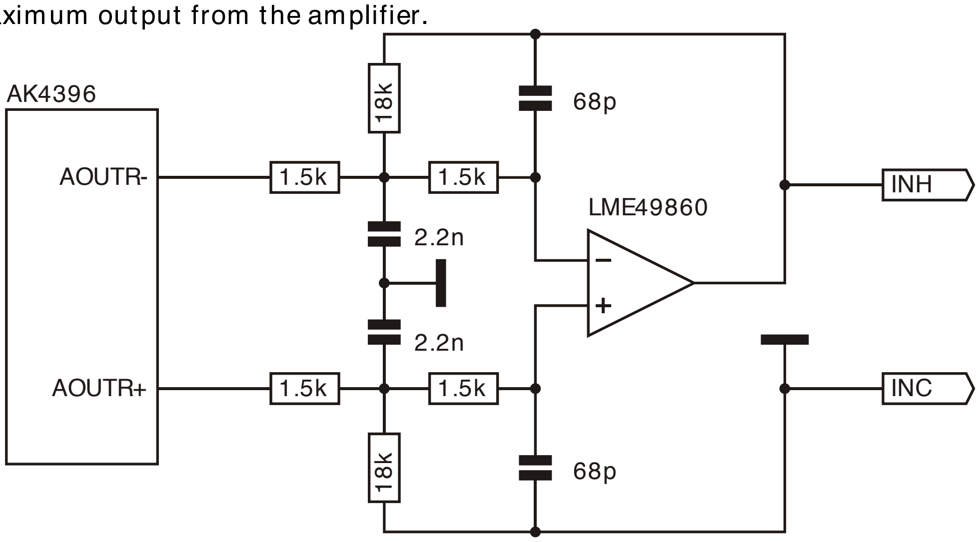


Figure 3: Recommended interface between Voltage-out DAC and NC500

The only potential drawback to this method is, depending on the maximum required speaker voltage, the need for fairly high supply rails for the op amp. A symmetrical output voltage solves this but again, this is only a practical consideration. There are no inherent performance benefits attached to symmetry. In fact, in order not to lose performance the drive circuit needs some forethought in order to keep the number of amplifying stages minimal (i.e. one).

The neatest and probably best, but not necessarily the cheapest, is to use an op amp with two outputs as shown in Figure 4.

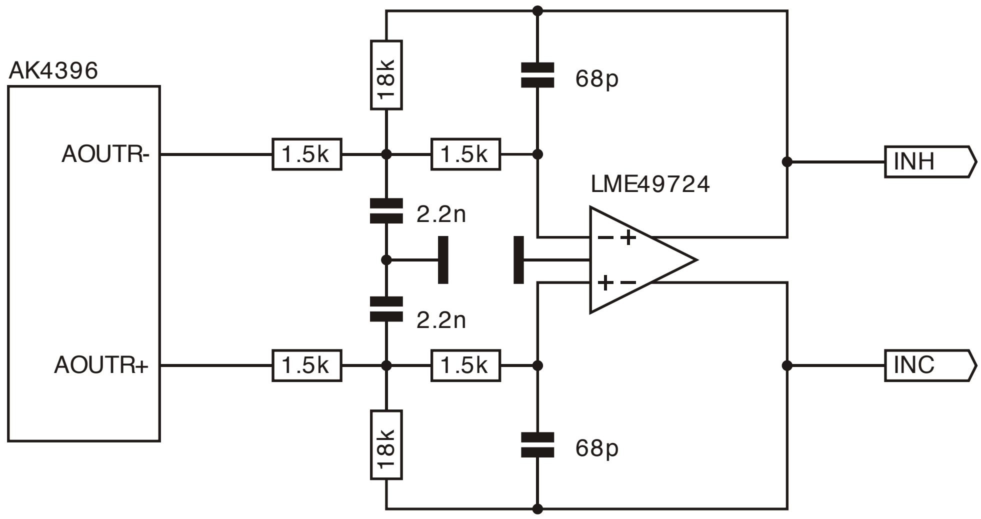
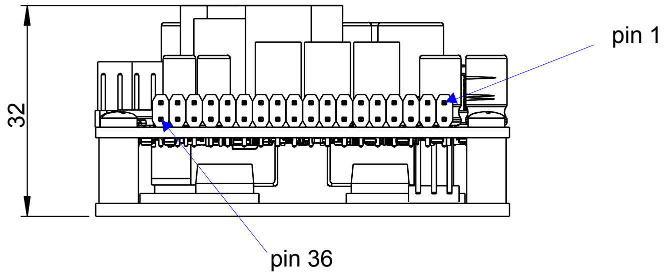
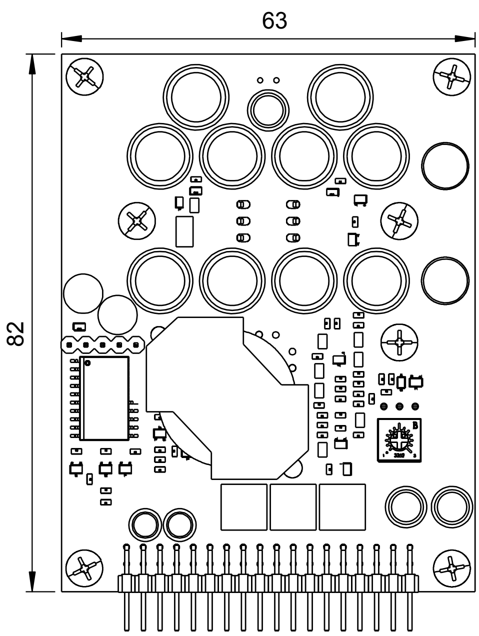


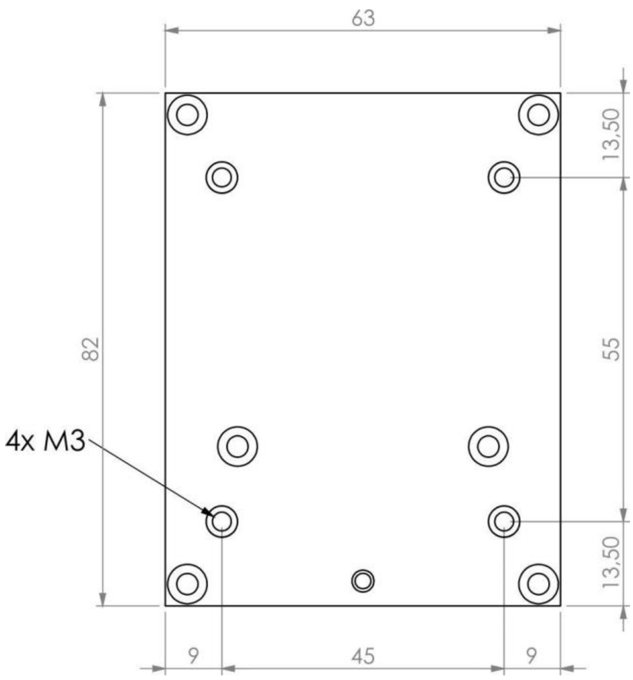
Figure 4: Interface circuit for low supply rails

A low-cost alternative is building the circuit of Figure 3 twice, once with the inputs reversed and tying INC to the other output. You get double the number of passives but this will be more than offset by the availability of much cheaper lower-voltage duals.

12 Drawings







Document Revision	PCB Version	Description	Date
R0	NC500 OEM V0.1	Draft/Preliminary	09.05.2014
R1	NC500OEM V1	New test data, section on audio input revised	
R2	NC500OEM V1	Thermal considerations section revised	11.09.2014
R3	NC500OEM V1	Dimensions heatsink added	29.09.2014
R4	NC500OEM V1	Clip function description changed	10.10.2014