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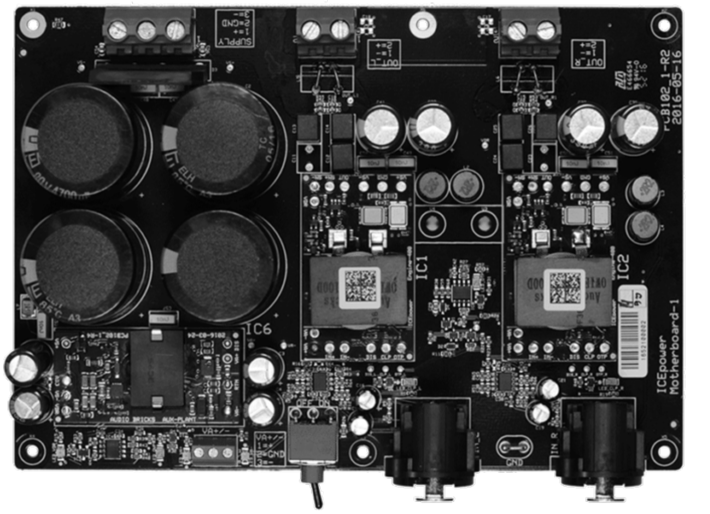

Motherboard-1

ICEbricks

ICEpower Motherboard-1

Motherboard-1 is a reference design for a 2 channel amplifier board

1 Contents

2 General Description

Motherboard-1 is a reference design for a 2-channel amplifier board using Engine-400 as amplifier channel and an AUX-plant for supplying OPAMPs and gate drivers. It contains balanced input buffers with the possibility to set gain, under/over voltage supervision circuitry, thermal supervision circuitry and start up delay. It displays the status of all features with different color LEDs and it has a connector available for accessing the VA+/- supplies in order to supply an additional board like a DSP or pre-amp. Large electrolytic storage caps are also included.

Features	Benefits
Reference design for ICEbricks Engine-400 - and AUX-plant modules	Allow very fast integration in product. Shorten time from early design to mass production.
Combines two Engine-400 and one AUX-plant	Insures well-defined high audio performance and functionality
Comphensive colour LED status output for VDR, over voltage, VA, clipping/current limiting and over temp protection	Easy status operation overview

2.1 Key Specifications

- +/-35V to +/-60V supply range
- 2x400Wrms into 4
- 0,002% THD+N @ 1Wrms
- 50 Vrms unweighted idle noise
- 120dB dynamic range
- <15 degrees phase shift in the audio band
- TBD W idle losses
- Balanced inputs
- VA+/- outputs (+/-15VDC)
- Optional common mode filtering
- Optional heat sinking
- Option to adjust gain and other parameters

3 Document History

Version	Date	Revised by	Changes
1.0	2016-02-12	PBM	First revision
1.1	2016-03-XX	PBM	Dimensions added
1.2	2017-10-05	DIT	Datasheet redesign

4 Getting Started

Motherboard-1 houses two Engine-400, one AUX-plant, storage capacitors, supervision, balanced input buffers and connectors to connect it to a +/- DC-source. It is the fastest and most convenient way of testing the performance of a system built on ICEbricks products.

ICEbricks designs modules in a new way where a lot of the choices are left to the user. Electrolytic capacitors, input stages, supervision/control and even the output filter capacitors are excluded from the modules leaving the customer with several new possibilities but also new responsibilities. This document will provide information for the customer to be able to make design choices.

The Motherboard-1 shows a typical implementation of Engine-400 and AUX-plant in a high quality two channel amplifier system capable of 400Wrms into 4 per channel or 800W into 8 ohm in BTL.

5 Block Diagram / Interfaces

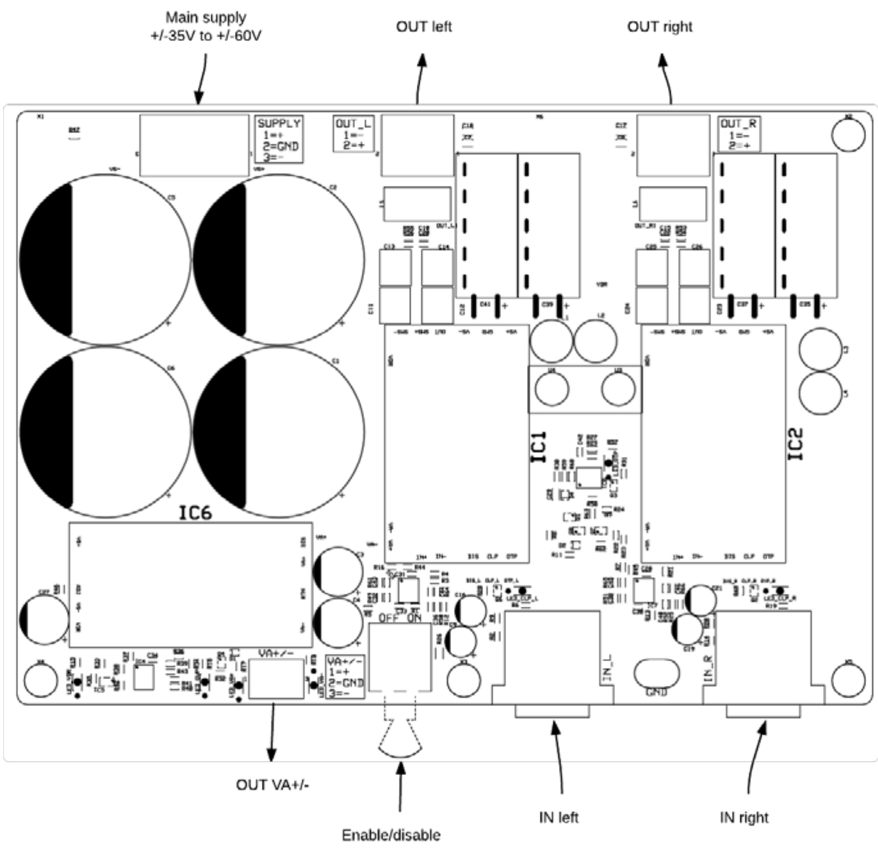

Figure 1: Motherboard-1 block diagram / Interfaces

5.1 Interfaces specifications

SUPPLY	Connection of bipolar DC supply (+/-). The Motherboard-1 starts with approximately +/-31V and shuts down at +/-70V approximately. More details on recommended voltage can be found in the Engine-400 datasheet.
OUT_L	Connection of left speaker, note polarity
OUT_R	Connection of right speaker, note polarity
VA+/-	Connection of external consumer of VA+/- like DSP board, preamp etc. Max 17W consumption. VA+ can supply more current than VA-. This voltage can be set to between +/-11V and +/-15V by adding resistor R46 (see datasheet for AUX-plant for more details).
OFF_ON	Enables and disables the AUX-plant and Engine-400 modules.
IN_L	Connection of left channel input signal. Buffered balanced inputs.
IN_R	Connection of right channel input signal. Buffered balanced inputs.

Table 1: Interfaces specifications

6 LEDs

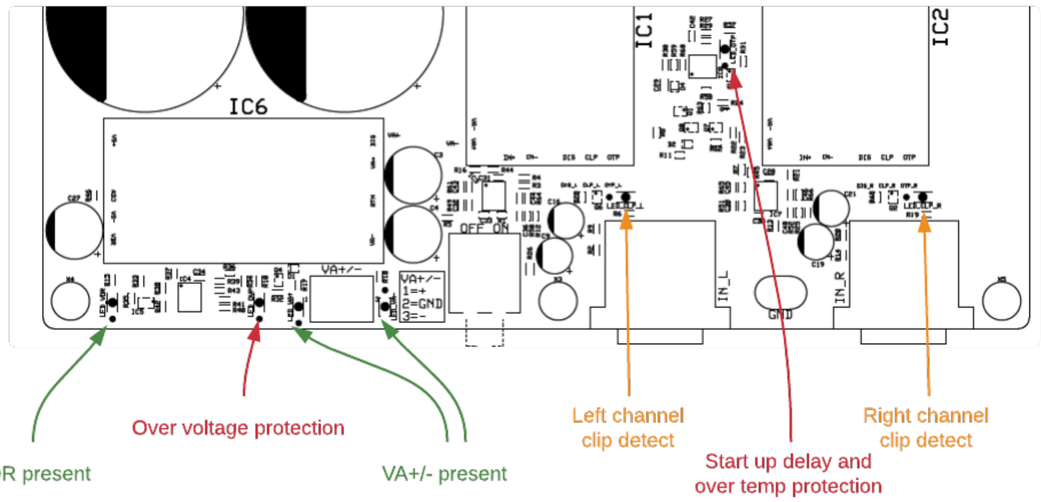

Figure 2: LEDs

6.1 LEDs specifications

LED_VDR	Green LED activates when VDR (gate drive voltage) is present
LED_OVP	Red LED activates when the Motherboard supervision shuts down the modules due to over voltage
LED_VA+	Green LED activates when VA+ is present
LED_VA-	Green LED activates when VA- is present
LED_CLP_L	Orange LED activates when left channel clips or is in current limit
LED_OTP	Red LED activates during start up delay or during over temp protection
LED_CLP_R	Orange LED activates when right channel clips or is in current limit

Table 2: LEDs specifications

7 Functional description

7.1 Differential stage

This section is a balanced input buffer stage which together with the first stage of the Engine-400 forms an instrumentation amplifier with high common mode rejection. The gain of this stage is set by R61, R64 and R44. With the component values above the gain will be zero but the values can be adjusted to the gain of preference.

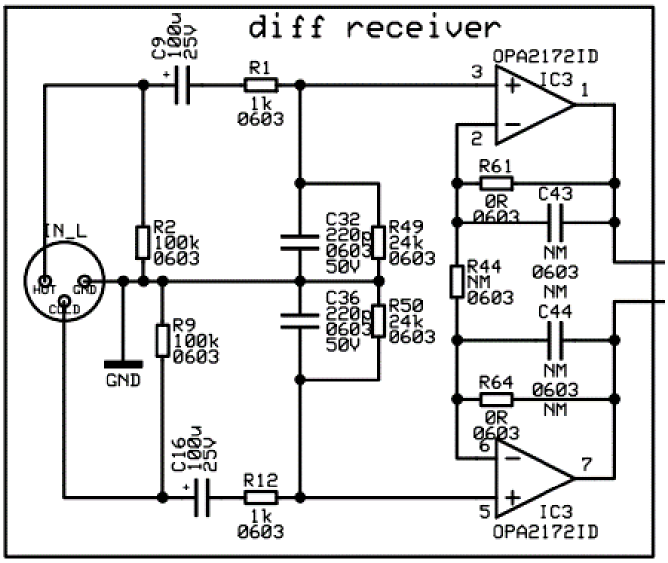

Figure 3: Diff receiver

7.2 Gain adjusting

The gain of this input stage is expressed as Vout/Vin=(R44+R61+R64)/R44

Gain	R44	R61,R64
2 (6dB)	3k	1k5
4 (12dB)	1k	1k5
5,9 (15.4dB)	820R	2k
7,9 (18.0dB)	750R	2k6
9,8 (19,8dB)	680R	3k

Table 3: Gain table, single ended

Note that the gain of Engine-400 is 6 times (15,6dB) which will be multiplied with the gain from the diff stage or added when counting in dB.

C43 and C44 should be at least 47pF if R61 and R64 are higher than 1k. This is to form a high frequency pole in the gain curve hence reducing noise outside the audio band which can cause modulation products in the audio band.

7.3 Common mode rejection

Common mode noise is noise which enters the signal input with the same amplitude and polarity on both positive and negative input (for a balanced cable). The most common type of noise is voltage differences between ground references of signal source and receiver. If a current flow though the ground wire of the cable this will cause the receiver to measure a noise which is equal on both inputs, at least ideally. Nothing is perfect and the design of the input stage determines the ability to attenuate this kind of noise. If the impedance in the HOT and COLD path between the source and receiver differ it will cause the noise to be different on both inputs and the only way to minimize this problem is to have very high common mode impedance. Motherboard-1 has a diff stage which has identical input impedance for both HOT and COLD and it is also the same for both differential and common mode signals. If a higher input impedance is wanted in order to reduce common mode noise further R2, R9, R49 and R50 can be increased. The OPAMP OPA2172 has JFET inputs and hence very low input currents so higher values can work well. If an OPAMP with bipolar inputs is used it is necessary to keep the values of R49 and R50 at fairly low values to maintain low DC-offsets.

7.4 Start up delay and disable circuitry

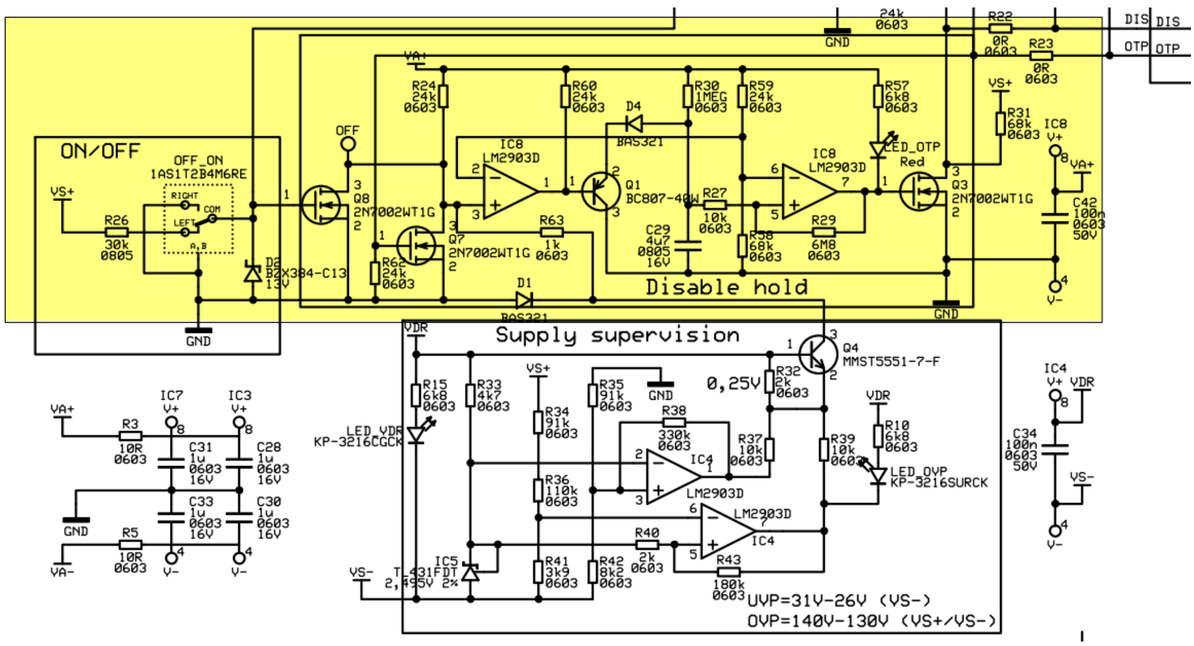

Figure 4 Start up and delay circuitry

The highlighted area shows the circuitry for start up delay and disabling the Engine-400 and the AUX-plant. The AUX-plant is disabled when the mechanical switch connects to VS+ through R26. At the same time Q8 is activated thereby eventually discharging C29 fast which leads to disabling of the Engine400s with Q3. They are disabled before VA+/VA- and VDR has dropped too far down hence the disabling is “click-less”. When the system is enabled the mechanical switch is disconnected from VS+ which immediately starts AUX-plant hence also VA+/VA- and VDR. Q8 is disabled which leads to disabling of Q1 at which point C29 starts being charged by R30.

After a few seconds Q3 is enabled which leads to enabling of the Engine400s. This circuit is also used as timer for thermal shutdown. The Engines send out thermal warning with a collector output with a series resistance of 82kohm.

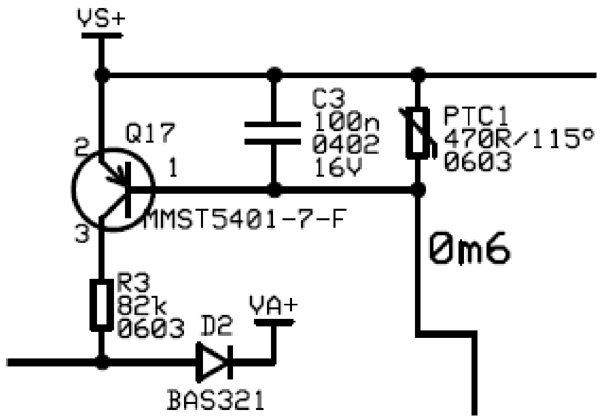

Figure 5 Temp warning out of Engine-400

The emitter is collected to VS+ which is the high rail voltage in the system but it is also clamped to VA+ through a diode. This output can be used to turn on a MOSFET, a BJT or a logic circuit through a resistive divider.

8 Supply supervision

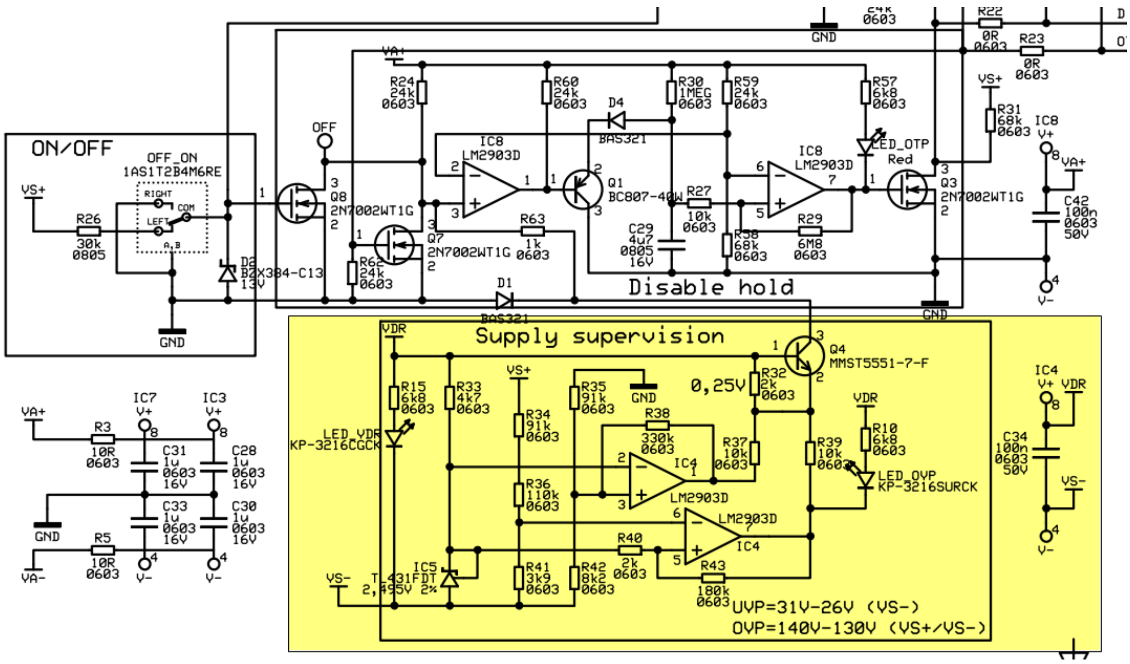

Figure 6 Supply supervision circuitry

The highlighted area shows the supply supervision. IC5 forms a 2% tolerance voltage reference to which the comparator IC4 compares the total voltage between VS- and VS+ but also the voltage between GND and VS-. Since the AUX-plant runs of the voltage between GND and VS-, in this case, this voltage is supervised for under voltage. The MOSFETs in the output stage of Engine-400 are rated to 150V and therefore the total voltage between VS- and VS+ has to be supervised for any voltage above 140V. If this occurs the output stages of the Engines will stop switching thereby increasing the tolerable voltage to 300V. If under voltage or over voltage is detected one of the comparator outputs will go low thereby drawing current from the emitter of Q4 which then pulls down pin 3 of IC8, causing the system to shut down.

9 Design choices

9.1 Output filter capacitors

Capacitors C11, 12, 13, 14 and C23, 24, 25, 26 form the second pole of the Engines output filters and they therefore have great impact on the quality of the amplifier. Their capacitance affect the switching frequency and therefore it is necessary to keep the total capacitance for each channel at 1,4 to 1,6uF. 3x330n+470n is one option, 4x360n is another. If a 1,5uF capacitor is chosen it is necessary to make sure it is of good enough quality to handle your specific application. One specification to keep an eye on is the allowable RMS voltage at different frequencies. Mounted on the Motherboard-1 are 3x470n 2222 470 86474 from Vishay BC components (MKT). They can handle 40Vrms (56Vpk) up to 3kHz continuously in 85ºC ambient. This is enough for most applications but if high continuous output power is needed at higher frequencies a capacitor like MKP479 (Vishay BC Components) is an option. Make sure that the capacitance tolerance is +/-5% so that the switching frequency is predictable.

9.2 Decoupling capacitors

Capacitors C35, 37, 39, 41 provide the Engines with high frequency current and must handle a minimum of 600mArms (measured when generating 50Wrms into 4 from +/-56V supplies corresponding to 1/8 power). Since they will be heated up by the Engines it is recommended that they are of 105ºC type (or higher) and have low ESR although the ripple current capability will automatically lead to low ESR. Also, choose the highest life time rating that the budget can allow for. The capacitors that are mounted on Motherboard-1 are United Chemicon EKYB800ELL471 (470uF/80V). These have an ESR of 33m and are rated to 1,95Arms@100kHz in 105ºC ambient during which they have 10 000h life. These are hence quote overkill on all parameters and a half as good one will do the job just as well.

10 EMI filtering on amplifier outputs

10.1 RC snubbers

Since the outputs usually are connected to several meters long speaker cables it is crucial to keep high frequency noise from exiting through them. Each time the amplifier output stage alternates there is a high frequency current flowing through the parasitic capacitance in the output inductor. A well designed inductor has very low levels of parasitic capacitance but it will never be zero. Any inductance in the output filter capacitor path will cause a hf ringing to arise on the output terminals. The snubbers formed by C10+R55, C20+R56, C15+R53 and C22+R54 absorb most of the energy in this ringing.

10.2 Common mode inductors

If it is desired to not interfere with AM broadcasting it may be necessary to use common mode filters on the outputs and therefore there is room to add common mode inductors (L5 and L6) plus additional common mode capacitors (C7, C18, C8 and C17). A properly designed common mode filter will transform a common mode signal to a differential signal.

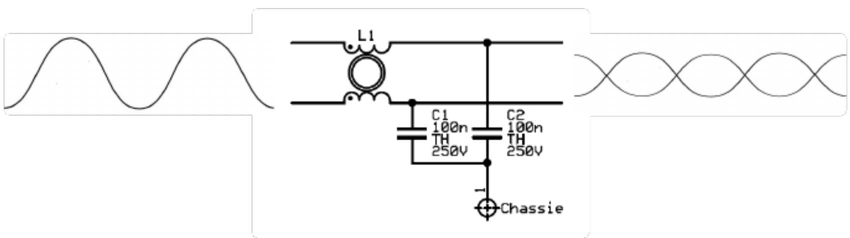

Figure 7 Common mode inductors

This means the radiated field becomes reduced as it ideally is cancelled out.

11 AUX-plant capacitors

C3, 4 and 27 are used to smooth out the voltage from the AUX-plant since this does not contain any electrolytic caps. Without them there will be a high frequency triwave with some ringing. Most of the ripple current from the flyback converter is contained in the ceramic caps on the AUX-plant but it is still smart to keep the ESR as low as possible in order to keep noise as low as possible. The capacitors that are mounted on Motherboard-1 are Panasonic EEUFC1E331 (330uF/25V). These have an ESR of 90m and are rated to 755mArms@100kHz in 105ºC ambient during which they have 3000h life.

12 PCB

12.1 Component placement

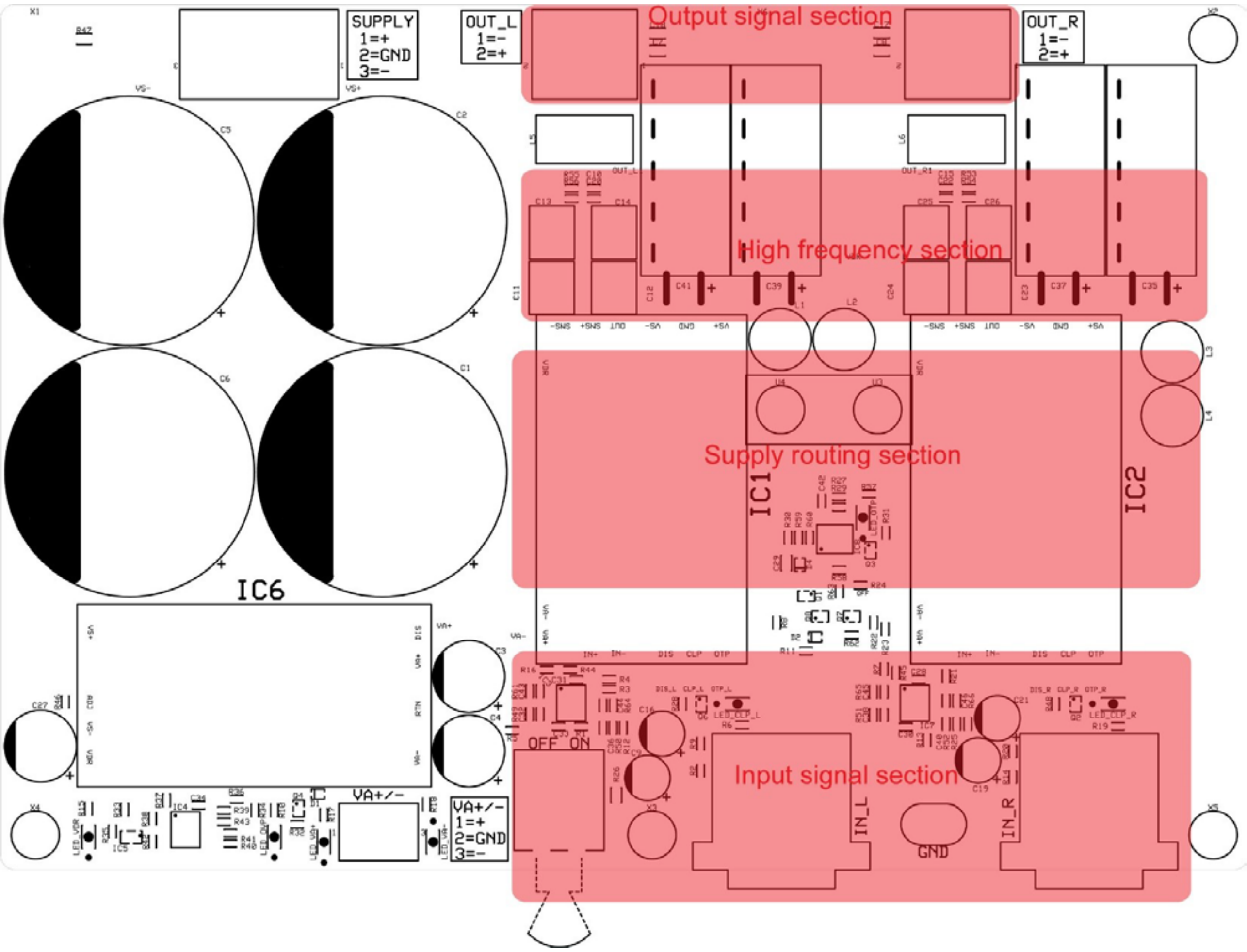

Figure 8 Component placement

12.2 Top copper

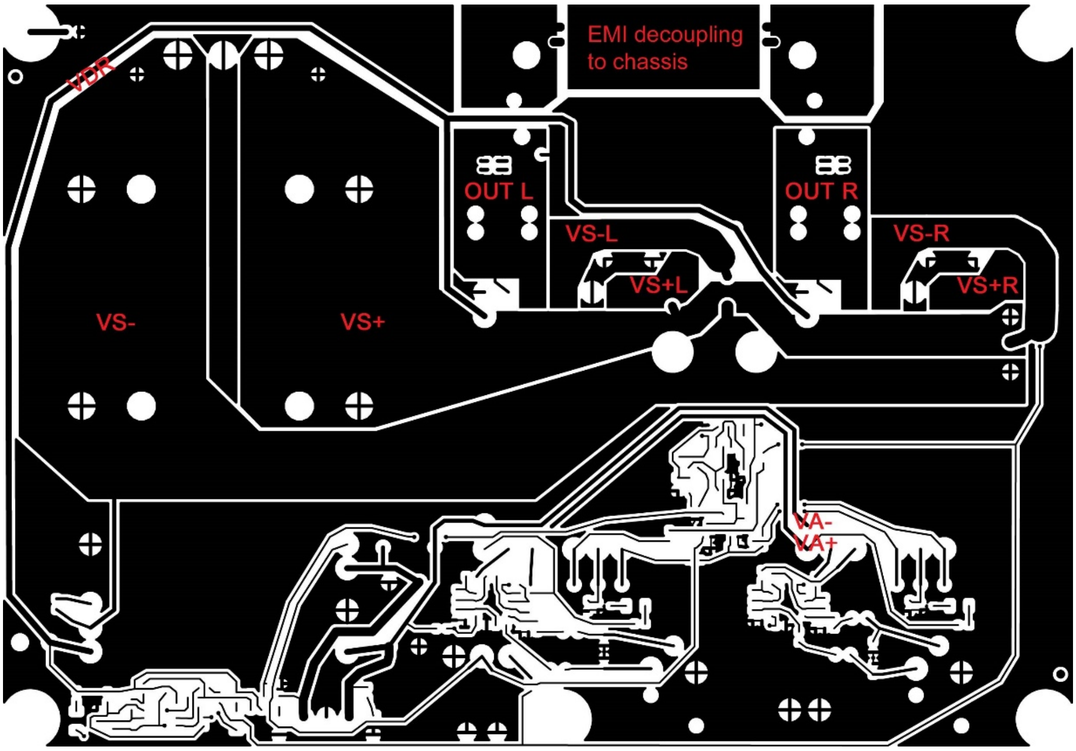

Figure 9 Top copper

12.3 Bottom copper

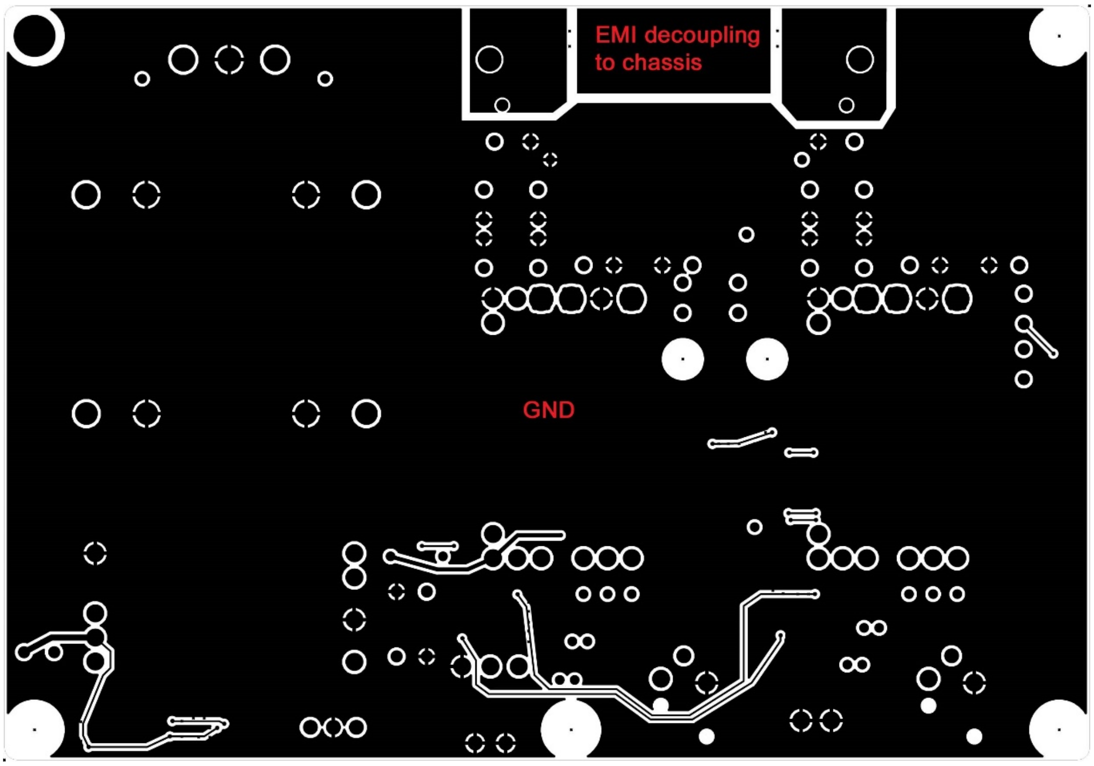

Figure 10 Bottom copper

12.4 Filter and decoupling capacitor section

The PCB design is an important part of the system design both for cooling and for keeping EMI and noise down. The high frequency filter capacitors plus the decoupling electrolytics are placed on the Motherboard and so the PCB has to be properly designed, especially in these areas. The best option is to use the PCB to form a high frequency capacitor by keeping GND as a plane under all the other traces/planes. A two layer board as the Motherboard-1 is sufficient to design the layout without major compromises.

12.5 Supply routing

By routing VS+ and VS- in the top layer GND can be filled underneath. It is important to not route input signals or output signals directly underneath VS+ or VS- as they will easily couple noise onto the signal. Since Engine-400 is raised 5mm from the Motherboard-1, routing them underneath the Engines is perfect.

12.6 Additional heat sinking

Engine-400 is capable of 50Wrms/4 continuously up to 50ºC ambient temp which corresponds to playing at full volume where some transients clip at 800Wpk. If more than 50Wrms is needed or a higher ambient temperature is desired, an additional heat sink can be attached to the two holes in the middle of the previous picture. The heat sink should connect thermally to the two MOSFETs (Q3 and Q4) on each Engine-400.

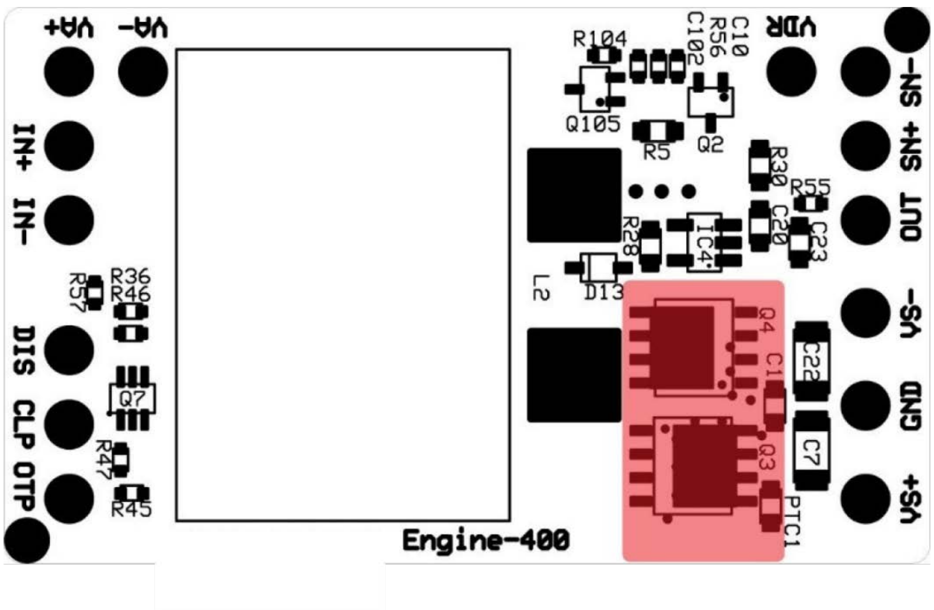

Figure 11 Hot components of Engine-400

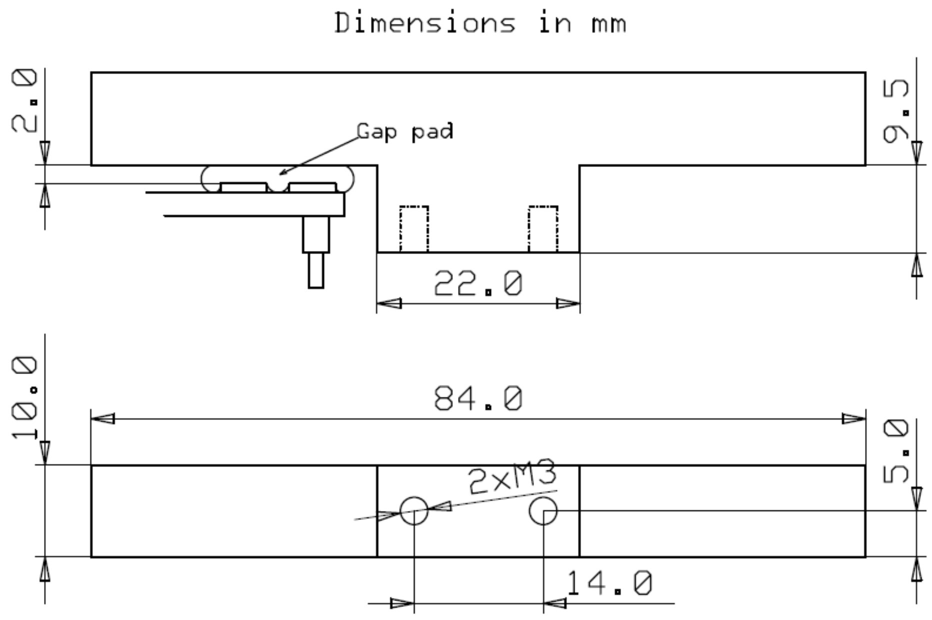

Figure 12 Heat sink proposal

Caution has to be made to not push down the heat sink to strongly towards the Engine-400. It is recommended to have 2mm distance between the top of the MOSFETs and the heat sink and to use a 100mil gap pad (from for example Bergquist Company). Further test results of different gap pads and heat sinks will be available on Audio Bricks webpage.

13 Mechanical Specification

13.1 Dimensions

Symbol	Parameter	Condition	Min	Typ	Max	Unit
L	Module length			180		mm
W	Module width			135		mm
H	Module height				40	mm
Mass	Weight			40		g

Table 5: Mechanical dimensions

13.2 Environmental Specifications

Symbol	Parameter	Conditions	Min	Typ	Max	Units
$T_{operating}$	Ambient temperature, operating		0		55	°C
	Altitude, operating				2000	m

Table 6: Environment specifications

14 Typical Performance Characteristics

Typical performance data for ICEbricks Motherboard-1 with two Engine-400 and one AUX-plant are shown in the following graphs.

Measured in an adapter board with minimum recommended capacitances.
Unless otherwise specified $T_a = 25$ °C. Audio Precision AUX0025 and AES17 20 kHz filter.

14.1 THD+N both channels driven

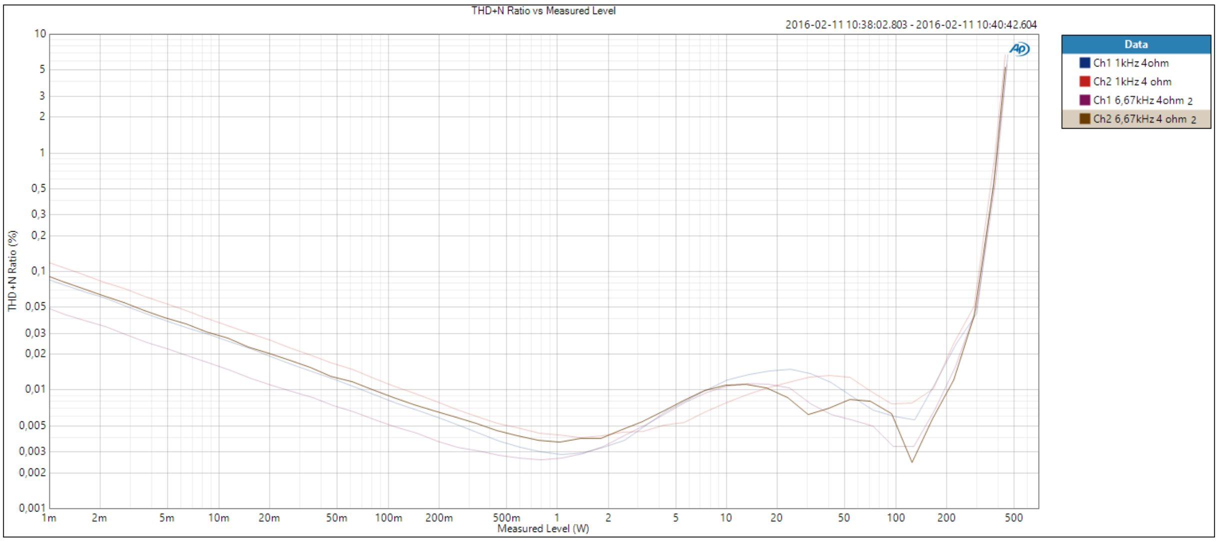

Figure 13: THD+N vs output power, both channels driven: Ch 1 $R_L = 4\ \Omega$, 1kHz(blue) / 6,67kHz (purple)
Ch 2 $R_L = 4\ \Omega$, 1kHz(red) / 6,67kHz (brown)

14.2 THD+N BTL 8ohm

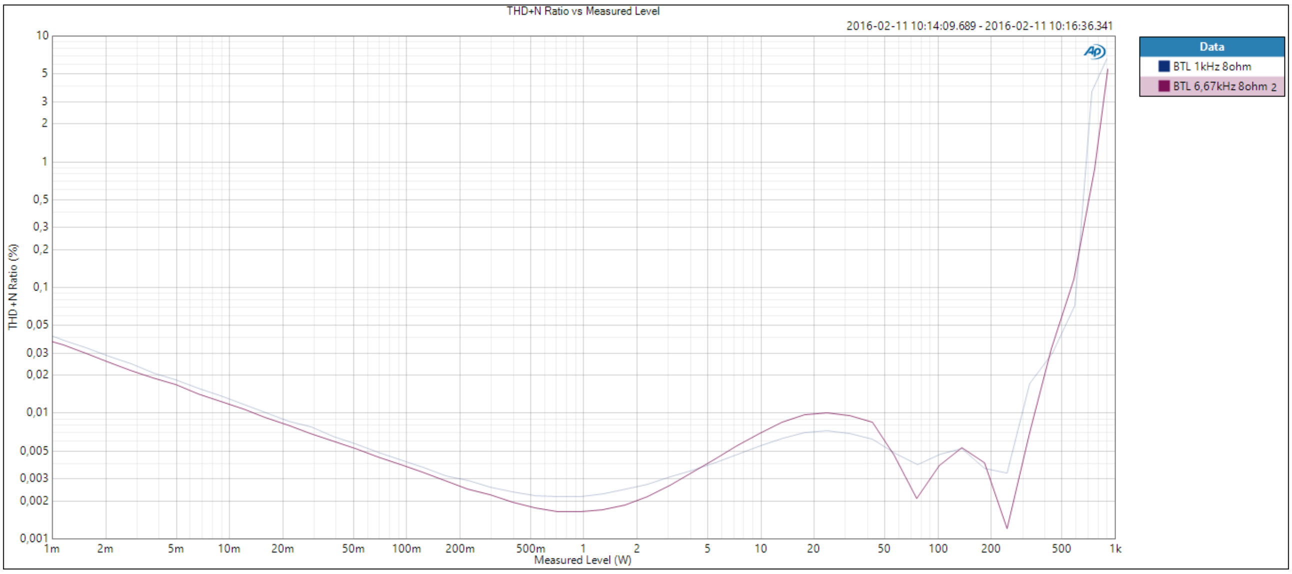

Figure 14: THD+N vs output power, BTL: $R_L = 8\ \Omega$, 1kHz(blue) / 6,67kHz (red)

14.3 Typical performance measurement plots

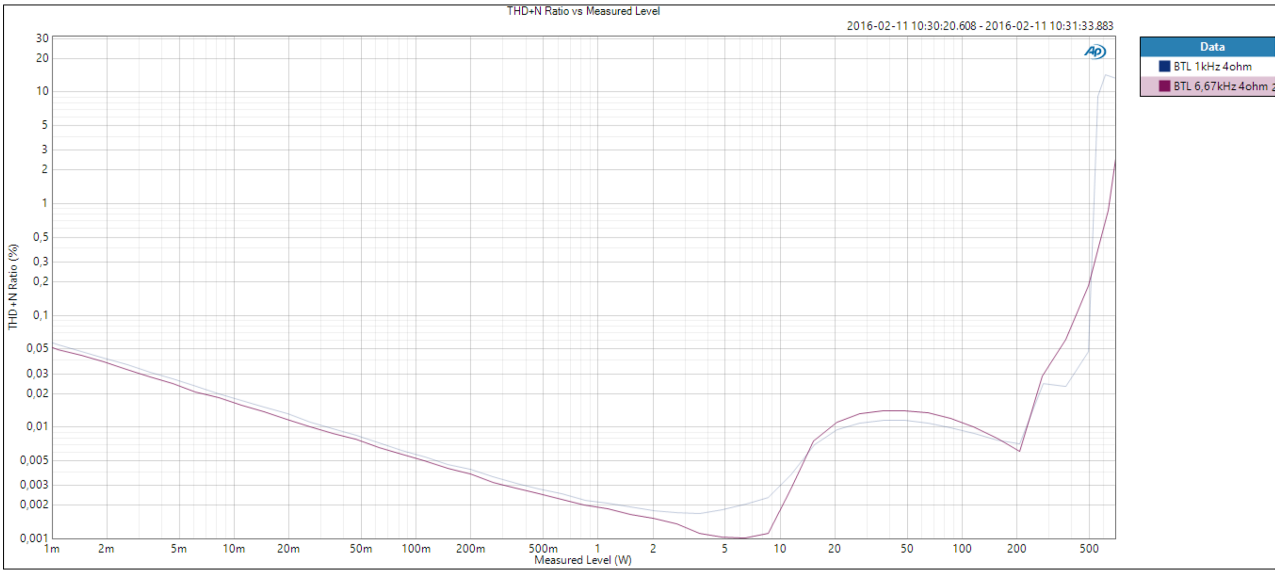

Figure 15: THD+N vs output power, BTL: R_L = 4 Ω, 1kHz(blue) / 6,67kHz (red)

14.4 Crosstalk

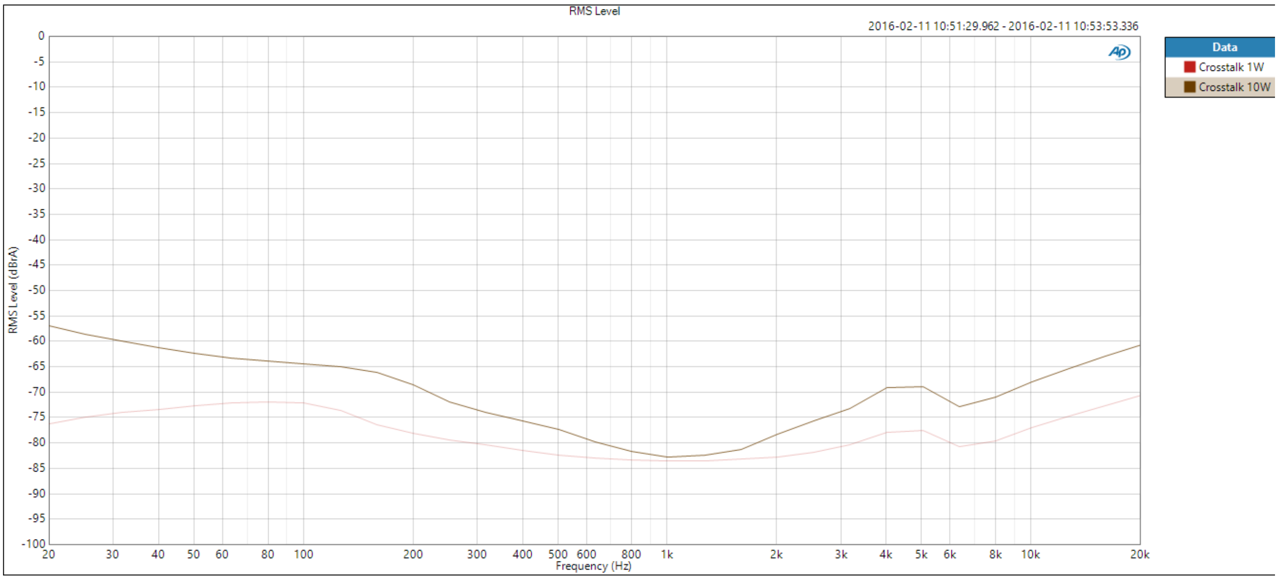

Figure 16: Crosstalk vs frequency channel 1: Ch 2 output power = 1W (red), Ch 2 output power = 10W (brown)

14.5 FFT at idle

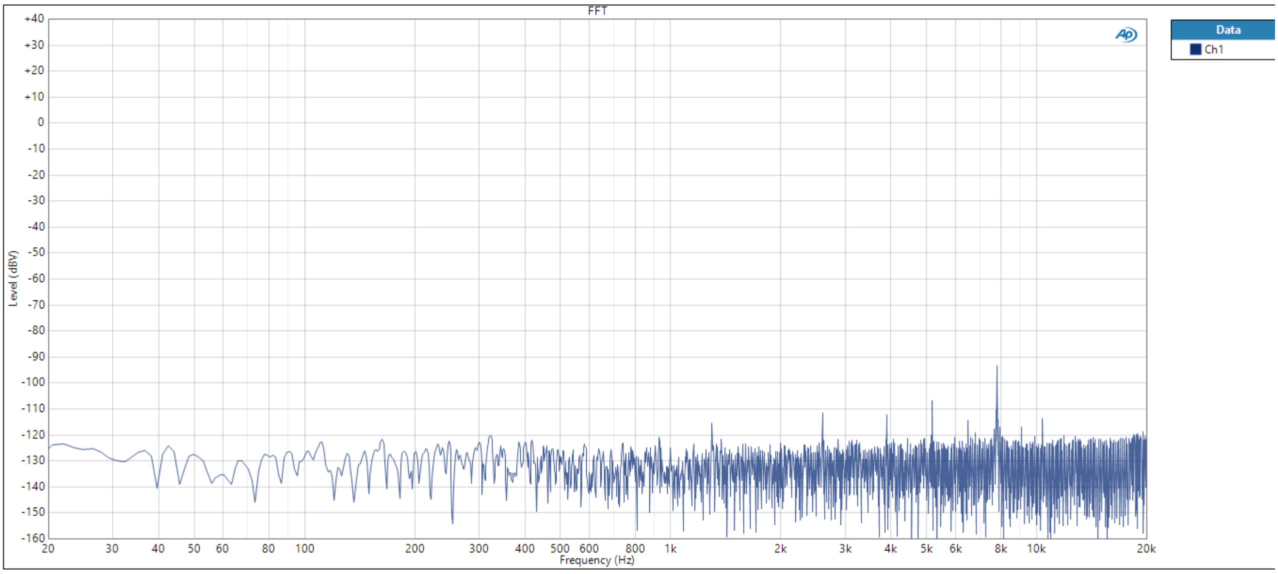

Figure 17: Ch 1 idle noise (16kFFT) 20-20kHz @ 0dB = 400W /4 Ω

15 Application information

See specification for ICEbricks Engine-400 and ICEbricks AUX-plant for further application notes, recommended PCB design and instructions of use.

15.1 EMC management

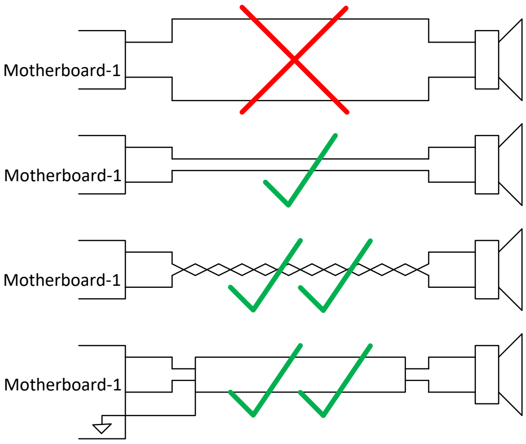

Figure 18: Speaker wire routing

16 ESD warning

ICEpower products are manufactured according to the following ESD precautions:

- ANSI/ESD-S20.20-2007: Protection of Electrical and Electronic Parts, Assemblies and Equipment.

Further handling of the products should comply with the same standard.

The general warranty policy of ICEpower a/s does not cover ESD damaged products due to improper handling.

17 Ordering, Packaging and Storage

All ICEpower modules are packaged in ESD safe bobble bags and cardboard boxes.

17.1 Ordering information

Order Codes	**Description**	**Part Number**
ICEbricks Motherboard-1	A reference design for a 2-channel amplifier	8004002

17.2 Shipping dimensions and weight

Package	**Quantity**	**Dimensions (w × d × h) [mm]**	**Gross Weight [kg]**
Carton	Modules	TBD	TBD
Pallet	Cartons	TBD	TBD

17.3 Storage conditions

Storage Humidity and Temperature:

Please find storage humidity and temperature information in Section 14.3, Environmental Specifications.

Stacking

Pallets may not be stacked on top of each other.

18 Contact

For additional information about the ICEpower® technology from ICEpower a/s, visit our web site or contact us.

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