

# PURE SOUND

Building a Straight Wire to the Soul of Music

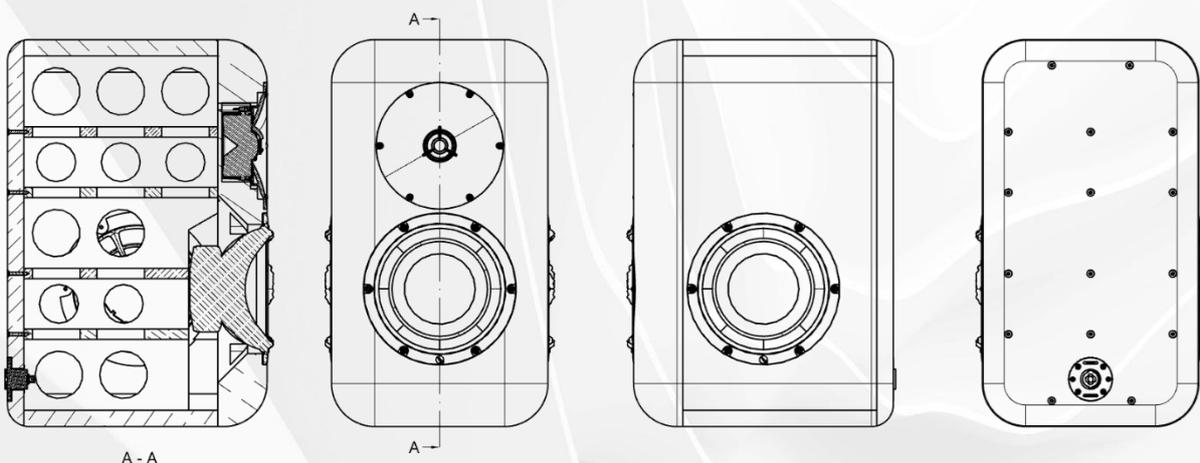


## SPK16 REF. DESIGN 2-Way Monitor

- ⊙ Compact 2-way Stand Mount Monitor using USHINDI drivers
- ⊙ Very Deep bass Extension for its Size
- ⊙ USHINDI Passive Radiators in force Cancelling Configuration
- ⊙ Very Wide and Smooth Dispersion
- ⊙ Model-based Design Methodology using Comsol and Matlab

### KEY SPECIFICATIONS

Type	Passive, 2-way, Passive Radiator
Woofer	PTT6.5X04-NAA-09
Passive Radiator	2 × PTT6.5PR-NA2-09 + mass kit
Tweeter	PTT1.3T04-HAG-10 (WG147 mm)
Bass Extension	32 Hz @ -3 dB
Volume	~19 L
Size (W×H×D)	250×450×300 mm
Crossover freq.	~1.8 kHz



## 1 Introduction

SPK16 is a demonstration platform, using the aluminium cone version of our 6.5" eXtended stroke woofer as well as our newly developed 1.3" dome tweeter in a 147 mm waveguide.

The speaker is a small 2-way monitor, utilizing passive radiators to enable extremely low bass from a relatively small cabinet. Furthermore, the cabinet has been shaped to ensure that the acoustic performance of the woofer and tweeter isn't negatively affected by the cabinet, hence the large fillet / round-over on corners. This enables the speaker to have a very wide and smooth dispersion pattern with a  $\pm 70$  degree beam width up to past 15 kHz.

SPK16 was first shown at High End München in 2023, but has been awaiting the recent final release of the tweeter in its 147 mm. The only changes since the May 2023 demo is that the woofers and PR's now use the inverted dustcap option since it offers a smoother frequency response. The design methodology is described in this [blog post](#).

This build description is not intended as a full step-by-step building instruction. But instead as a guide showing how a cabinet can be made, letting most of the woodworking and construction details be up to the user. We highly encourage the DIY community to adapt this design and share tips and tricks. The outside dimensions of the front baffle and the internal volume are the most important parameters acoustically. And there are plenty opportunities for improvements for easier assembly or manufacturing.

\* Supplied drawings and CAD files are meant as reference only.

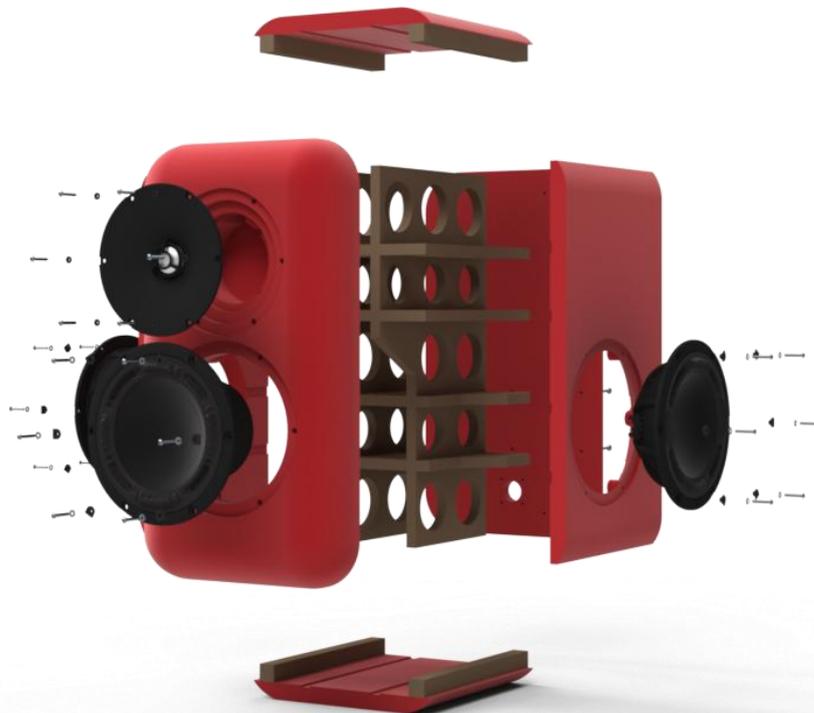


Figure 1 Exploded view of SPK16

## 2 Cabinet construction

The cabinet is constructed of 19mm MDF for the enclosure panels and 12mm plywood for the internal bracing matrix.

Most of the cabinet is glued together with generous amounts of wood glue ensuring airtightness and structural strength. Moreover, the wood-glue serve as a constrained layer damping. The screws in the rear panel are used to allow disassembly of the cabinet after glue-up.

As modelled, the bracing includes 2mm deep slots, to aid in assembly. We highly recommend the DIY community to experiment and share other solutions here. (We are sure there are people out there with more experience in woodworking 😊)

## 3 Damping material

For SPK16 we used a damping material normally called, bonded or recycled open-cell foam. This is a general purpose open-cell foam made from recycled material, with a density of  $\sim 140 \text{ kg/m}^3$ . It can quite easily be cut to size using a breadknife or similar.

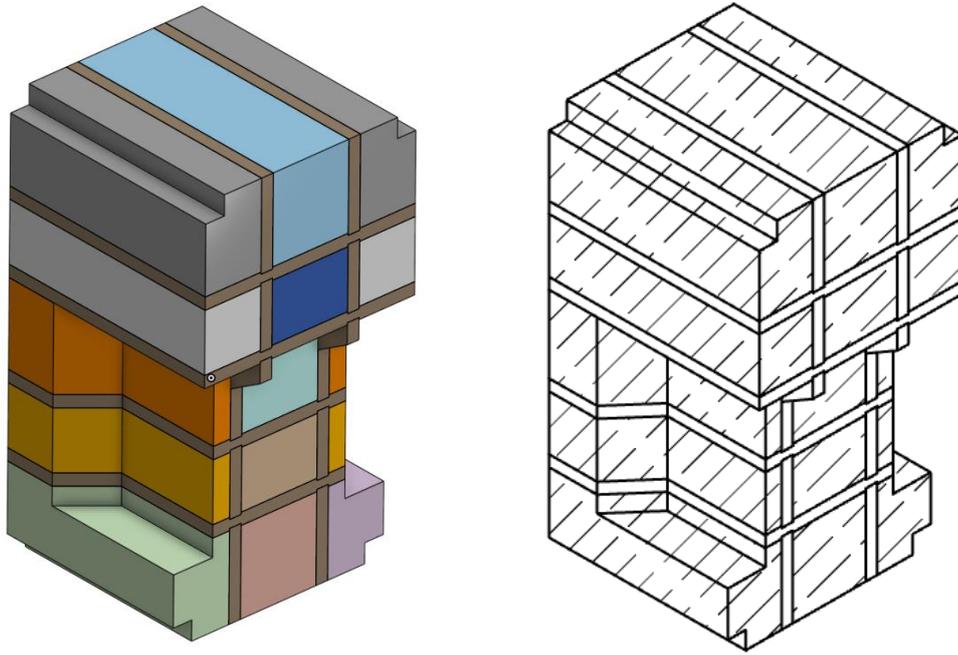


Figure 2 Damping material: Open cell bonded foam<sup>1</sup>

The damping material is placed nearly everywhere in between the bracing. Such open cell foam increases the effective acoustic cavity volume markedly. It is very important that the foam is tightly clamped and held in place since damping material that gets moved by the high internal sound pressure is a nonlinear effect. In addition, the damping material must not block the free air flow between the woofer and the passive radiators on the sides.

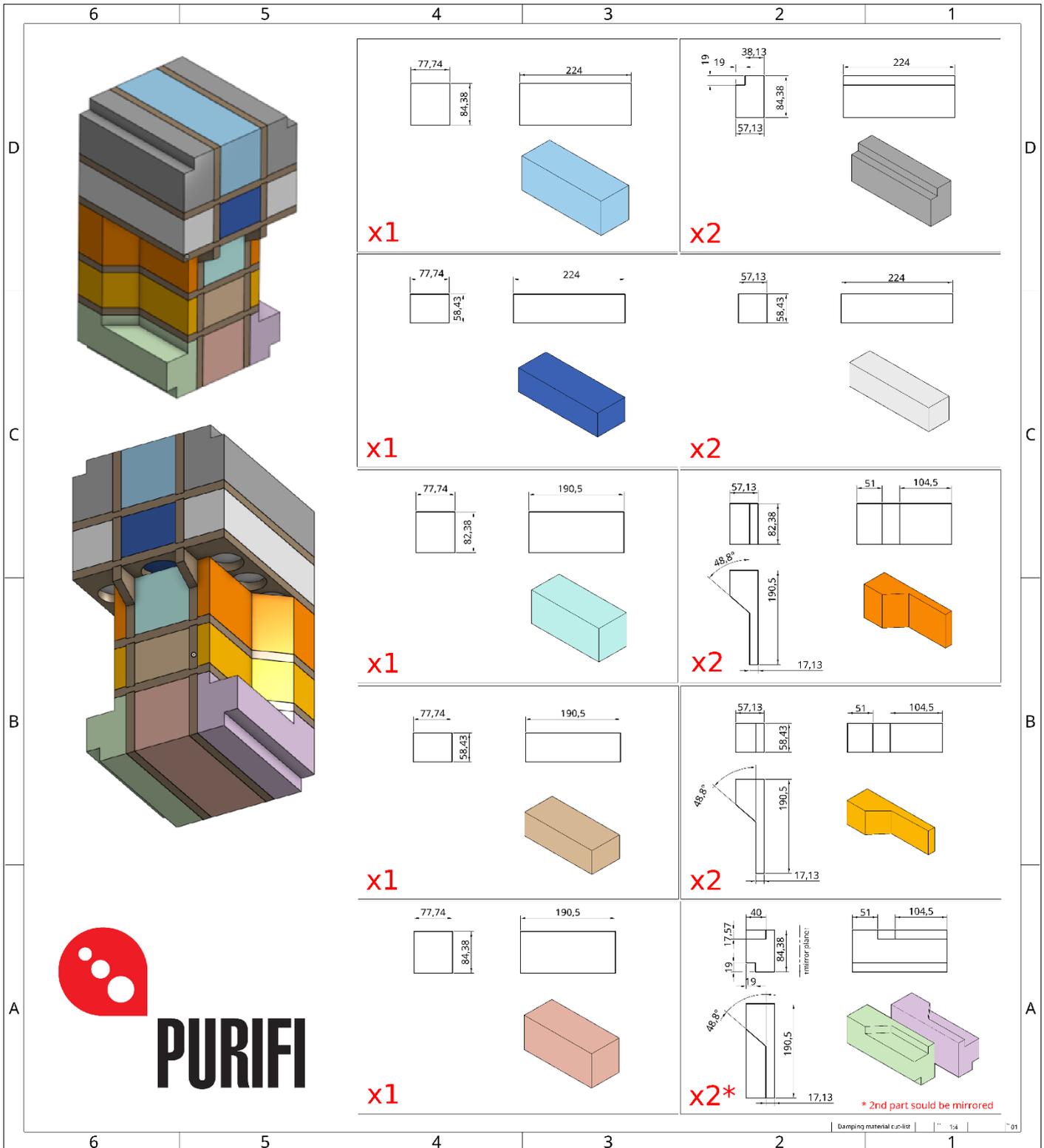
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<sup>1</sup><https://skumfabrikken.dk/produkt/skum/granulatplade/> Danish supplier.



*Figure 3 Damping material suggestion*

Figure 3 Damping material suggestion - shows one way to cut the damping material. On the drawing equal-colored pieces are equal in size (only transformed). The bottom two corners are mirror copies of each other (but with chirality).



## 4 Passive Radiator

The Passive radiators need a specific moving mass to tune the box according to the optimisation described in the blog post. This is achieved by screwing the washer kit and M6 bolt onto the mass plugs of each PR. The tuning can be checked by measuring the impedance curve of the woofer and compare to the curve published in the electrical section. The tuning impedance dip at 33.2 Hz (saddle point) is indicative of the box tuning frequency.

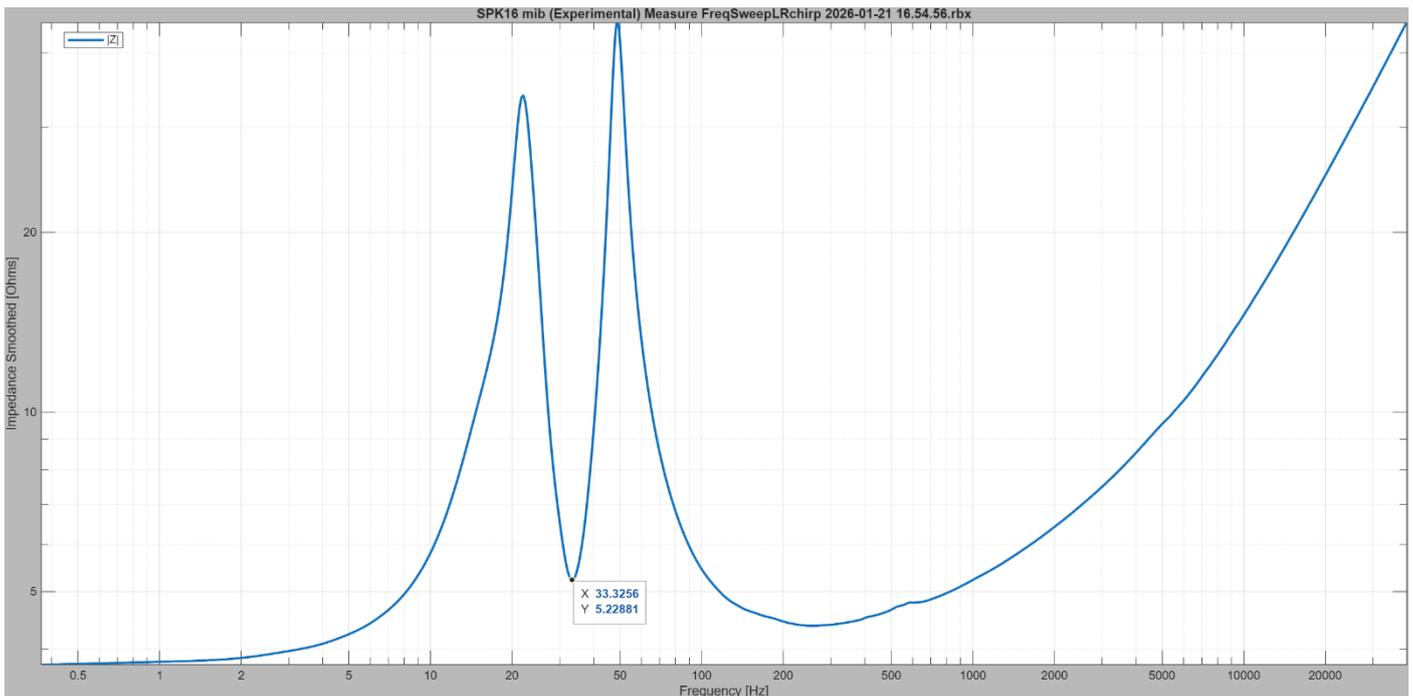


Figure 4 Impedance of the woofer with the tuning dip marked

### 4.1 PR tuning

The screw and washer kit included in the SPK16 kit, are necessary to tune the passive radiators to the correct tuning frequency.

The mass-kit consists of:

- 1x Buttonhead Machine Screw - M6x16mm T30

- 1x Ø35 Penny Washer - M6

The total mass added to each passive driver is:

$$M_{add} \approx 15.3 \text{ g}$$

We strongly recommend using some form of thread locking adhesive (i.e. Loctite or similar), when mounting the extra mass to the passive radiators.



## 5 Assembly tips

### 5.1 TPU-grommets for mounting screws

A soft foam gasket is supplied with all PURIFI woofers. The main purpose of this is to ensure an airtight seal between the basket and cabinet.

The same issue is prevalent when using thru holes for mounting drivers in a cabinet, as air can then potentially leak out around the screws.

Using a soft material between the woofer basket and the screw also eliminates the possibility that any of the mounting screw buzz against the basket (Murphy's law, if it possibly can buzz it will buzz sooner or later when constantly exposed to vibrations). For this purpose, we designed a grommet 3D printed in TPU (a soft rubbery material).

The TPU-grommet helps lower the Q values of mechanical resonances by breaking the mechanical short circuiting that the screws otherwise provide between the basket and front panel. If one were to screw directly into the basket (metal-to-metal) then the vibrations from the cabinet are effectively shorted to the basket, essentially letting those vibrations couple directly to the driver.

So, all in all, the purpose of the TPU-grommet, is to ensure airtightness, reduce the chance for buzz and bridge the connection between cabinet and driver without shorting mechanical vibrations.



Figure 5 TPU-grommet for the PTT 6.5" woofer

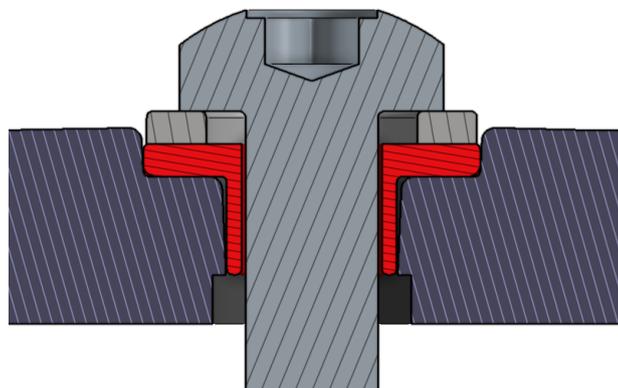
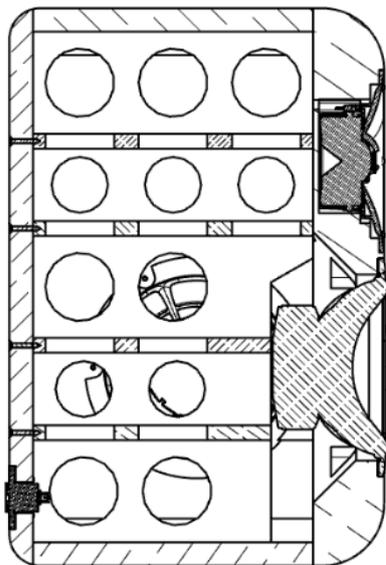


Figure 6 Example section view of TPU-grommet in PTT 6.5" woofer

3D CAD files (.step) are supplied for both woofer and tweeter TPU-grommets. The woofer TPU-grommet exists as two versions (D-shape and round) The D-shape version fills out the whole screw recess into the basket – but is prone to spinning around when screws are tightened. The round version eliminates this issue.

## 5.2 Termination of the Newtonian Forces of the Woofer Motor

When a current runs through the voice-coil (VC) of a loudspeaker driver a force is applied to the VC pushing it back and forwards. But due to the tyranny Newton's 3<sup>rd</sup> law: "for every action there is an equal and opposite reaction". This means that the magnet will have an equal and opposite force applied to it – often called Newtonian forces. These forces must go somewhere unless the driver is free floating in space. The conventional mounting of the driver is by its frame (screws through the basket into the front baffle/panel). However, this will form an unwanted resonance formed by the stiffness of the basket and the mass of the motor (as pointed out by the late Siegfried Linkwitz years back). Worst case, such poorly damped resonance can lead to distortion or even buzzing. To mitigate such resonance, it is preferable to terminate most of the Newtonian forces into the strong core of the cabinet instead of via the basket into the front panel. In addition, some damping applied will help reduce the Q value. We suggest letting the motor press against the internal bracing via a thin viscoelastic layer. This means that when the woofer mounting screws are tightened then we apply tension to the motor-brace interface. The Newtonian forces will now primarily terminate into the core of the box and less via its basket. (I.e. putty, bluetack. Must be non-hardening, and viscous enough to not 'run').



A - A

Figure 7 Cross section through the woofer

## 5.3 Air tightness

The box shall be completely airtight and sealed. This can easily be verified by pushing one of the bass drivers and verify that the other two drivers move and hold up their position for several seconds before relaxing to their rest positions.

## 6 Crossover Filter

The driver responses in the complete box were measured at 2.5 m distance on the tweeter axis with the speaker elevated on a pole to the tweeter center approx. 3.7 m above the floor. A gating window ending at 7.5 m distance was applied to the measured impulse response to remove the reflections from the hall and floor. This yields responses that are highly accurate down to about 200 Hz.



*Figure 8 Measurement setup-up in the gym*

A filter network was optimized using Matlab. This optimization co-optimises the model based bass response (see the [blog post](#)) up to about 450 Hz together with the measured response from 200 Hz and up. The optimization priorities on axis response flatness as well as phase matching in the crossover frequency range. The filter network was exported to VCAD2 from which the following results are taken:

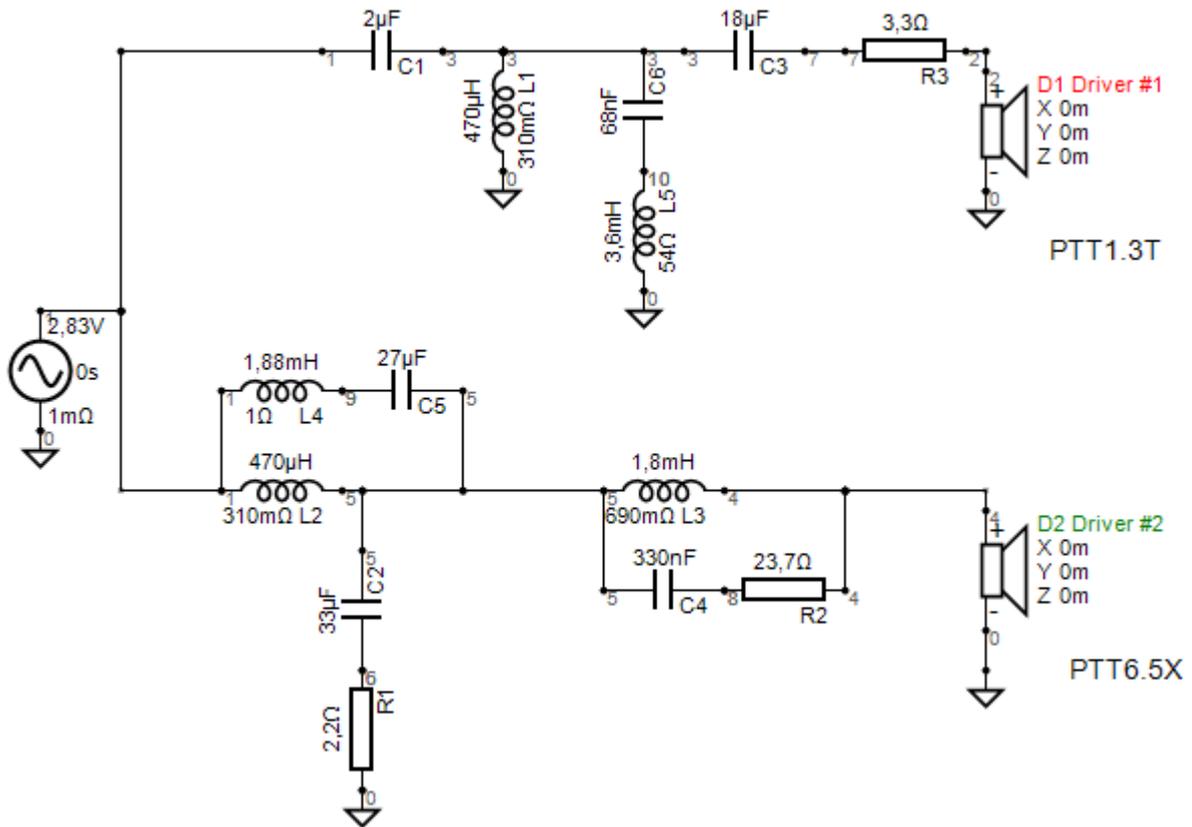


Figure 9 The optimised crossover filter

The resistors should be non-magnetic to avoid magnetic hysteresis distortion. Resistor R1 will burn the most power when playing music and should handle 10 W or more (see Figure 16). Air cored Inductors should be used and their DCR should match the schematic (we deliberately add DC resistance to the woofer to tune the bass deep). Examples of inductors:

Ref. Des.	Value	Example
L1 & L2	0.47 mH / 0.31 Ω	Mundorf CFC18-0.47
L3	1.8 mH / 0.62 Ω	Mundorf CFC18-1.8
L4	1.88 mH / 1 Ω	Jantzen Air Core Coil - 2,000 mH +/-3% - DCR 1,16 Ω - Wire 0,80 mm - 20 AWG - Ø 42 mm / H 30 mm <b>Unwound to reach the target value</b>
L5	3.6 mH / 54 Ω	Jantzen Air Core 3,600 mH +/-3% - DCR 7,87 Ω - Wire 0,30 mm - 29 AWG - Ø 23 mm / H 15 mm. <b>Needs extra series resistor</b>

Table 1 Suggestions for Inductors

Acoustic response on axis:

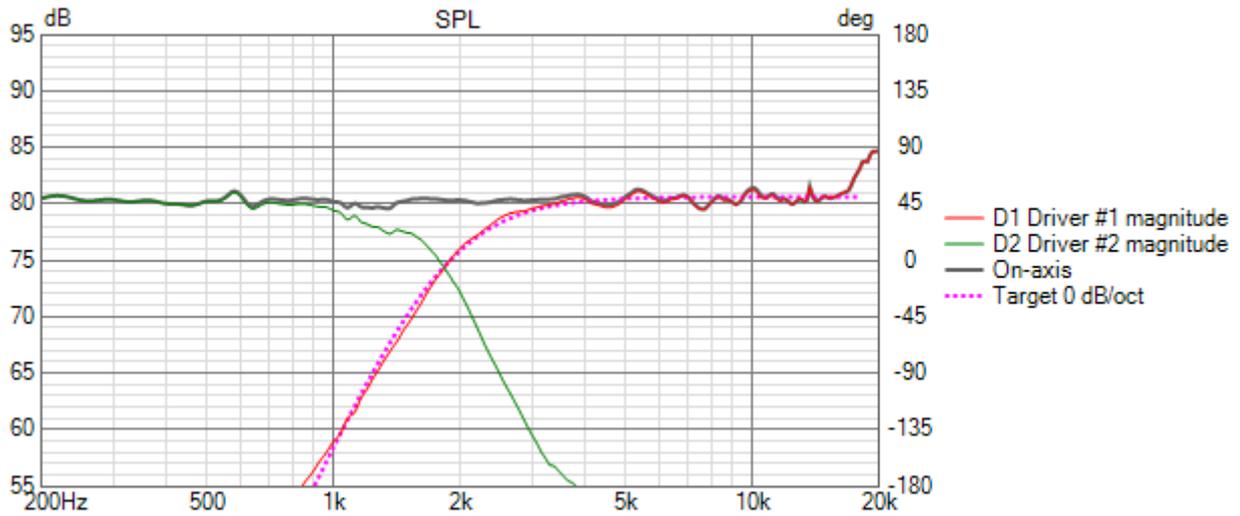


Figure 10 On axis response 2.83 V<sub>RMS</sub> from VCAD2

The on-axis response is rising towards the ultra-sonic tweeter breakup at 27 kHz. However, the radiation pattern narrows sharply above 17 kHz, so the actual sound power (spatial average of the power) is drooping slightly despite the rising on axis response:

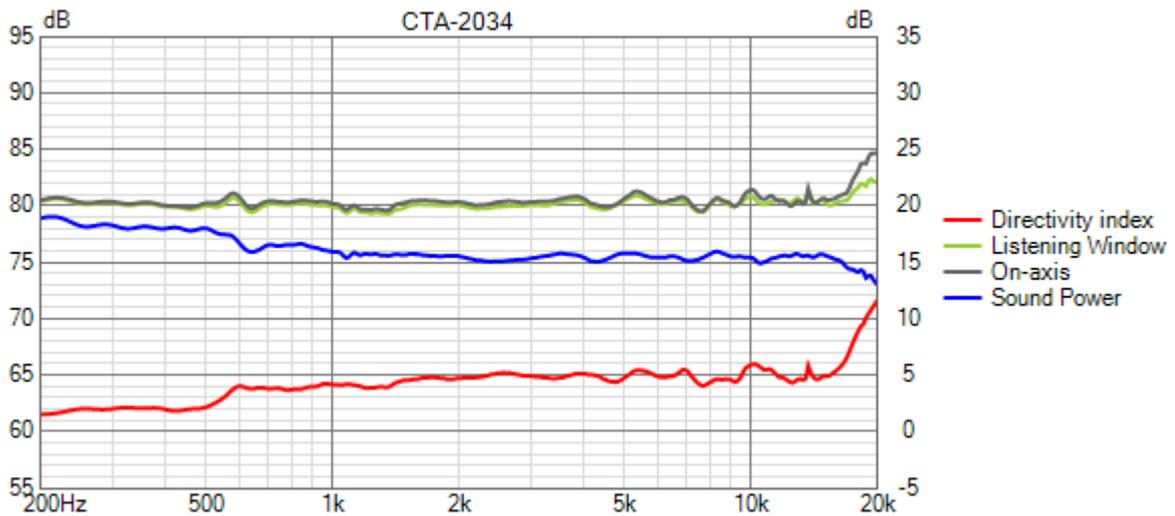


Figure 11 CTA-20234 graphs from VCAD2 (based on horizontal 0-120 deg)

The Directivity Index (ratio of the Listening Window power average and full horizontal power average) is very constant at 5dB from 2 kHz and up.

Horizontal radiation pattern (normalized & simulated) shows an attractive smooth, constant and wide dispersion (3 dB step contours) with a beam width of approx.  $\pm 70$  dB:

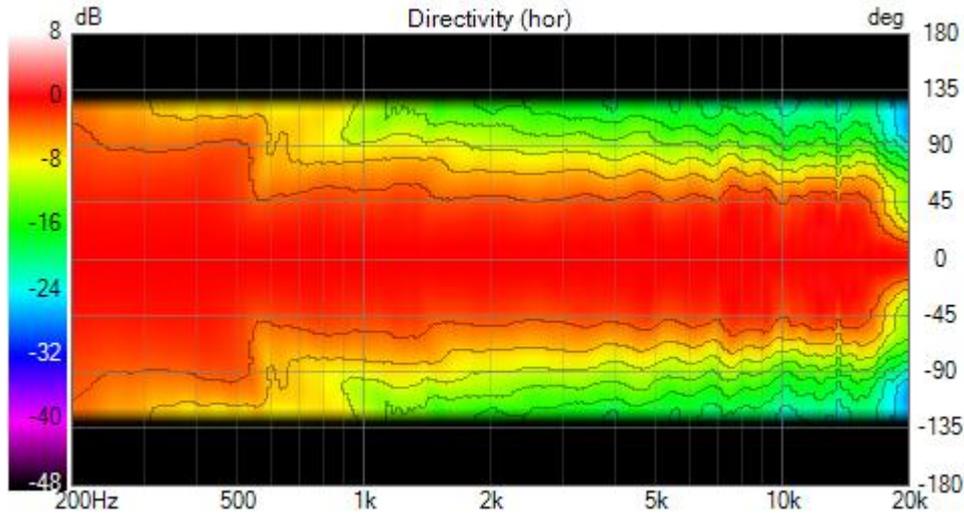


Figure 12 Horizontal directivity pattern

Matlab optimization result:

flatn.:0.25317 dB, ph dif=10.9401 deg, fc =1828.9719 Hz, Zmin=3.2093,SPLavg= 80.434:

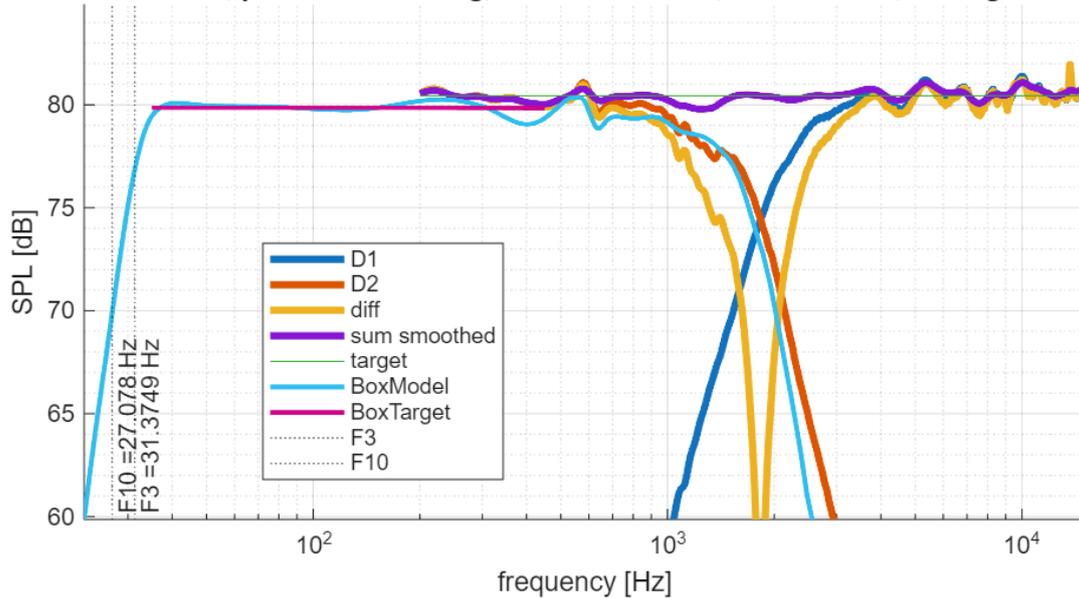


Figure 13 Graphs from the Matlab optimization

The light blue trace is the modelled response from the box model (including filter and simulated baffle step). This is included in the optimization process and ensures that the baffle step compensation and bass response is optimal despite the actual measurements not being valid much below 200 Hz. The orange trace shows the summed response with one driver inverted (i.e., the reverse null).

Phase response showing excellent phase match in the crossover region:

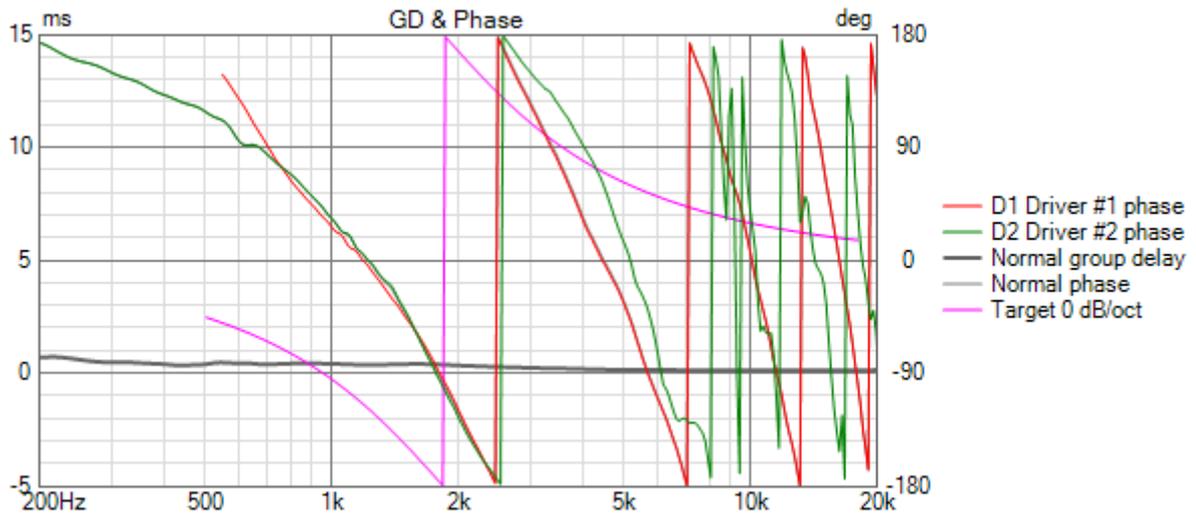


Figure 14 Phase responses from VCAD2

The following plot shows the electrical response of the filter including the sensitivity to back EMF as the dashed curves). This sensitivity is defined as the transfer function from a voltage source in series with each driver to the voltage across the driver. This indicates how sensitive the system is to hysteretic distortion and noise from the driver (see this [blog post](#) ). We see that the woofer filter helps suppress hysteresis distortion very effectively above 2 kHz. Note that the woofer plays signals up to about 2 kHz, but the harmonics can extend much higher and, consequently, the distortion suppression up in this range matters.

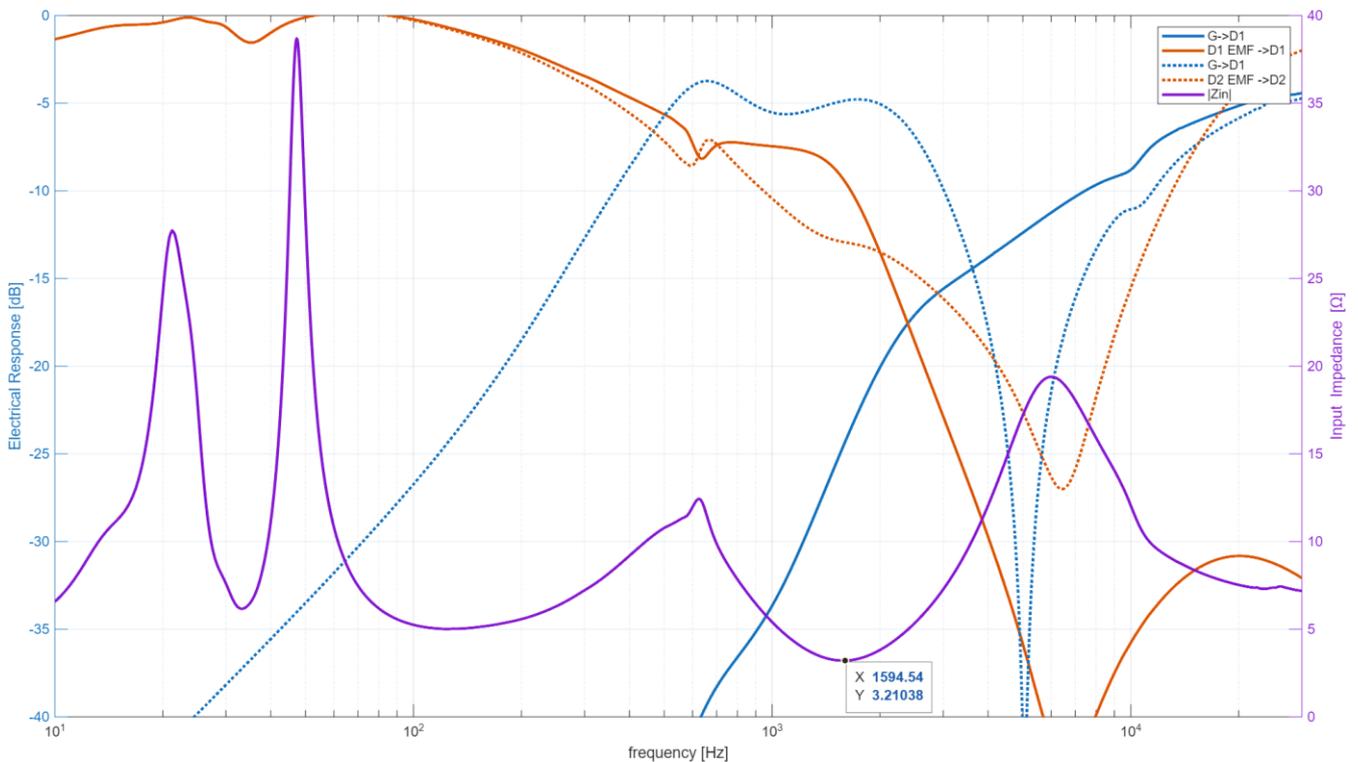


Figure 15 Electrical responses of the crossover filter from Matlab

Power dissipation analysis for sinusoidal 1V<sub>RMS</sub> input:

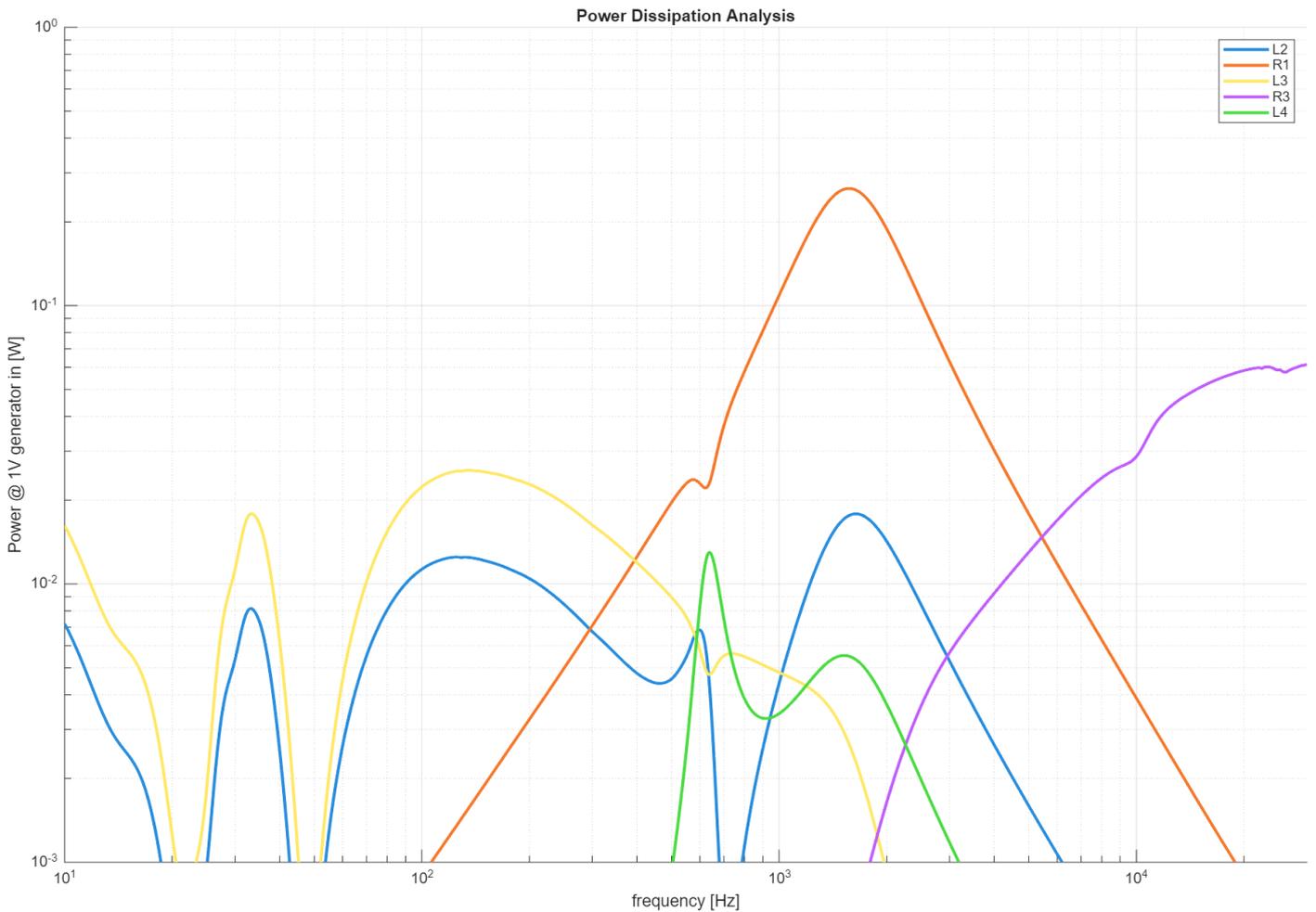


Figure 16 Power dissipation for 1 V<sub>RMS</sub> input per filter component

We see that R1 burns the most power but only in a narrow band around 1.5 kHz. Next after we have R3 which is in series with the tweeter but that is not of much concern since it will only burn a fraction of the power compared to the tweeter. Moreover, this is also only at very high treble frequencies where there is very little average power in most source material.

## 7 Verification

A fully assembled SPK16 with crossover filter was measured in the large hall again for verification. This time both horizontal and vertical polars were taken to 180 deg. In addition, near field measurements of the woofer and passive radiators were performed together with a microphone inside the box. The microphone in the box (MIB) gives a low frequency proxy for the far field response (the pressure inside the box precisely reflects the sum of the pressure generated by the woofer and PR's). However, the MIB is only accurate at low frequencies since we get internal standing waves in the box and there is also a baffle step when measuring in the far field. To overcome this, a mathematical method was used to combine the near field measurements including the MIB and a far field measurement (at 2.5 m distance) to get a synthesized far field response with very high accuracy down in the bass region despite using a gated far field measurement.

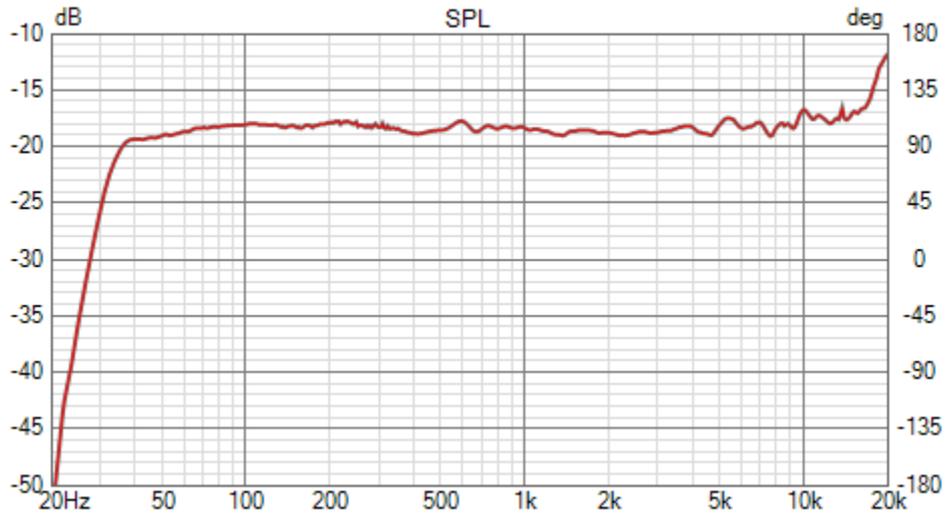


Figure 17 On axis response (arbitrary dB reference) synthesized from in-box, nearfield and far fields, unsmoothed

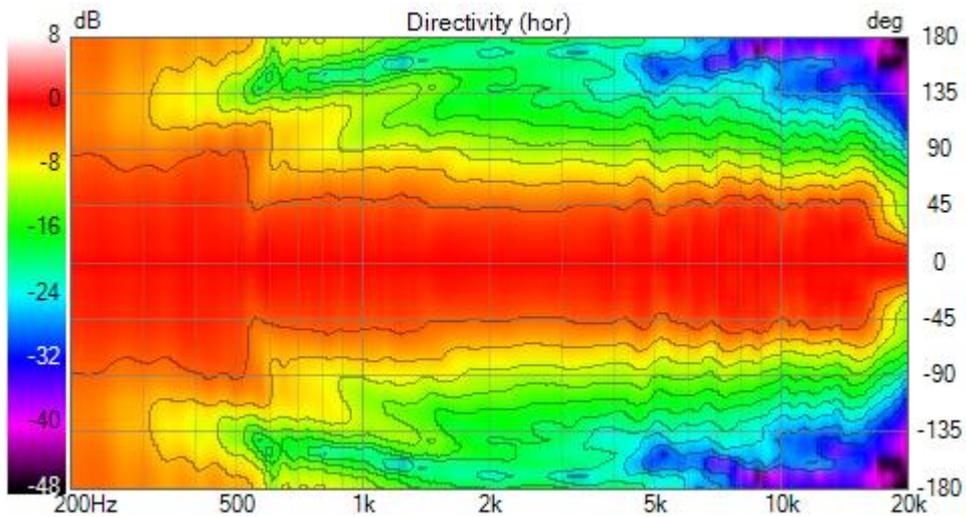


Figure 18 Horizontal directivity using gated measurements, 1/24 oct. smoothing

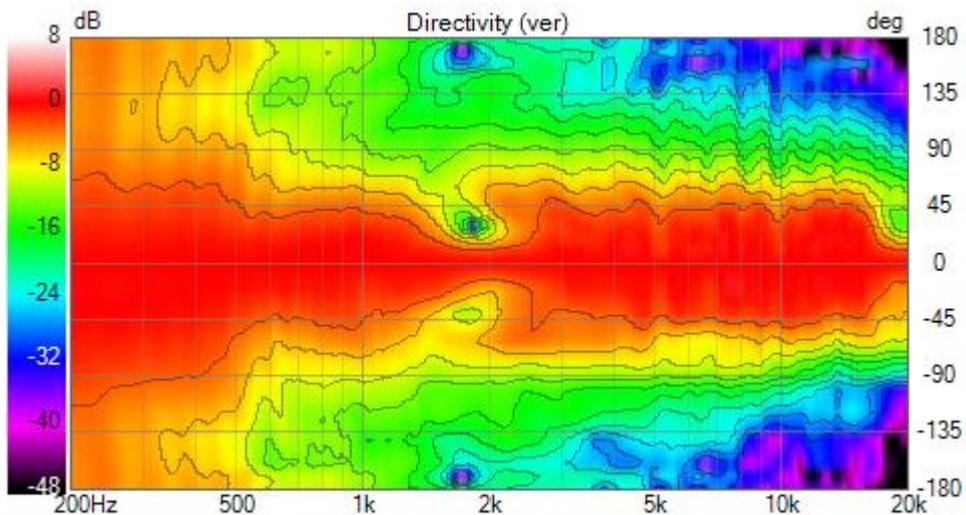


Figure 19 Vertical directivity using gated measurements, 1/24 oct. smoothing

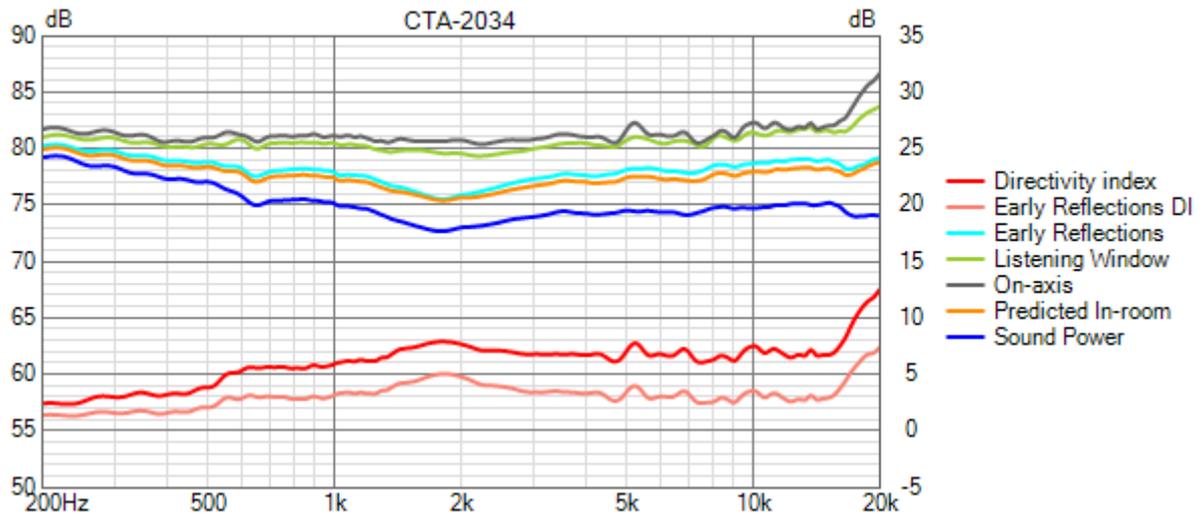
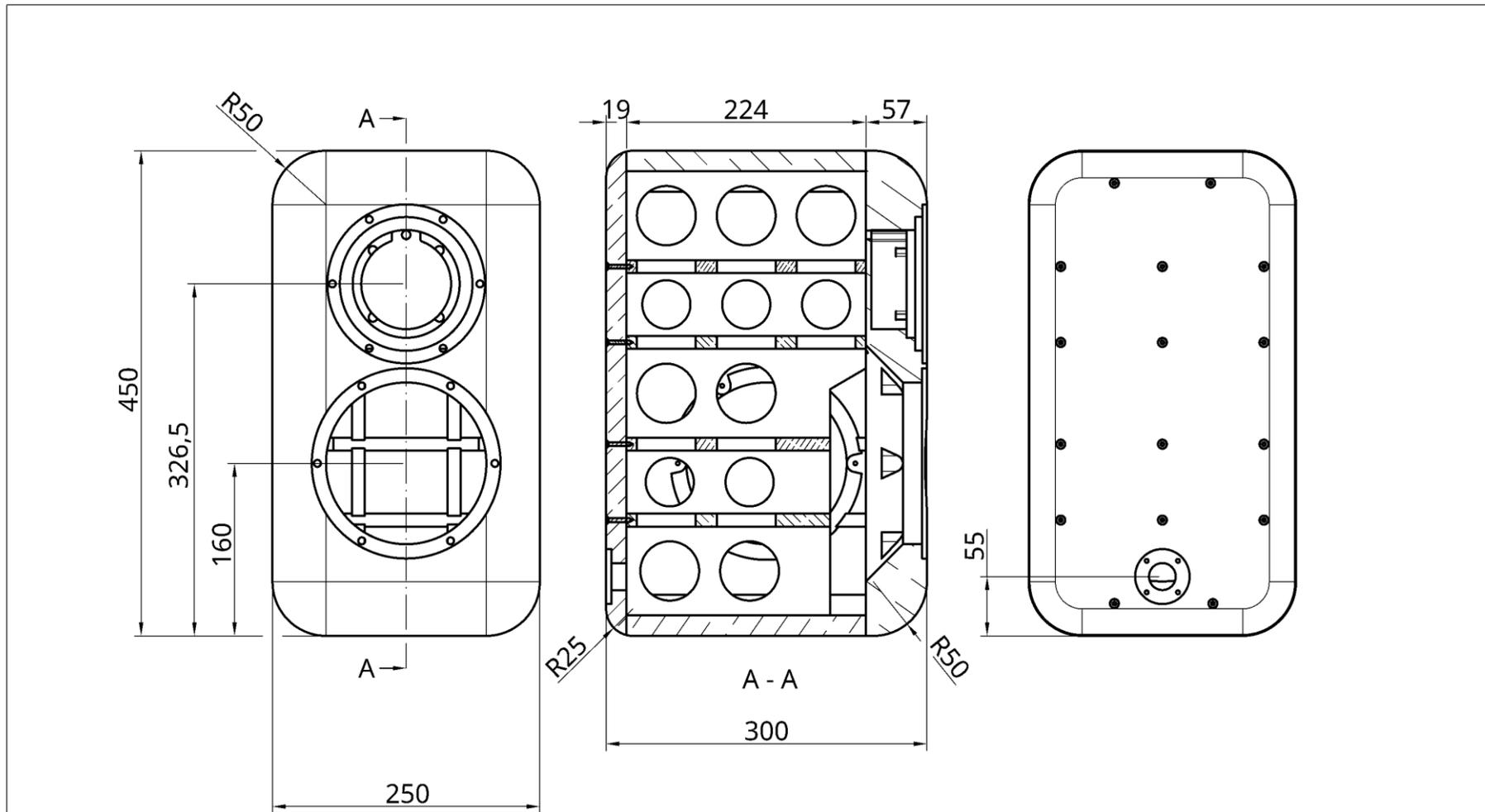


Figure 20 CTA-2034 graphs form VCAD2 using both horisontal and vertical data, 1/24 oct. smoothing

## 8 Revision History

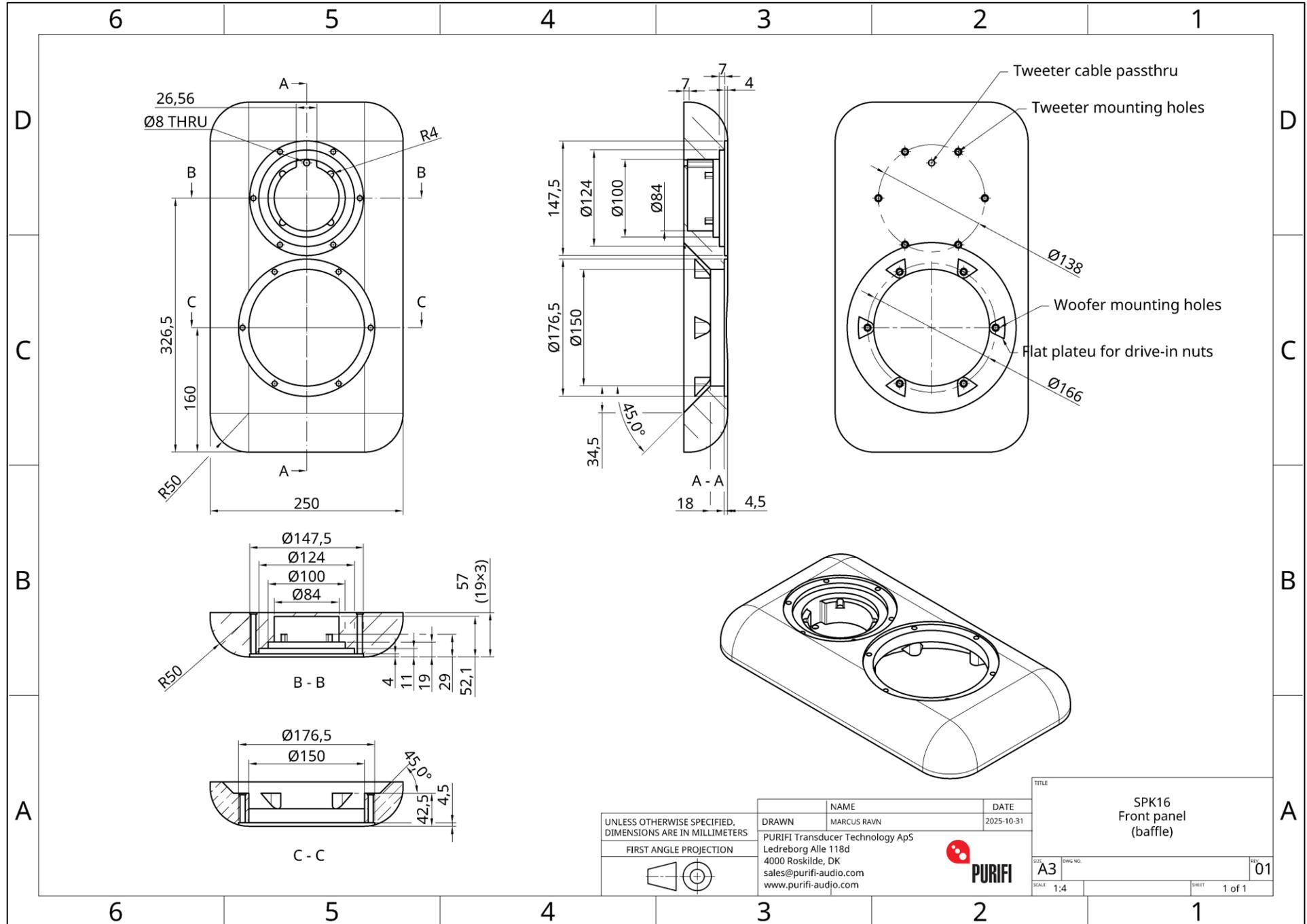
Rev	Date	Description	ID
1.00	2026-03-12	Release	MH

SPK16 - Build Description



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FIRST ANGLE PROJECTION				SIZE	REV
				A4	01
				SCALE	SHEET
				1:5	1 of 1

SPK16 - Build Description



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DIMENSIONS ARE IN MILLIMETERS

FIRST ANGLE PROJECTION

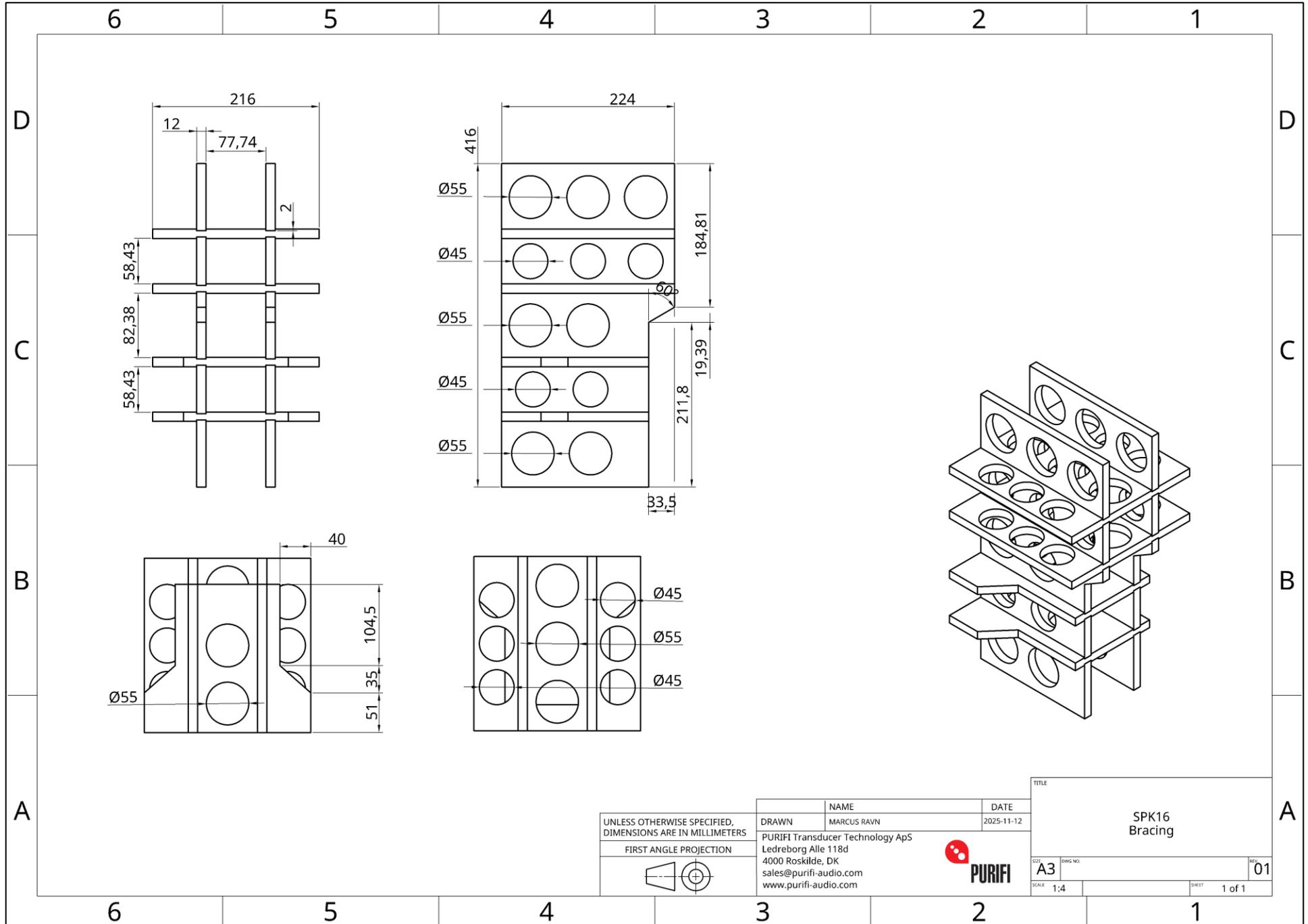


NAME	MARCUS RAVN	DATE	2025-10-31
DRAWN	MARCUS RAVN	PURIFI Transducer Technology ApS Ledreborg Alle 118d 4000 Roskilde, DK sales@purifi-audio.com www.purifi-audio.com	



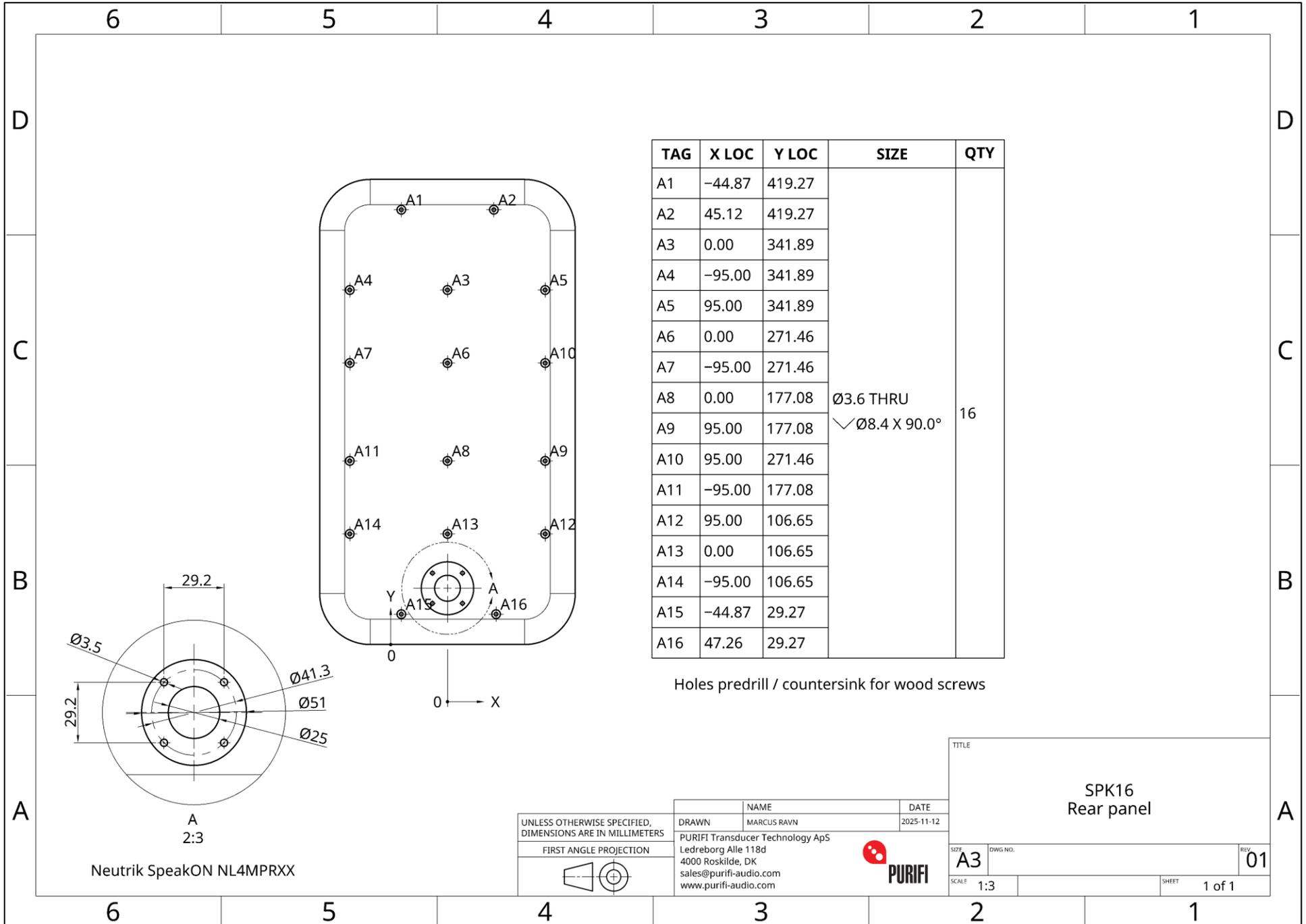
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# SPK16 - Build Description



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FIRST ANGLE PROJECTION				SIZE A3
				DWG NO. 01
				SCALE 1:4
				SHEET 1 of 1

SPK16 - Build Description



TAG	X LOC	Y LOC	SIZE	QTY
A1	-44.87	419.27	Ø3.6 THRU ∇Ø8.4 X 90.0°	16
A2	45.12	419.27		
A3	0.00	341.89		
A4	-95.00	341.89		
A5	95.00	341.89		
A6	0.00	271.46		
A7	-95.00	271.46		
A8	0.00	177.08		
A9	95.00	177.08		
A10	95.00	271.46		
A11	-95.00	177.08		
A12	95.00	106.65		
A13	0.00	106.65		
A14	-95.00	106.65		
A15	-44.87	29.27		
A16	47.26	29.27		

Holes predrill / countersink for wood screws

Neutrik SpeakON NL4MPRXX

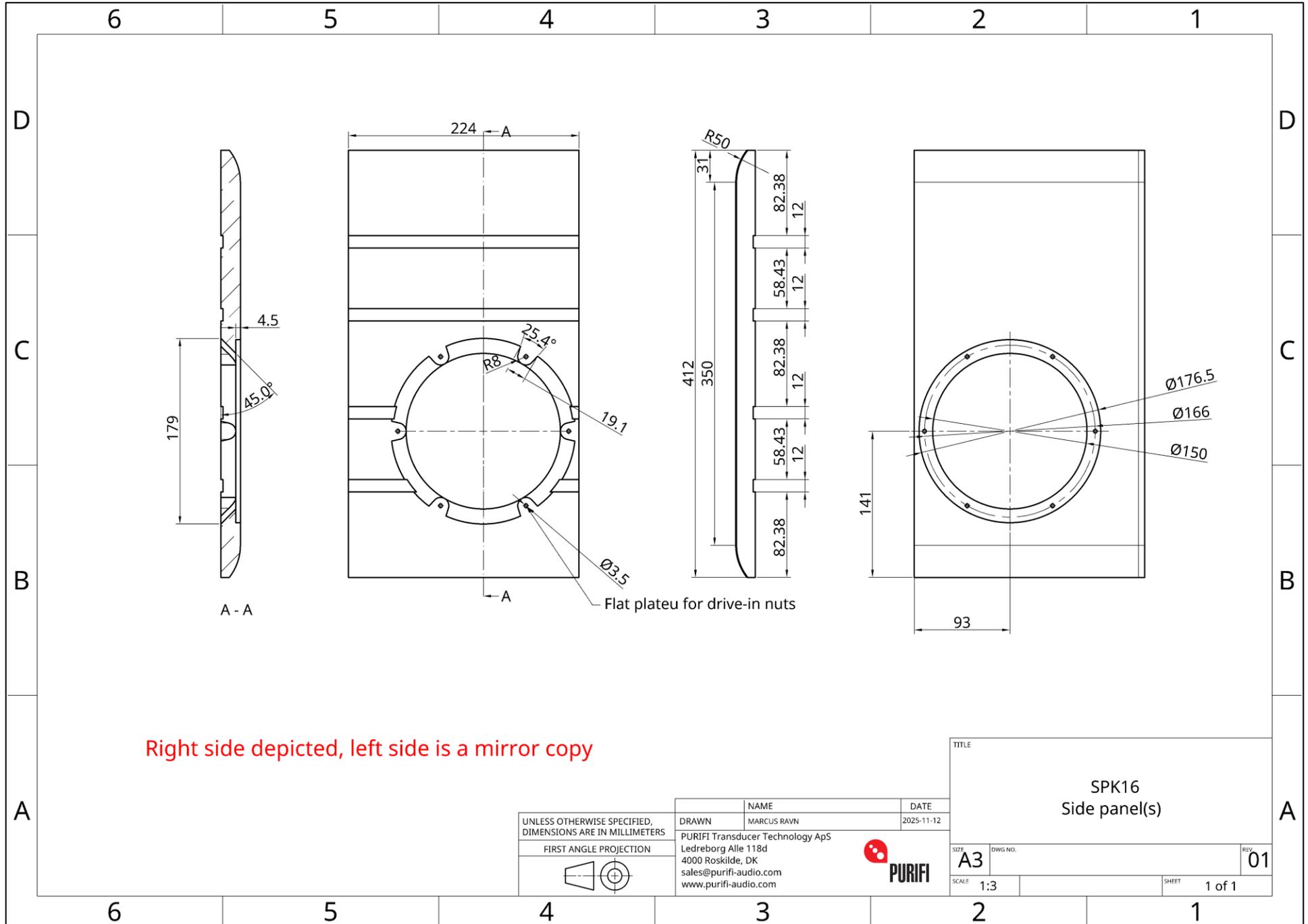
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FIRST ANGLE PROJECTION

NAME	MARCUS RAVN	DATE	2025-11-12
DRAWN			
PURIFI Transducer Technology ApS			
Ledreborg Alle 118d			
4000 Roskilde, DK			
sales@purifi-audio.com			
www.purifi-audio.com			

TITLE		SPK16 Rear panel	
SIZE	A3	DWG NO.	
SCALE	1:3	SHEET	1 of 1
REV	01		

SPK16 - Build Description

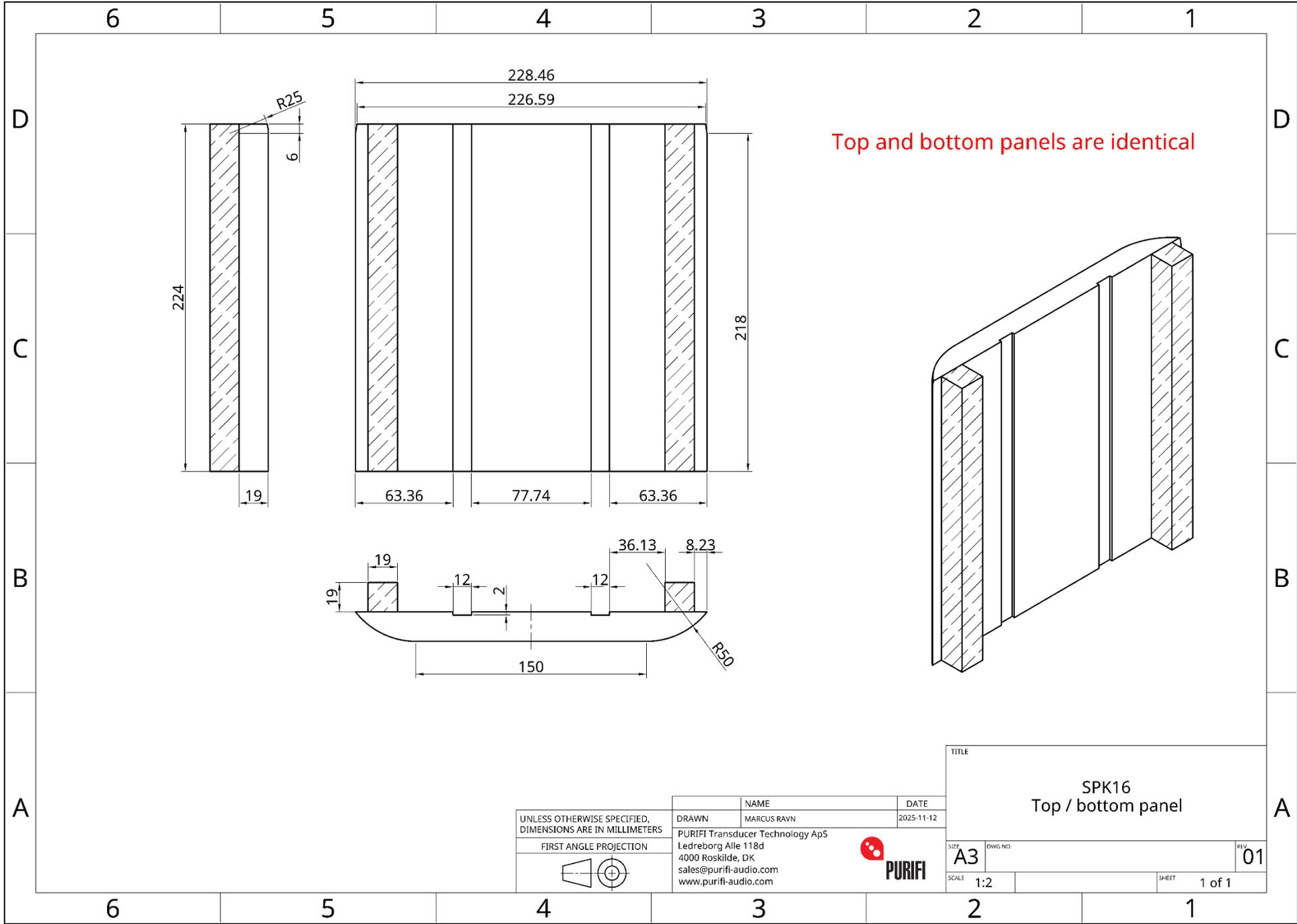


Right side depicted, left side is a mirror copy

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		DRAWN		NAME	DATE
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		SIZE	DWG NO.	REV. 01	
SCALE 1:3		SHEET		1 of 1	

TITLE  
 SPK16  
 Side panel(s)

SPK16 - Build Description



Top and bottom panels are identical

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS	DRAWN	NAME	DATE
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FIRST ANGLE PROJECTION			

TITLE			
SPK16 Top / bottom panel			
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A3			
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