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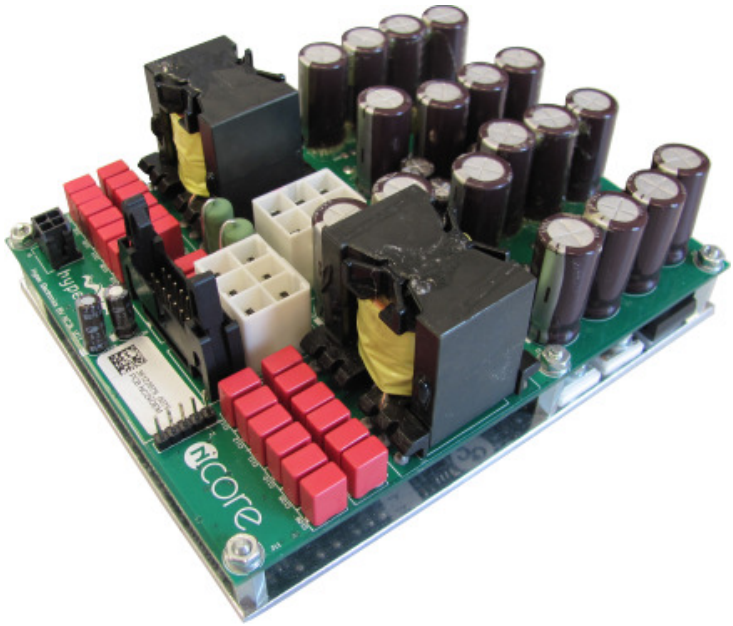
Ultrahigh performance class D amplifier



Highlights

- Extremely low distortion over frequency and power range
- Extremely low output impedance
- Extremely low noise
- Extremely neutral and transparent

Features

- Differential audio input
- Up to +/-98V operation
- 48A current capability
- Extensive, microprocessor-controlled error protection

Applications

- Audiophile stand-alone power amplifiers for professional and consumer use
- Active loudspeakers for recording and mastering studios
- Very high-end home theatre systems

Description

The NC2K 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 = +/-84V, Load=4Ω, MBW=20kHz, Source imp=40Ω ,unless otherwise noted

Item	Symbol	Min	Typ	Max	Unit	Notes
Rated Output Power	P_R	2000			W	THD=1%, Load=2Ω
		2500			W	THD=1%, Load=4Ω
		1600			W	THD=1%, Load=8Ω
Distortion	THD+N, IMD[1)]		0.002	0.005	%	20Hz<f<20kHz[1)], 4Ω Pout<P_R/2
			0.0006	0.001		20Hz<f<20kHz Pout=1W
Output noise	U_N		18	20	µV	Unwtd
Signal-to-noise ratio (unweighted, add 2dB for A-weighted)	SNR		133		dB	P_R
			103			1W 8Ω
Output Impedance	Z_{OUT}			3	mΩ	f<1kHz
				2	mΩ	f<20kHz
Power Bandwidth	PBW		20-35k		Hz	[2)]
Frequency Response		0		50	kHz	+0/-3dB. All loads.
Voltage Gain	A_V	19,5	20,0	20,5	dB	
Supply Ripple Rejection	PSRR		70		dB	Either rail, f<1kHz.
Efficiency	η		93		%	Full power
Idle Losses	P_0		34		W	
Current Limit		47	48	49	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 15kHz.

2 Audio Input Characteristics

Item	Symbol	Min	Typ	Max	Unit	Notes
DM Input Impedance	$Z_{IN,DM}$		5k		Ω	
CM Input Impedance	$Z_{IN,CM}$		14,7k		Ω	
CM Rejection Ratio	CMRR		55		dB	All frequencies

3 Control I/O Characteristics

Item	Symbol	Min	Typ	Max	Unit	Notes
Weak Pullup	R_{WPU}		27k		Ω	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 high leakage current	I_{OH}			1µ	A	SCCP, CLIP, FATAL
Logical low output voltage	V_{OL}			0.4	V	SCCP, CLIP, FATAL, I_{OL}=1mA

4 Absolute maximum ratings

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

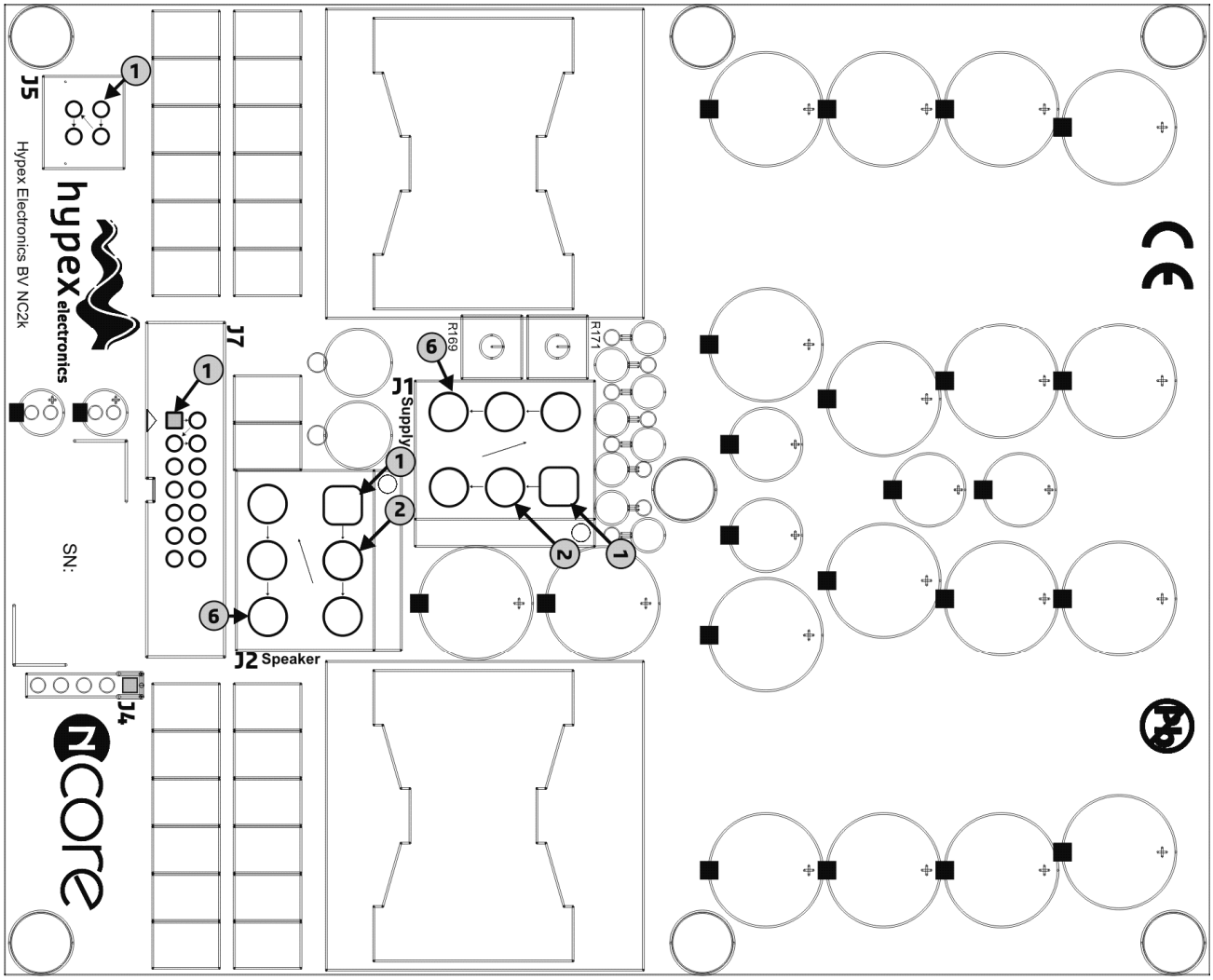
Item	Symbol	Rating	Unit	Notes
Power supply voltage	V_B	+/-105	V	See section 7.2
VDR supply voltage	V_{DR}	20	V	Floating and referenced to V_{B-}. See section 7.2
Signal stage supply voltage	V_{SIG}	+/-15	V	
Peak output current	$I_{OUT,P}$	50	A	Unit current-limits safely at 48A
Input voltage	V_{IN}	+/-15	V	Either input referenced to ground
Input current	I_{IN}	10m	A	Logical 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	ºC	
Heat-sink temperature	T_{SINK}	85	ºC	Thermistor limited. User to select heat sink to insure this condition under most adverse use case

5 Recommended Operating Conditions

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}	12	12	15	V	
Signal stage supply current	I_{VSIG}		40		mA	
Driver supply voltage	V_{DR}	14.5	15	15.5	V	Unit protects when allowable range is exceeded
Driver supply current	I_{DR}		200		mA	
Load impedance	Z_{LOAD}	1			Ω	
Source impedance	Z_{SRC}			100	Ω	For correct operation
Effective power supply storage capacitance [1)]	C_{SUP}	10m			F	Per rail, per attached amplifier. 4Ω load presumed.

Note 1: The effective power supply storage capacitance of Hypex SMPS is already in excess of 10mF. Do not add supplementary capacitance.

6 Connections



6.1 J2 Loudspeaker output and sense

Connector type: JST (www.jst.com) B06P-VL. Matching cable part: VLP-06V.
Pinout:

Pin	Type	Function
2	LS out	Loudspeaker output, hot (pair 1).
3	LS out	Loudspeaker output, hot (pair 2).
5	LS out	Loudspeaker output, cold (pair 1).
6	LS out	Loudspeaker output, cold (pair 2).
1	Analogue in	Sense, hot, optional, see section 8
4	Analogue in	Sense, cold, optional, see section 8

The two pairs of output pins may either be paralleled or used for biwiring. Because of the proximity of the three connectors and the magnitude of the currents, make sure that each pair of wires connected to J2 is twisted. Not twisting can cause crosstalk from the loudspeaker wires back into the audio input, or from the DC power lines (which carry a distorted version of the signal) into the loudspeaker lines.
The sense lines allow feedback to be taken from the far end of a speaker cable using a secondary small gauge twisted pair. This is not normally necessary unless the resistance of the speaker cable becomes considerable, as in theatre installations. The Kelvin Sense network is a first order passive crossover mixing local feedback for HF and modulation with remote feedback at audio frequencies.

6.2 J7 Control and optional audio input

Connector type: 14-pole, dual row male 2.54mm shrouded (box) header. Mates with female IDC connector. For hardware-controlled modules powered by an SMPS3K, a straight female-to-female ribbon cable is all that is needed.

Pin	Type	Function
1	Pwr in	+Vsig, positive supply for op amps
2	Pwr in	-Vsig, negative supply for op amps
3	Pwr	GND
4	i/o, wpu	Ready output (HW mode) or SDA (I2C mode). Weakly pulled up.
5	o/c	CLIP: Clip indication. Active low
6	i/o, wpu	nAMPON (HW mode)
7	Analogue in	INH: Audio input, hot
8	Analogue in	INC: Audio input, cold
9	o/c	SCCP: single-cycle current limiter indication. Active low
10	o/c or i/o	FATAL (HW mode): Catastrophic fault indication or SCL (I2C mode).
11	i/o	I²C address selection, see section 8.4 Software (I2C) control
12	n.c.	
13	i/o	Current monitor output, hot (0.1V per Ampere)
14	i/o	Current monitor output, cold

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

6.3 J1 Power stage supply

Connector type JST (www.jst.com) B06P-VL. Matching cable part: VLP-06V.
Pinout:

Pin	Type	Function
3, 6	Pwr	GND: return for +HV and –HV. Parallelled pins for current capacity reasons
2	Pwr in	+HV: unregulated supply (nominally +84V)
5	Pwr in	-HV: unregulated supply (nominally -84V)
1	Pwr in	VDRH: +15V referenced to pin 4
4	Pwr in	VDRL: return for pin 1. A floating 15V supply should be connected between pins 1 and 4. Pin 4 is internally connected with pin 5.

The SMPS3k output connects to J1 on a pin-for-pin basis and premade cables can be supplied.

6.4 J5 Audio input

Connector type: 2x2 pin Microfit header type 43045-0412 (see www.molex.com), Matching cable part 43025-0400.

Pin	Type	Function
1	Analogue in	INH: noninverting audio input
2	Analogue in	INC: inverting audio input
3	in, wpu[1)]	nAMPON. Electrically connected to pin 6 of J7
4	passive	Ground.

Note 1: wpu=weakly pulled up to 3.3V, not to be driven above 3.3V.

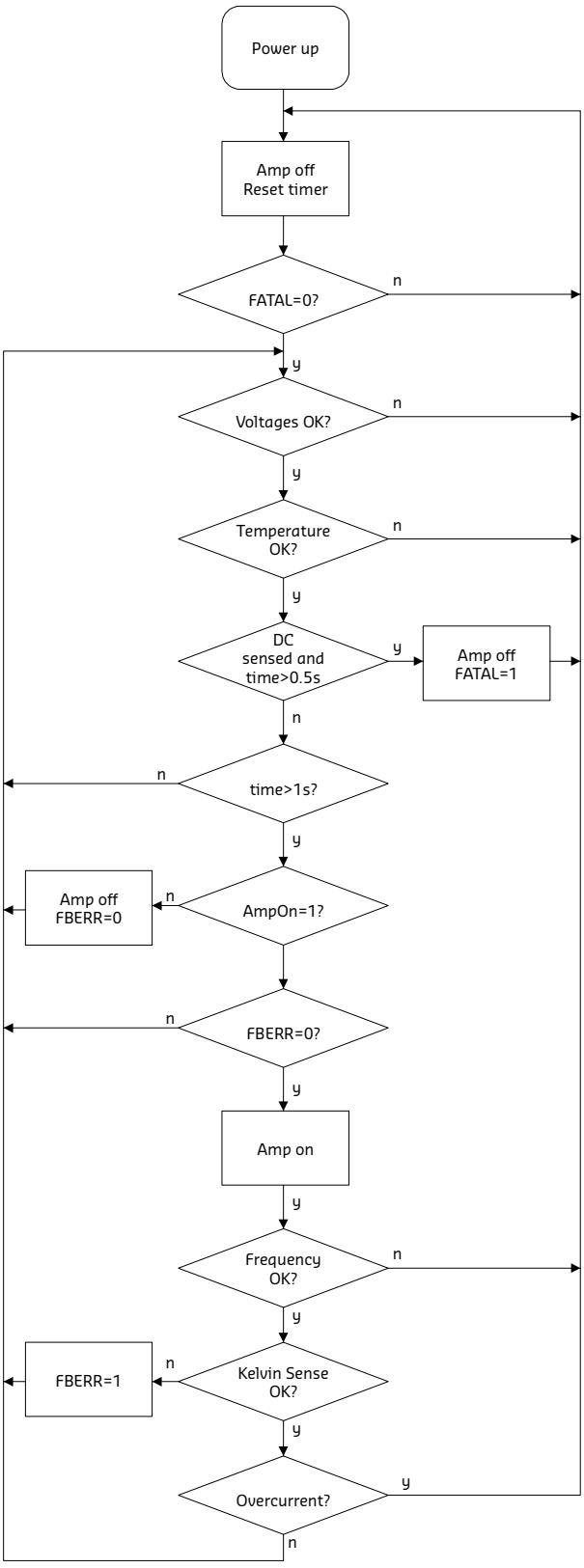
The audio input is DC coupled, this means the audio source has to be free of any DC voltage.
The audio input is differential. This means that ground is not part of the audio signal. When connecting an unbalanced source, treat pins 1 and 2 as a floating input with pin 2 being the “audio ground”. Pin 4 may be used to attach the shield of a shielded twisted pair cable, but the “audio ground” connection of an unbalanced cable should never connect here.

7 Microprocessor functions

Whether the module is to be used for hardware or software control is determined by the settings on the address pin, J7-p11.

7.1 Firmware operation

The microprocessor has three main functions: to provide an interface for controlling the amplifier, to monitor the supply voltages in order to prevent spurious operation during power up/down and to detect error conditions. Most errors clear automatically as soon as the error condition lifts. The exceptions are kelvin sense feedback errors and a fatal DC fault because the former requires user interaction (checking the wiring) and the latter almost certainly stems from a broken power FET. The kelvin sense error can be cleared by cycling the enable bit or the nAMPON line while the FATAL signal should not be cleared externally. Instead the +/-HV supplies must be shut down immediately to prevent or mitigate damage to attached loudspeakers.


Power up
Amp off
Reset timer
FATAL=0?
n
y
Voltages OK?
n
y
Temperature
OK?
n
y
DC
sensed and
time>0.5s
y
Amp off
FATAL=1
n
time>1s?
n
y
Amp off
FBERR=0
n
AmpOn=1?
FBERR=0?
n
y
Amp on
y
Frequency
OK?
n
y
FBERR=1
n
Kelvin Sense
OK?
y
Overcurrent?
y
n

7.2 Protection limits

Item	Symbol	Rating	Unit	Notes
+/-HV undervoltage		35	V	
+/-HV overvoltage		101	V	
VDR undervoltage		13,5	V	
VDR overvoltage		16	V	
Overtemperature		95	ºC	
Overtemp, lower hysteresis		85	ºC	
Voltage across Kelvin Sense network		10	V	

7.3 Hardware control

When I2C address selection pin (J7 - pin 11) is left unconnected, the amplifier is operated in Hardware mode.
Hardware control consists of a single control line, nAMPON (available both on J5 and J7). Pulling nAMPON low enables the amplifier as soon as all error conditions have been cleared for at least one second. In hardware mode, pin 10 of J7 is the FATAL signal which is pulled low when the power stage suffers an irrecoverable breakdown.

7.4 Software (I2C) control

In software mode, pin 10 of J7 is configured as SCL and pin 4 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. Please make sure the I2C bus to this amplifier is isolated from other I2C buses, in order to prevent an I2C bus hangup when the supply for the amplifier is turned off.

7.4.1 Address selection

The NC2kOEM supports up to 16 I2C addresses. Set the address by pulling the I2C address selection pin (J7 -pin 11) to GND through a resistor.

Pull-down resistor at Pin 11	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.

7.4.2 Register 0: Error monitor bits

Bit	R/W	Function
7	R	Amp fail. This bit replaces the FATAL line in I2C mode.
6	R	Direct short (tested by checking for an abnormally high switching frequency). Cleared after a mute cycle.
5	R	Sustained overcurrent condition (hiccup mode). Cleared after a mute cycle.
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. Cleared after a mute cycle.

7.4.3 Register 1: Further error monitor bits

Bit	R/W	Function
7		Always set to 0
6		Always set to 1
5		Reserved
4	R	Kelvin sense connection error. This bit only clears after the AmpEnable bit of register 2 is cycled.
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

7.4.4 Register 2: Command byte

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

7.4.5 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 (20 for NC2K)

8 Options

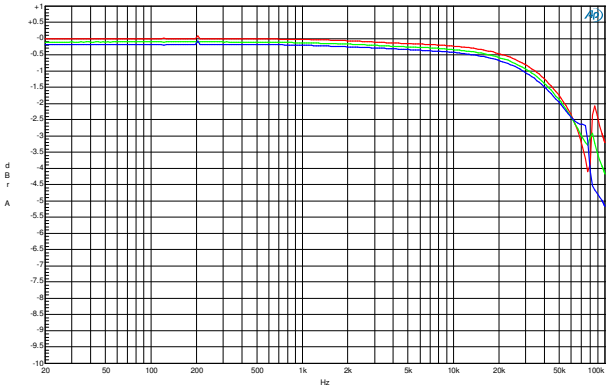
The standard design offers quite some flexibility already. The following table lists the possible options and notes which are on the stock version.

Option	Description	Stock
Kelvin Sense	Allows feedback from the far end of a speaker cable.	Installed
Customization	Ask sales for MOQ values.	

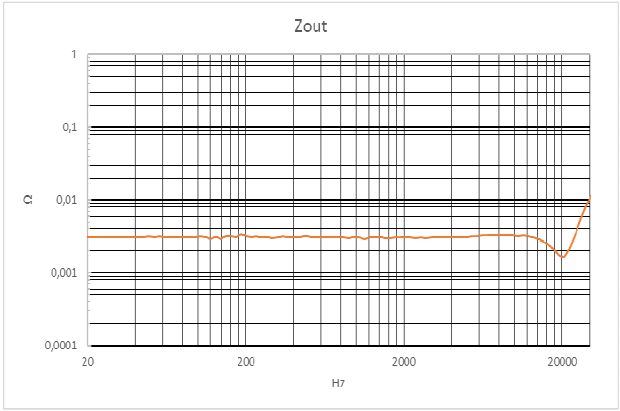
9 Typical performance graphs

The graphs were taken on one stock NC2K module powered by an SMPS3K. Refer to the tables in section 4 for guaranteed limits.

9.1 Small signal tests (all loads)

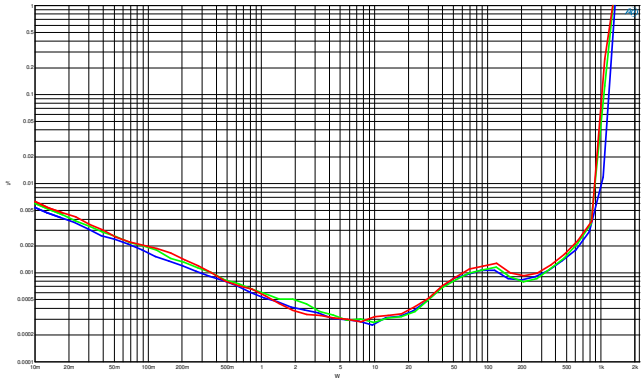


Frequency response in 2Ω (blue), 4Ω (green) and 8Ω (red).

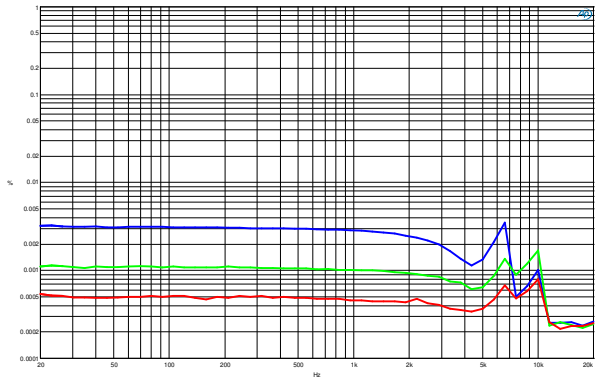


Output impedance, measured directly at J2

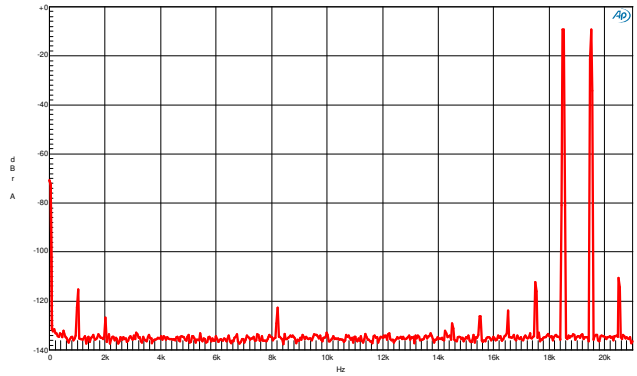
9.2 Large signal tests (8Ω)



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

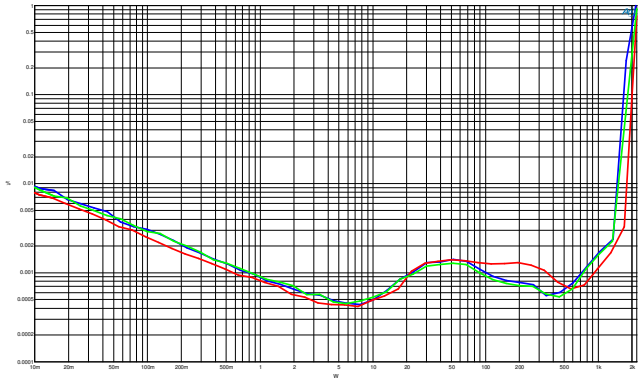


THD vs frequency at 25W (red), 250W (green) and 750W (blue)

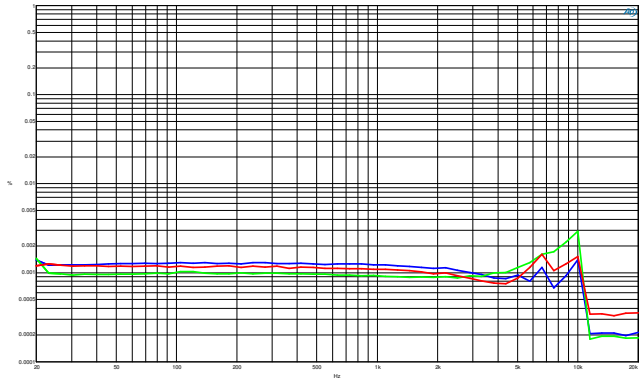


IMD spectrum at 18.5kHz+19.5kHz, 100W+100W. Peak voltage corresponds to a 400W sine.

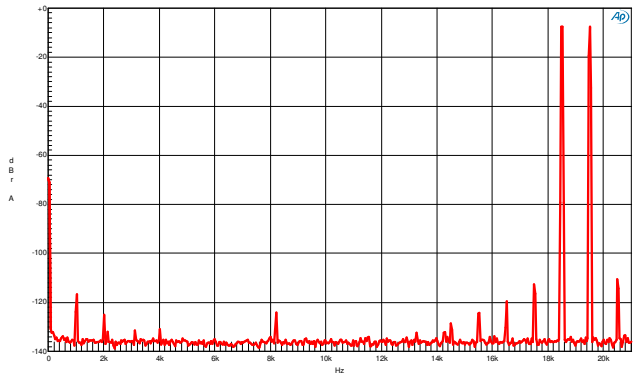
9.3 Large signal tests (4Ω)



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

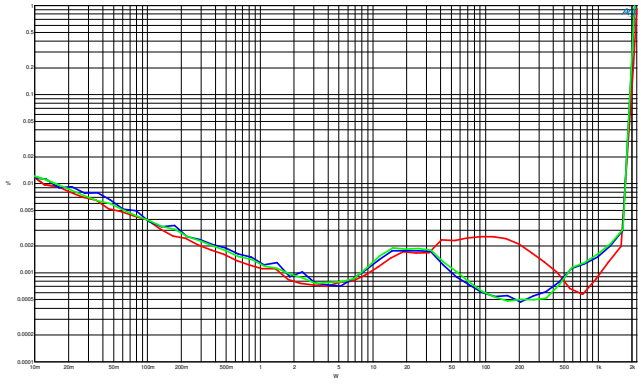


THD vs frequency at 25W (red), 250W (green) and 750W (blue)

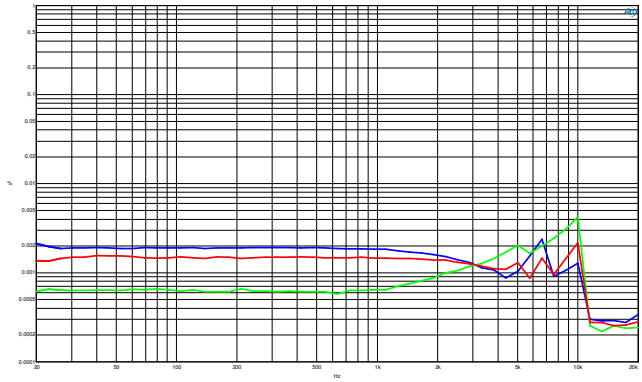


IMD spectrum at 18.5kHz+19.5kHz, 100W+100W. Peak voltage corresponds to a 400W sine.

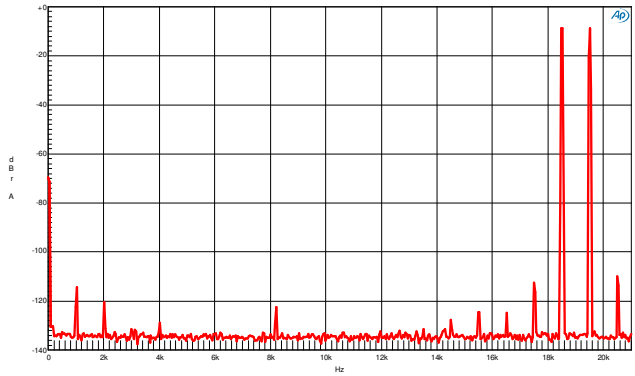
9.4 Large signal tests (2Ω)



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

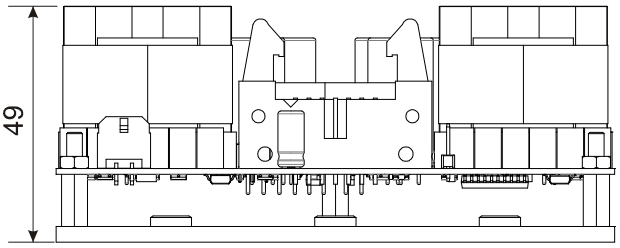


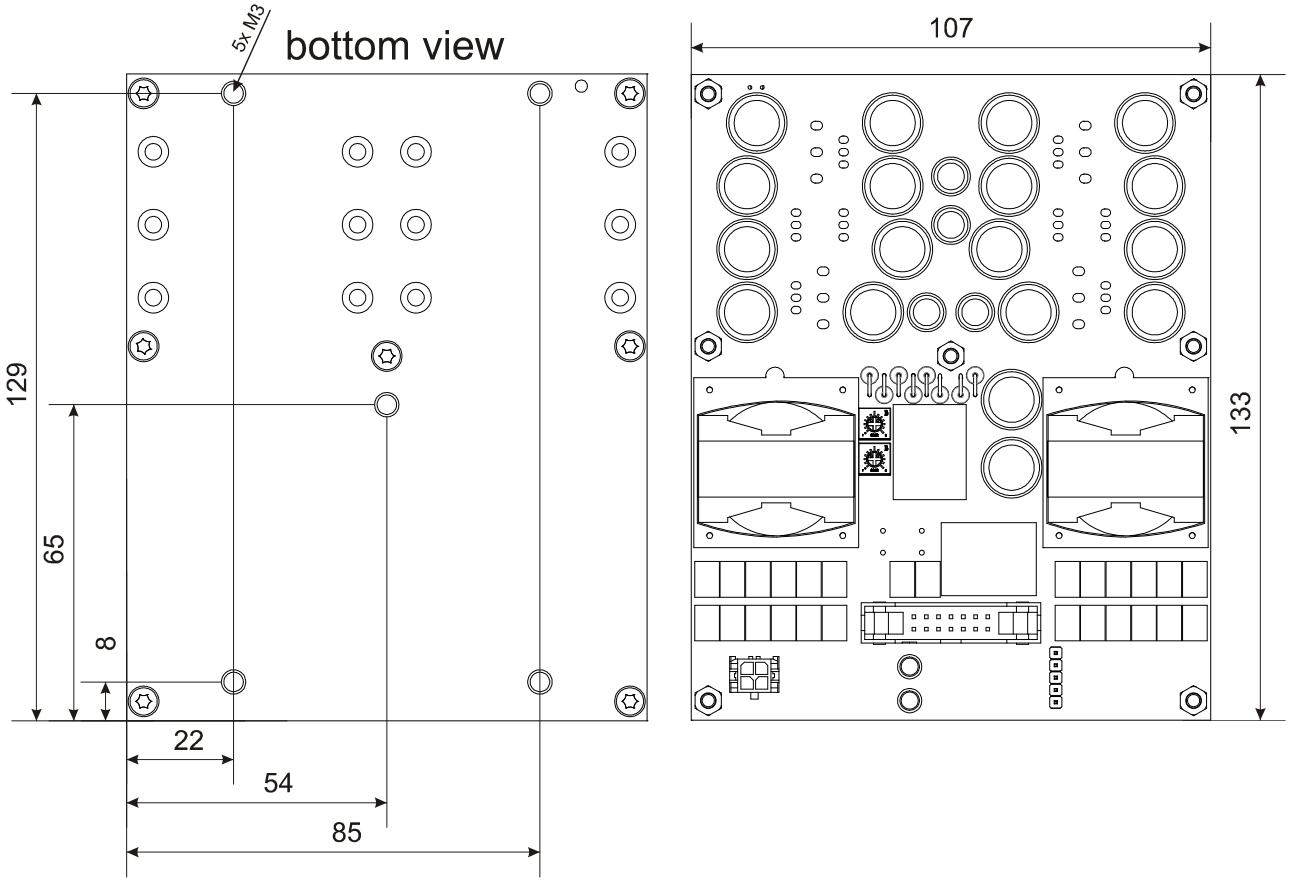
THD vs frequency at 25W (red), 250W (green) and 750W (blue)



IMD spectrum at 18.5kHz+19.5kHz, 100W+100W. Peak voltage corresponds to a 400W sine.

10 Mechanical drawing





Note : Not shown is the mated JST VL connector. Add bend radius and wire thickness to obtain final minimum required height for the mounted assembly.

DISCLAIMER: This subassembly is designed for use in music reproduction equipment only. No representations are made as to fitness for other uses. Except where noted otherwise any specifications given pertain to this subassembly only. Responsibility for verifying the performance, safety, reliability and compliance with legal standards of end products using this subassembly falls to the manufacturer of said end product.

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Document Revision	PCB Version	Description	Date
R0.0	NC2kOEM V0.0	Initial Draft.	12.04.2012
R0.1	NC2kOEM V0.1	I²C information added Connector 7 pin out changed to new standard	25.09.2012
R0.2	NC2kOEM V0.1	Input buffer description added	29.09.2012
R0.3	NC2kOEM V0.1		
R0.4	NC2kOEM V0.2	Updated for new PCB	17.06.2014
R0.5	NC2kOEM V0.2	Typical performance graphs added	27.11.2014
R1	NC2KOEM V0.2	Typos changed	5.12.2014
R2	NC2KOEM V0.2	I2C hangup prevent information added	
R3	NC2KOEM V0.2	New spec. plots	8.02.2019
R4	NC2KOEM V0.2	New spec. plots	21.02.2019