



## Company Overview

JANUARY 2018

# THE AGENDA FOR TODAY

MERUS AUDIO COMPANY PRESENTATION



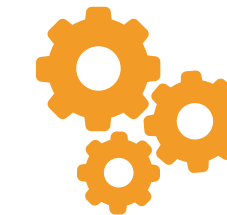
## 1. INTRODUCTION

COMPANY OVERVIEW



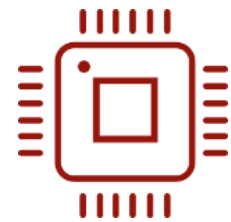
## 2. TRENDS

MARKET OPPORTUNITIES



## 3. EXIMO®

OUR TECHNOLOGY IN BRIEF



## 4. PRODUCTS

OUR IC PORTFOLIO



## 5. COFFEE BREAK

IMPORTANT!



## 6. DEMOS

HEAR, SEE & FEEL FOR YOURSELF



## 7. USECASES

CUSTOMER EXAMPLES



## 8. PROJECTS

YOUR REQUIREMENTS



## 9. STAY IN TOUCH

CONTACT DETAILS FOR REFERENCE



# INTRODUCTION

COMPANY OVERVIEW



# MERUS AUDIO TIMELINE

FROM IDEA TO COMMERCIAL SUCCESS



2010 THE  
FOUNDATION

—  
First discrete prototype  
implementation of an  
eximo® multi-level  
audio amplifier



2011  
THE PATENT  
APPLICATION

—  
First patent filing for  
the eximo® audio  
amplifier topology.



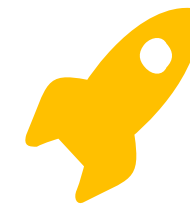
2014 THE PROOF OF  
CONCEPT

—  
First public  
demonstration of the  
MA12040 eximo®  
amplifier IC, at Stanford  
University



2015  
THE PROMOTION

—  
Customer sampling of  
MA12040 and  
MA12040P



## 2016 THE LAUNCH

—

Market launch of  
MA12040, MA12040P,  
MA12070, MA12070P  
audio amplifiers



2017

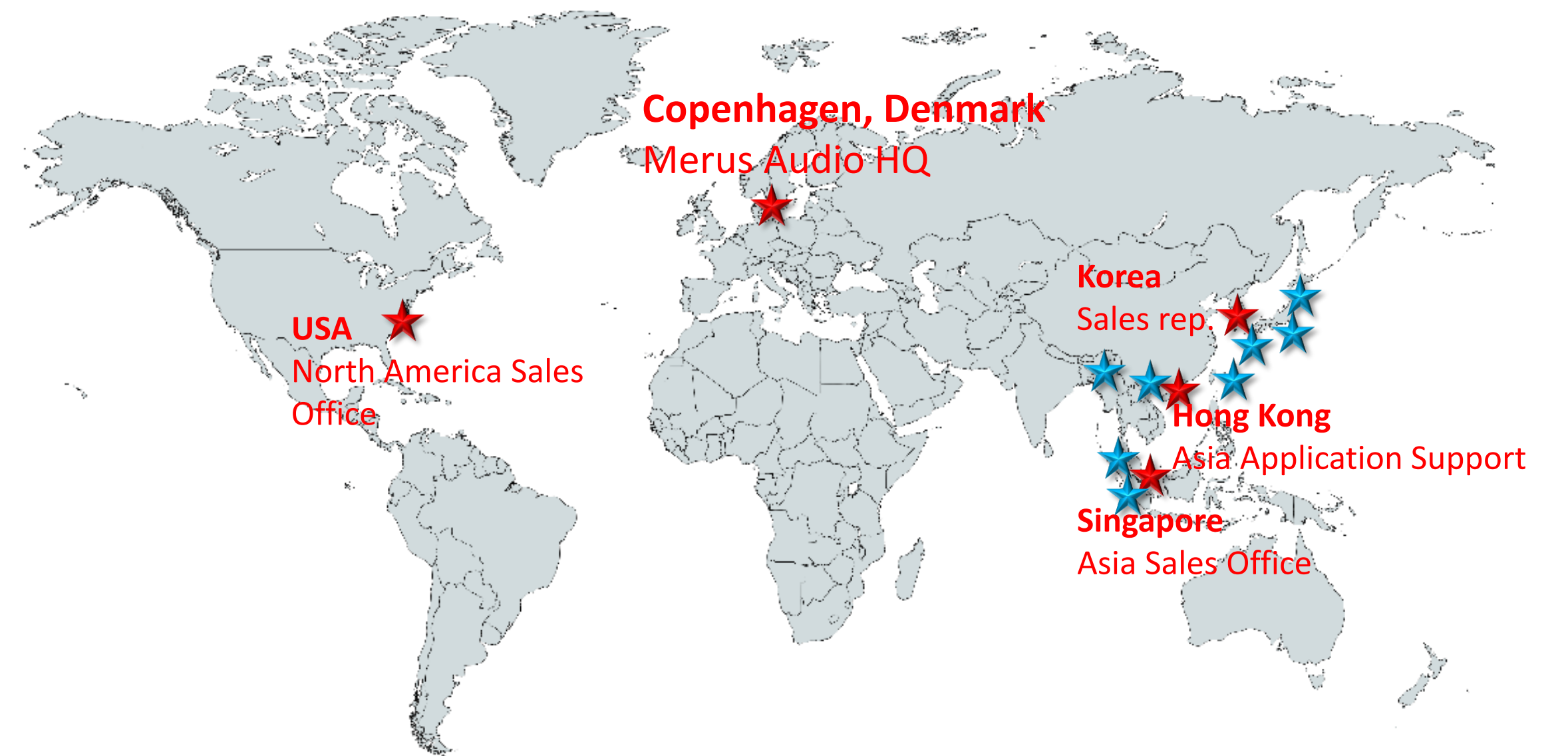
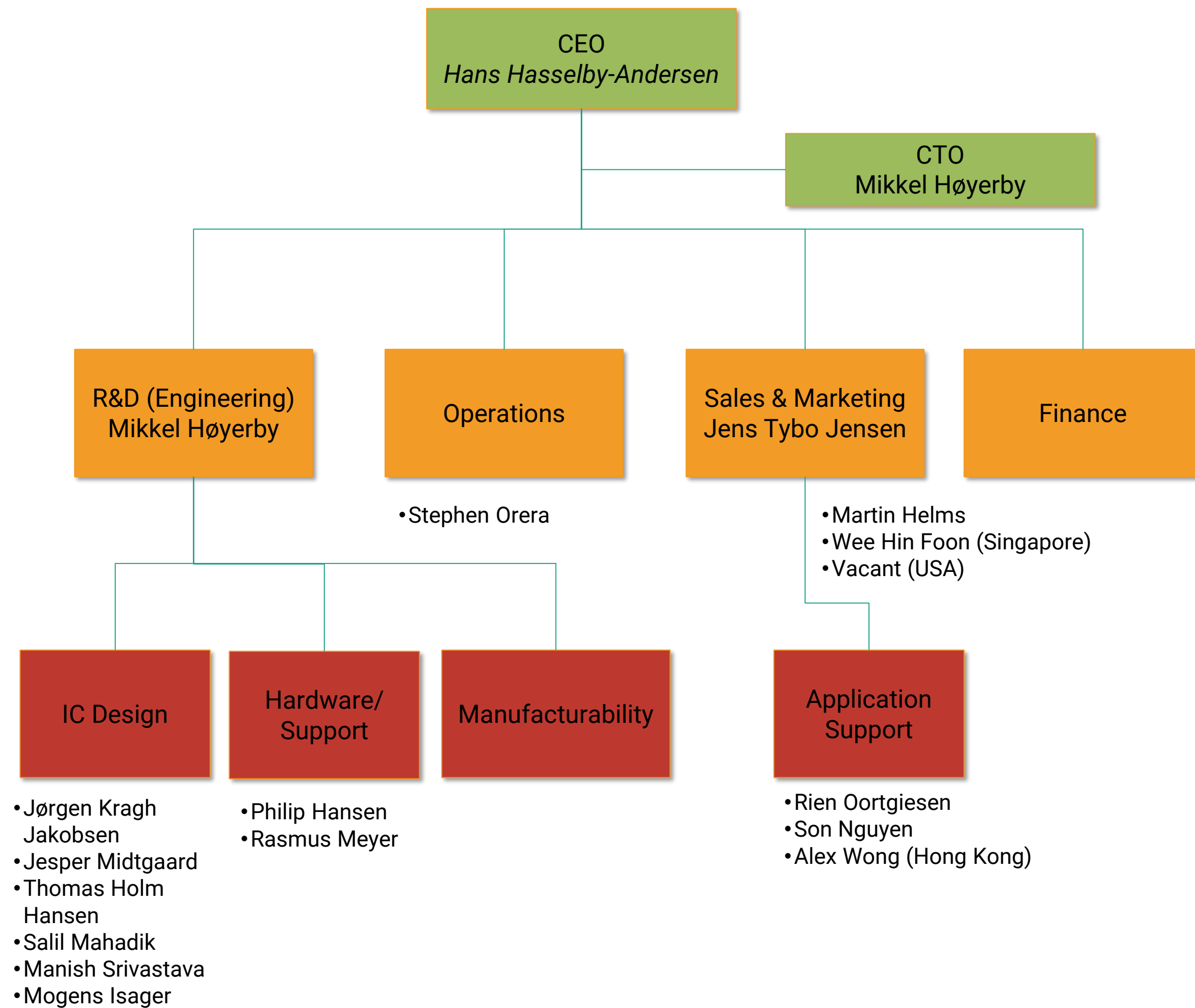
## MARKET TRACTION

—

Multiple customer design-wins  
and initial volume production

# ORGANIZATION

## OUR GLOBAL FOOTPRINT



★ = Merus Audio office

★ = Merus Audio distributor

# WHAT WE BELIEVE

WHY WE ARE HERE?

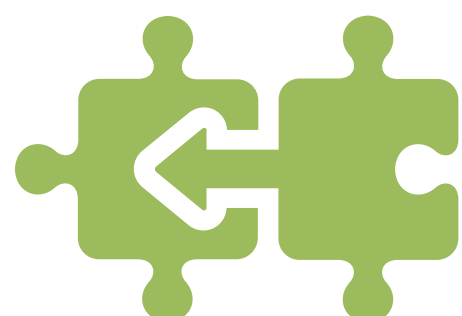


## EFFICIENCY

We believe that amplifiers should produce sound in your speakers, not heat to your surroundings

## COMPACTNESS

We believe that smaller and lighter is better. Bulky and heavy is history.



## INTEGRATION

We believe that amplifiers should be heard, not seen.

## QUALITY

We believe that amplifiers should be robust and flexible - not delicate and demanding



By challenging conventional wisdom, we are helping our customers create **cooler, smaller, lighter and better sounding products** – for the benefit of all who love audio.





# TRENDS

MARKET OPPORTUNITIES



# AUDIO INDUSTRY TRENDS

TIMES ARE CHANGING



## AUDIO IN EVERY ROOM

Multi-zone audio in digital smart homes are setting new standards for pervasive audio



## HIGH RESOLUTION AUDIO ON-THE-GO

Consumers want audio on-demand and on-the-go without sacrificing sound quality



## LOW POWER IoT COMMUNICATION

New connectivity technologies and devices are lowering the bar for power consumption



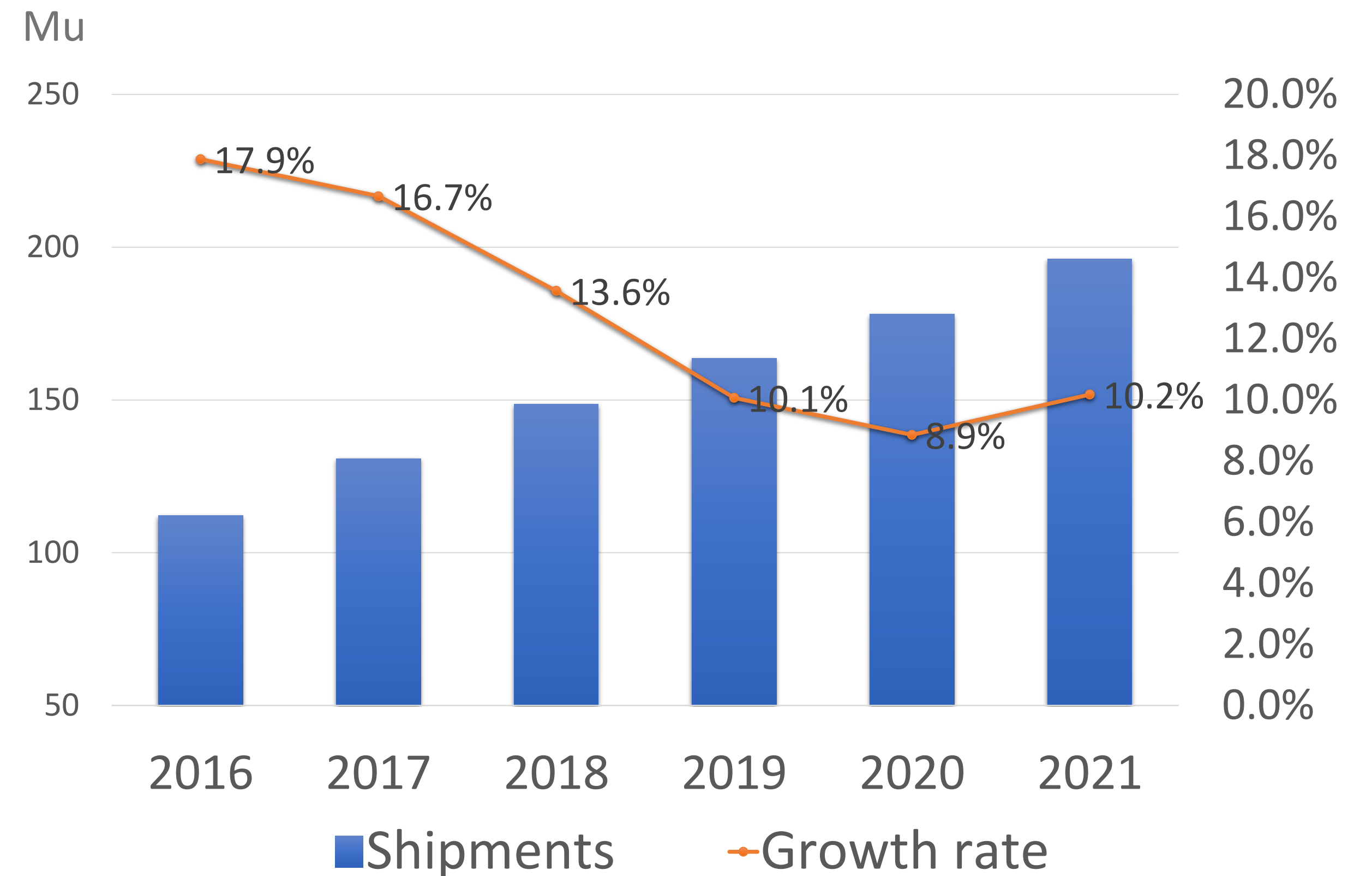
## VOICE AND GESTURE CONTROL

Requires always-on capabilities with lower power consumption

# PORTABLE SPEAKER MARKET

## EXPECTED SHIPMENTS AND GROWTH RATES

- Parent market: Global Smart Home Market
- Approx. 132 million Portable Speakers shipped globally in 2017
- Shipments expected to grow to over 200 million units by 2021 (>12% CAGR)



Source: Technavio Global Portable Speaker Market 2017-2021





# EXIMO®

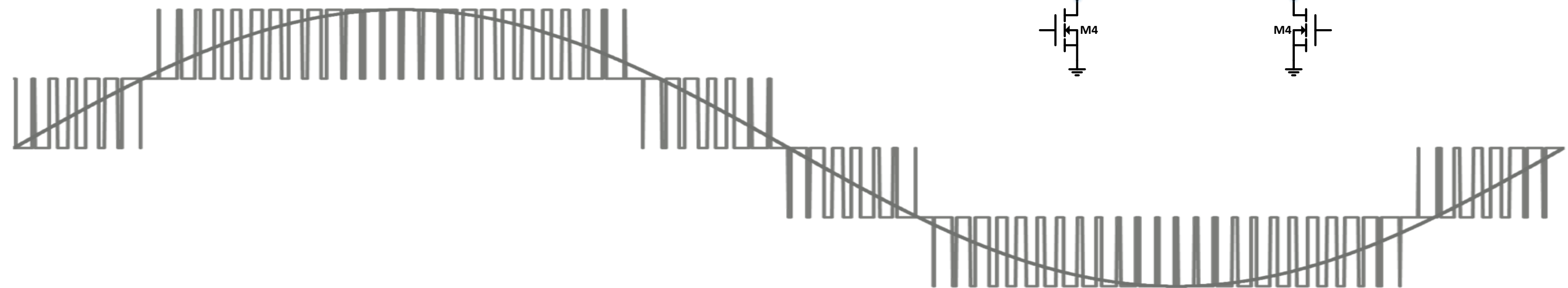
OUR TECHNOLOGY IN BRIEF

# MULTI-LEVEL AMPLIFIER TECHNOLOGY

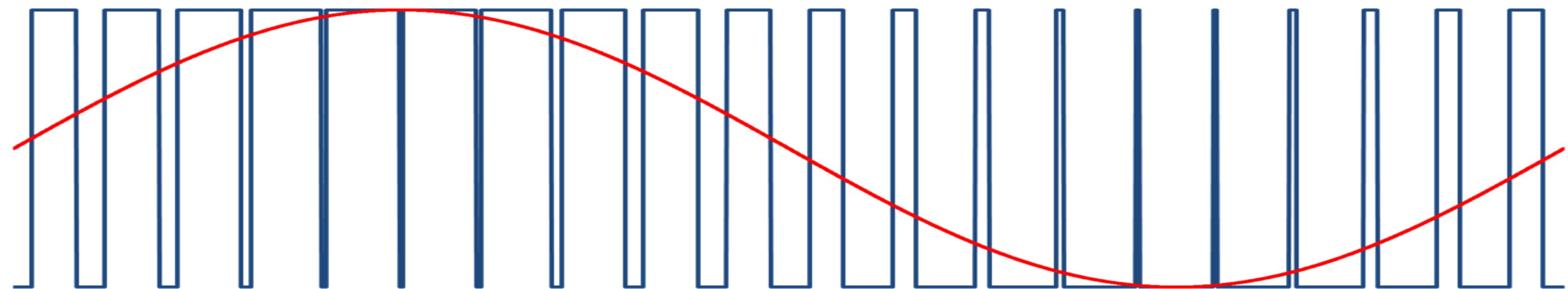
OUR PROPRIETARY AND PATENTED eximo® TECHNOLOGY

## UNIQUE MULTI-LEVEL OUTPUT STAGE:

eximo® AMPLIFIERS  
GENERATE OUTPUT WITH  
UP TO 5 LEVELS WHICH  
ELIMINATES EXTERNAL  
OUTPUT STAGE FILTERING  
AND MINIMIZES OVERALL  
POWER LOSS



CONVENTIONAL CLASS D  
AMPLIFIERS PROVIDE  
FEWER LEVELS OF  
OUTPUT (MAX 3 IN  
DIFFERENTIAL MODE)  
WHICH REQUIRES FILTER  
COMPONENTS TO  
SMOOTHE THE PULSE  
SIGNAL AND LOOSES  
MORE POWER



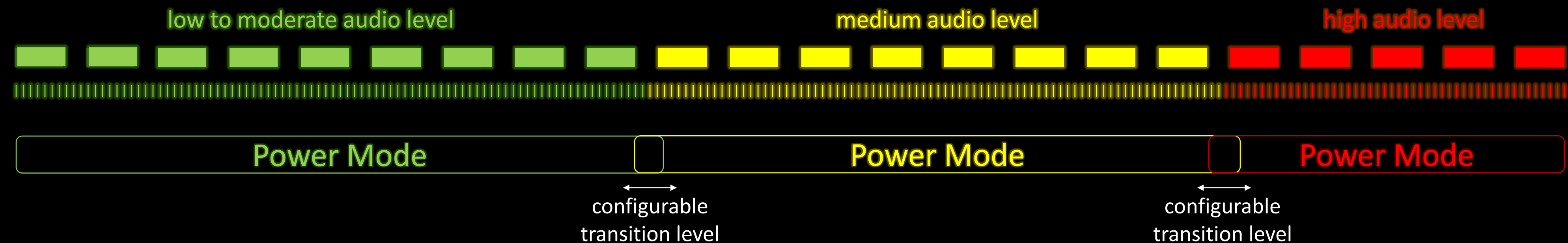


# POWER MODE PROFILES

## DYNAMIC POWER MODE MANAGEMENT

During audio playback eximo® amplifiers transition seamlessly between Power Modes to minimize power consumption in a wide variety of applications and use scenarios.

- A Power Mode for low-to-moderate audio levels
- A Power Mode for medium audio levels
- A Power Mode for high audio levels





# KEY PRODUCT FEATURES & BENEFITS

UNRIVALED POWER EFFICIENCY AND SOLUTION COMPACTNESS

## LOW INTERFERENCE

EMC compliance without use of  
large filter components



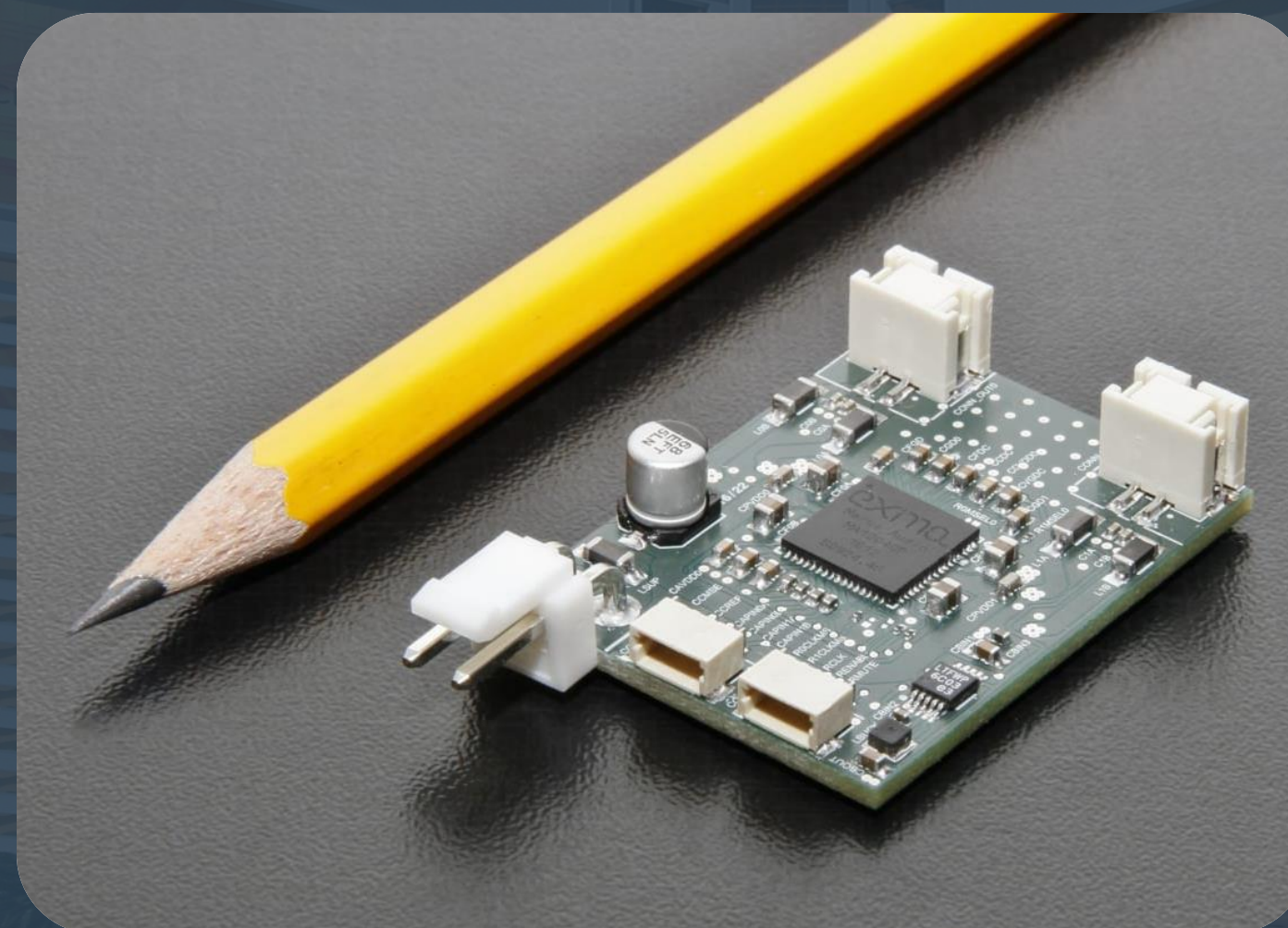
## REDUCED BOM & COST

Reduction of battery sizes  
No output filter components  
Eliminate complex dynamic rail tracking  
No heatsinking required



## COMPACT SOLUTIONS

High power in a very small form factor



*The ultra-compact 2x40W "Snowflake" reference design featuring Merus Audio's MA12040/40P IC*



## POWER EFFICIENT

Very low power losses  
Cool operation



## BEST IN CLASS PERFORMANCE

High dynamic range  
Down to 0.003% distortion  
Low noise



## FLEXIBLE

Support for both analog and digital audio input  
Highly configurable for tailored performance in individual applications

Merus Audio amplifiers utilize proprietary and patented eximo® switching amplifier technology to address some of the most important challenges in consumer audio product design





# PRODUCTS

OUR IC PORTFOLIO



# PRODUCT PORTFOLIO

## MA120XX SERIES



**MA12040P**

**Digital 2x40W eximo® Amplifier IC**

- I2S digital audio input
- Digital volume control & limiter
- 4-18V Supply Voltage



**MA12040**

**Analog 2x40W eximo® Amplifier IC**

- Analog audio input
- Selectable Gain (20dB/26dB)
- 4-18V Supply Voltage



**MA12070P**

**Digital 2x80W eximo® Amplifier IC**

- I2S digital audio input
- Digital volume control & limiter
- 4-26V Supply Voltage



**MA12070**

**Analog 2x80W eximo® Amplifier IC**

- Analog audio input
- Selectable Gain (20dB/26dB)
- 4-26V Supply Voltage

### Common features:

- Multi-level eximo® Switching Technology with 3-level and 5-level modulation for ultra-high power efficiency and filter-less amplification
- Fourth order closed loop feedback error control for HD audio quality and suppression of supply voltage disturbance
- Low idle power dissipation (100 – 160mW)
- Low THD+N (0.003% - 0.007%)
- Low EMI emission
- 64-pin thermally enhanced QFN package with pad-down exposed thermal pad (EPAD) for heatsink free operation

ALL ICs ARE FULLY QUALIFIED AND IN MASS PRODUCTION

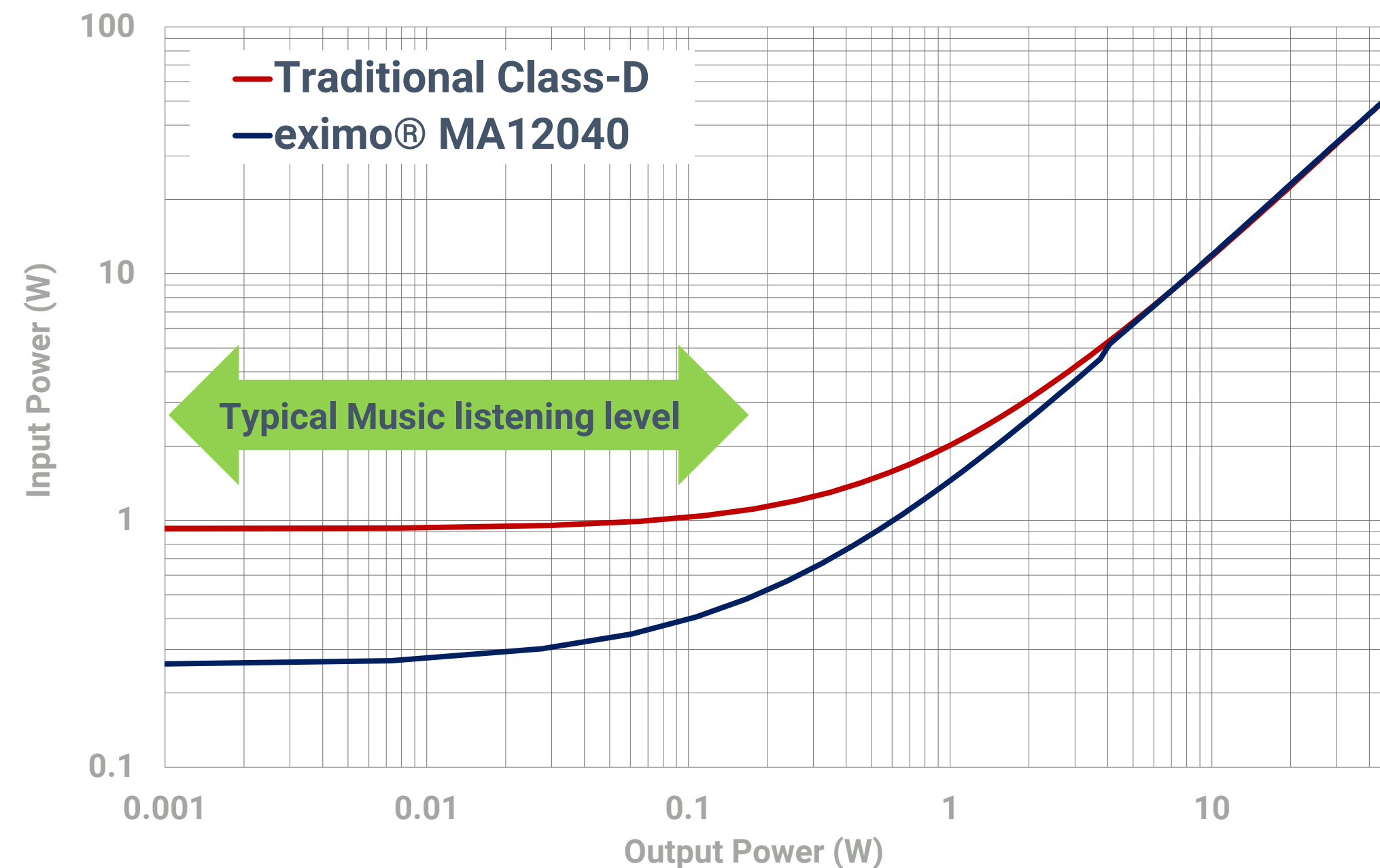


# POWER CONSUMPTION ADVANTAGE

CONVENTIONAL CLASS D AMPLIFIERS CONSUME UP TO 5X MORE POWER



Input vs. Output power, 18V Pvdd<sup>1</sup>, PMP 0



low to medium    medium to max    headroom

Output volume indication for **MUSIC** playback

Amplifier to Amplifier comparison:

Pvdd	Output power <sup>3</sup>	Consumption		
		Traditional Class D	Merus Audio	Traditional in % of Merus Audio
12V	Idle	0,46 W	0,21 W	220%
12V	0,1W	0,55 W	0,36 W	160%
18V	Idle	0,92 W	0,24 W <sup>1</sup>	380%
18V	0,1W	1,00 W	0,41 W <sup>1</sup>	250%
26V	Idle	1,80 W	0,31 W <sup>2</sup>	580%
26V	0,1W	2,00 W	0,51 W <sup>2</sup>	280%

Notes: Measured on EVKs, <sup>1</sup> MA12040, <sup>2</sup> MA12070, <sup>3</sup> Total output power for 2 channels

For Portable Speaker (system) this means:

- Up to 100% increased battery life or
- Up to \$6 battery cost saving



# THE eximo® ADVANTAGE

Extended Battery Life

Popular battery-powered speakers retrofitted with Merus Audio amplifiers.  
Comparison of battery life and BoM impact / cost saving.

Amazon  
Tap



Creative  
iRoar



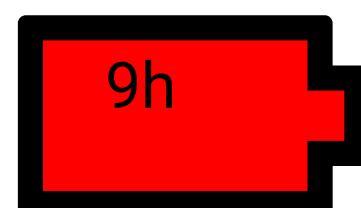
Monster  
MonsterBlaster



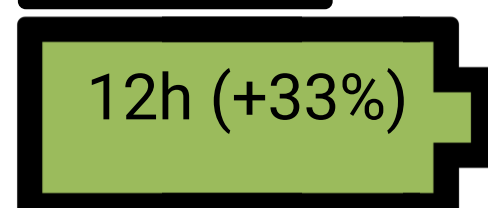
Canton  
Musicbox S



Original



Merus Audio



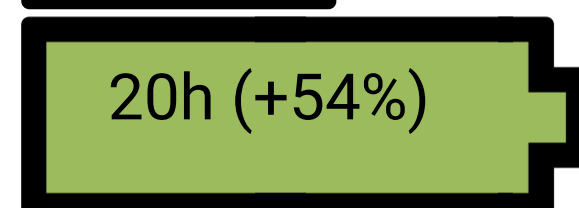
Battery  
cost saving

\$1.2

13h

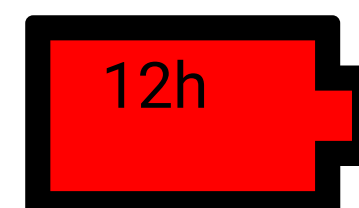


20h (+54%)

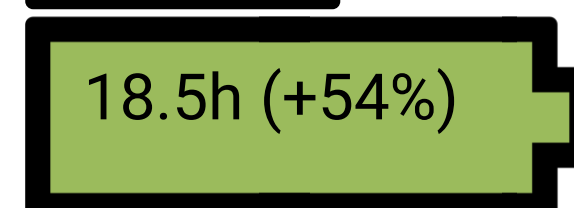


\$3.0

12h



18.5h (+54%)

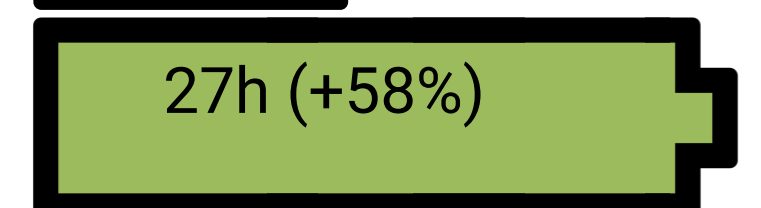


\$6.6

18h



27h (+58%)

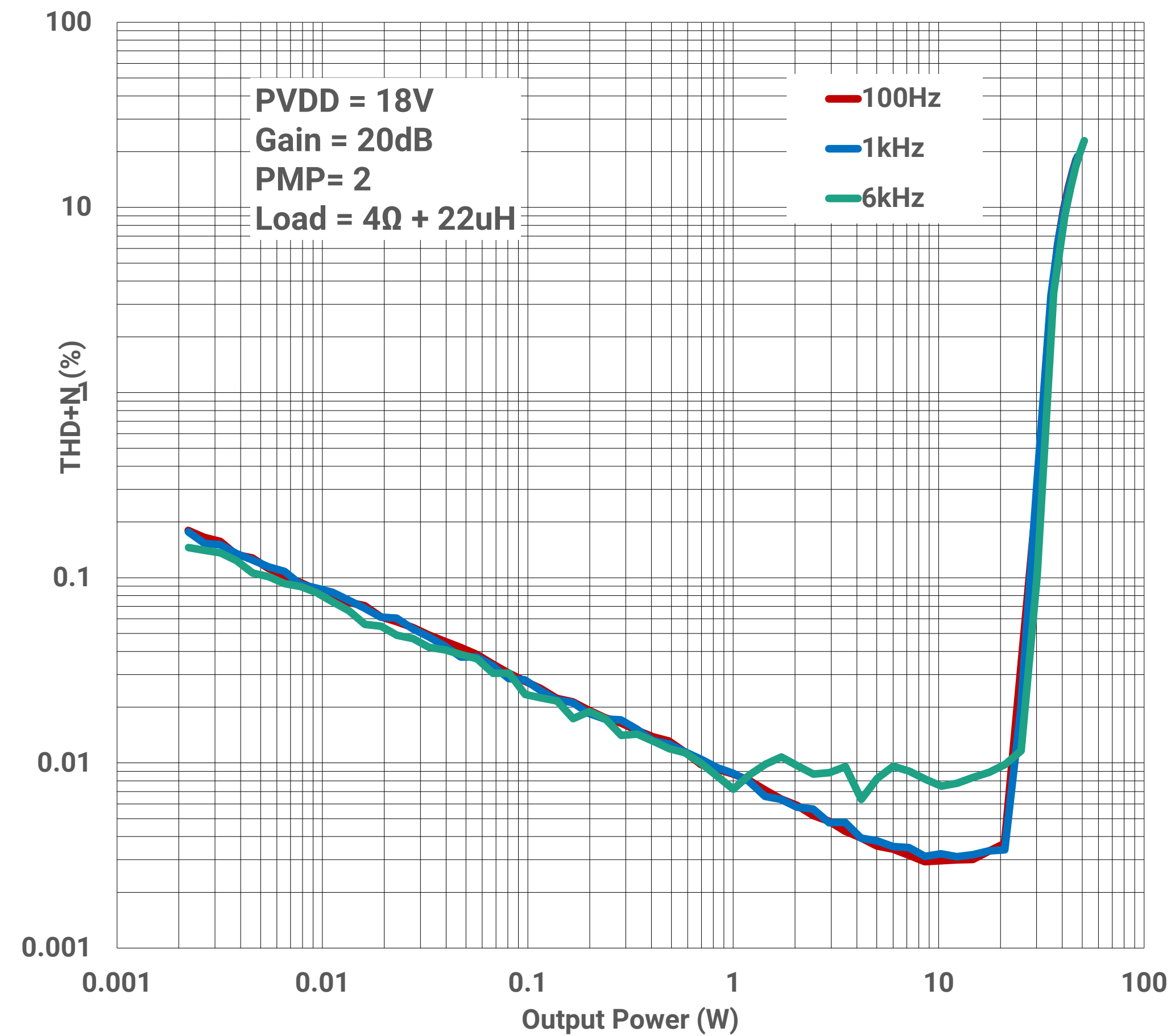


\$2.2

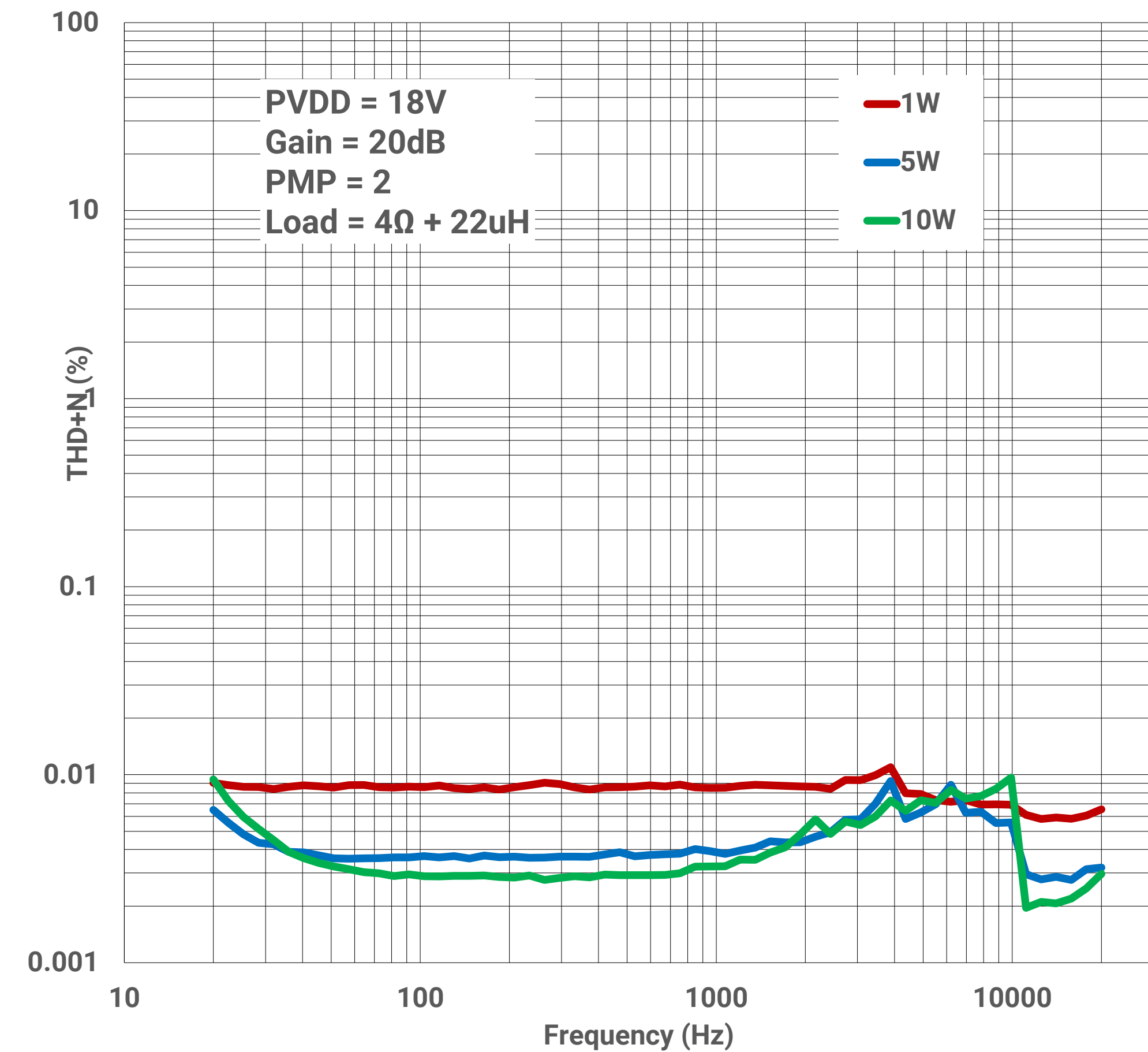
# BEST IN CLASS AUDIO PERFORMANCE

MA12040 EXAMPLE

THD+N vs. Output Power (Power Mode Profile 2)



THD+N vs. Frequency (Power Mode Profile 2)



# SUPERIOR EMI PROPERTIES

MULTI-LEVEL SWITCHING ENTAILS MUCH LOWER INTERFERENCE

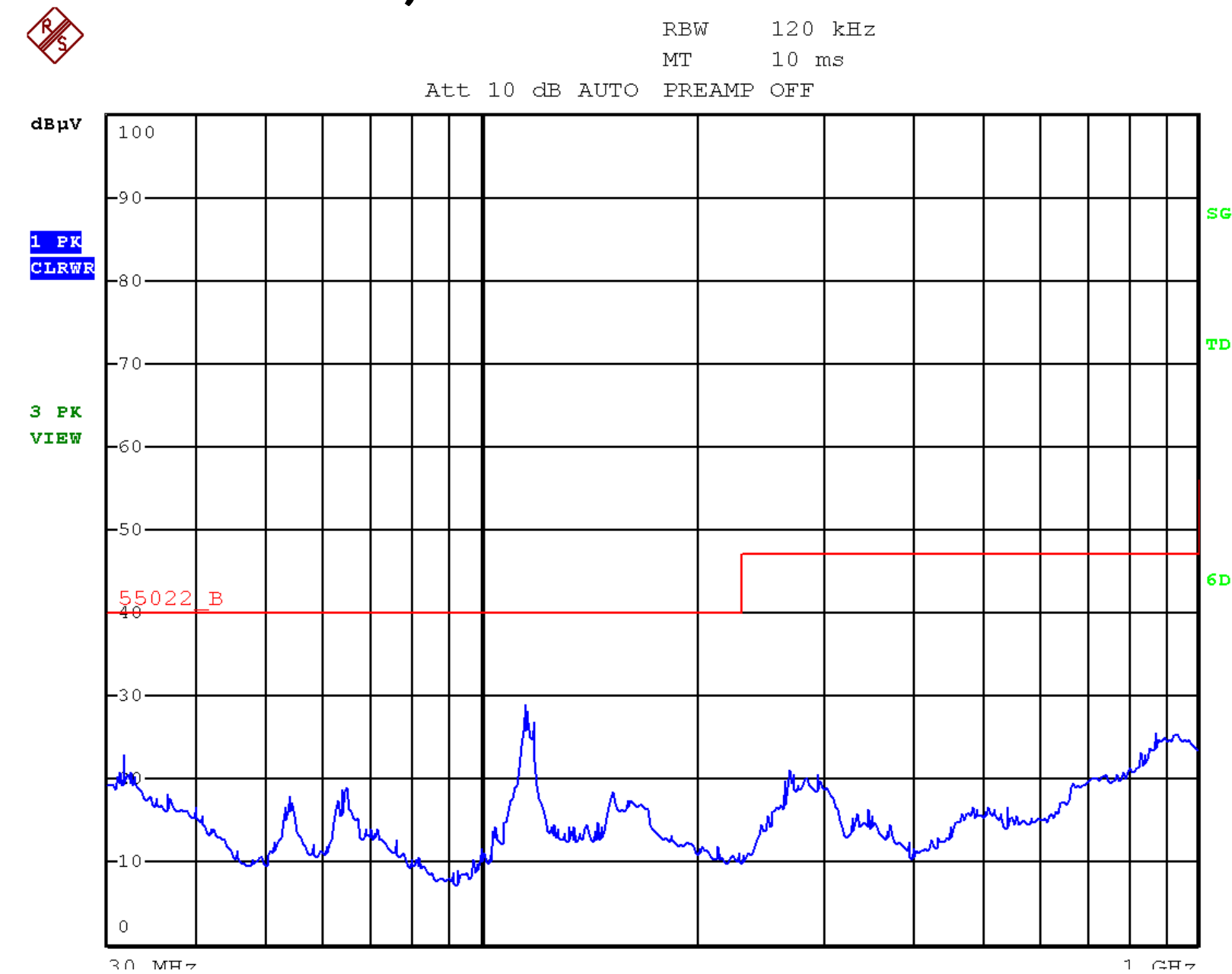
EMC compliance (EN55022) without use of large filter components

## EMC – Radiated emission

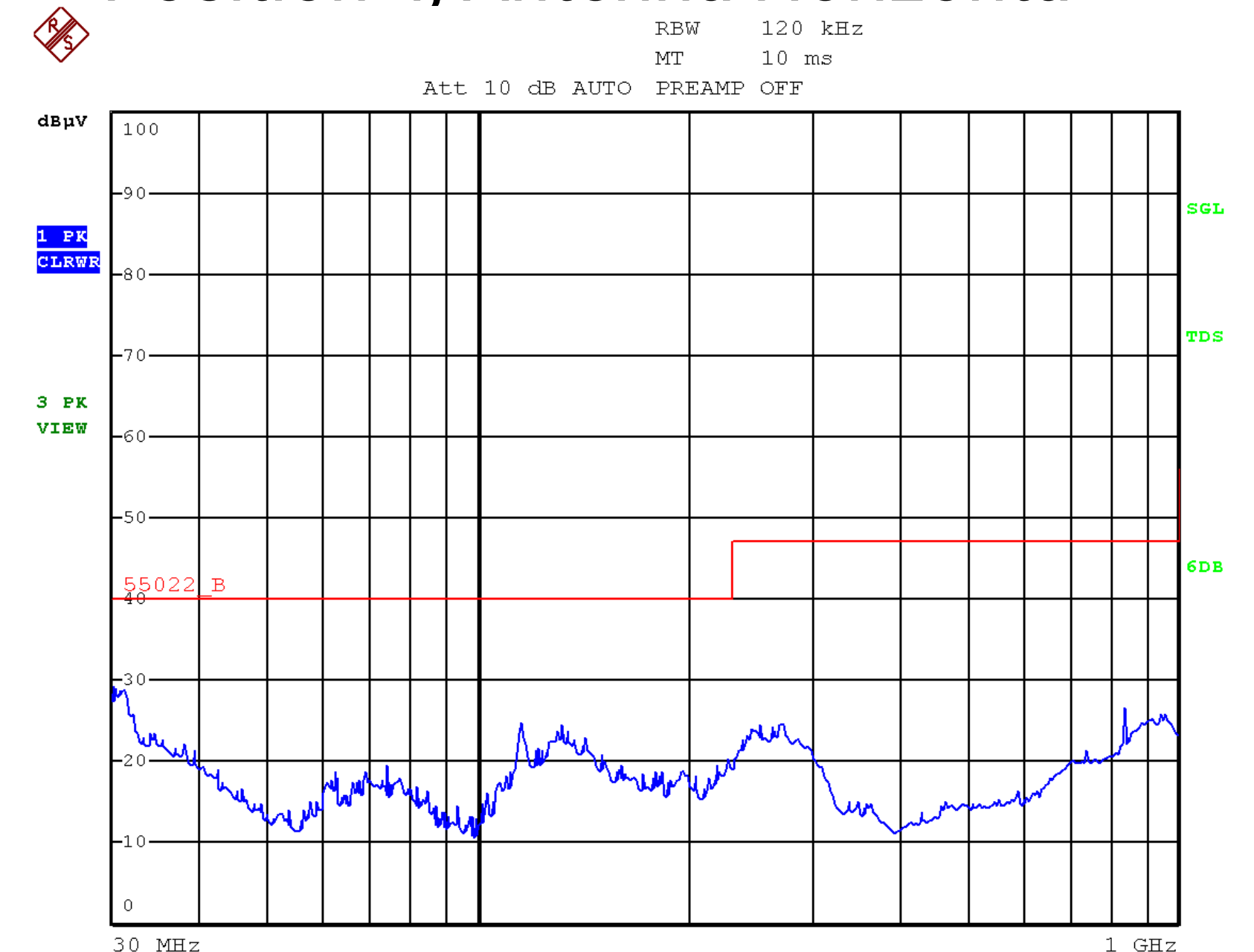
### Conditions:

- Output filter:  
Ferrite (30ohm) + 1nF cap,
- 40cm speaker cable,
- test signal=Pink Noise,
- PVDD=18V,
- 20dB gain,
- PVDD filter:  
Ferrite (56ohm)+2x22nF  
capacitor.

### Position 3, Antenna Horizontal



### Position 4, Antenna Horizontal



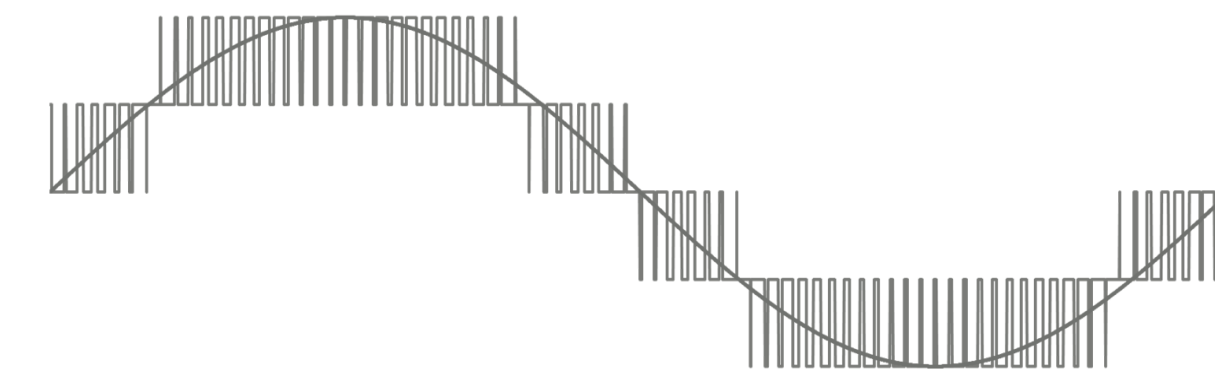
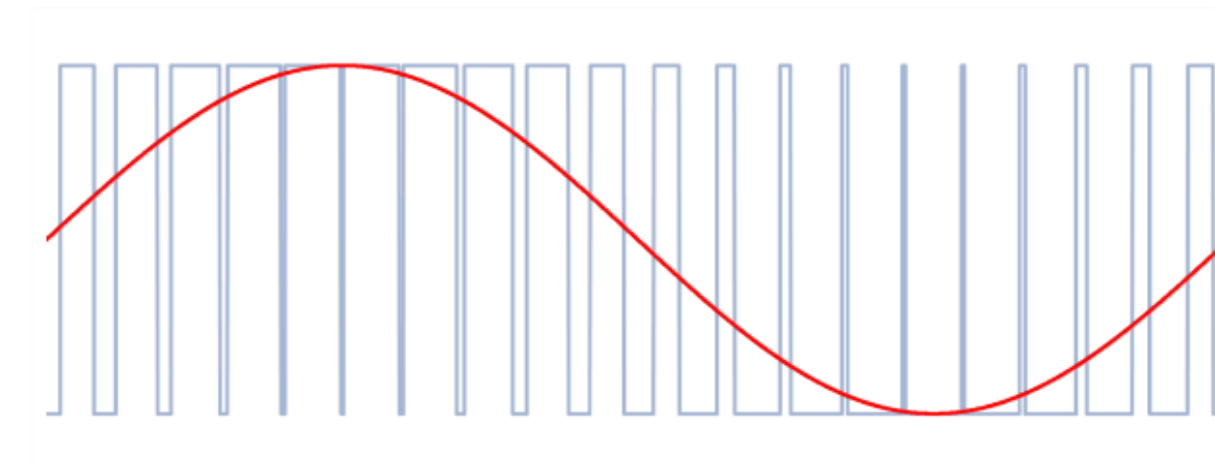
# MOST COMPACT SOLUTION

EXIMO® ELIMINATES LC FILTERS IN MOST TARGET APPLICATIONS

A conventional class-D amplifier halfbridge produces a **2-level output signal**

The output has significant **high-frequency content** → must be filtered by a passive output filter (inductors + capacitors)

A multi-level output signal can be handled by the speaker unfiltered.  
Potential **cost savings** from 40c to \$4!

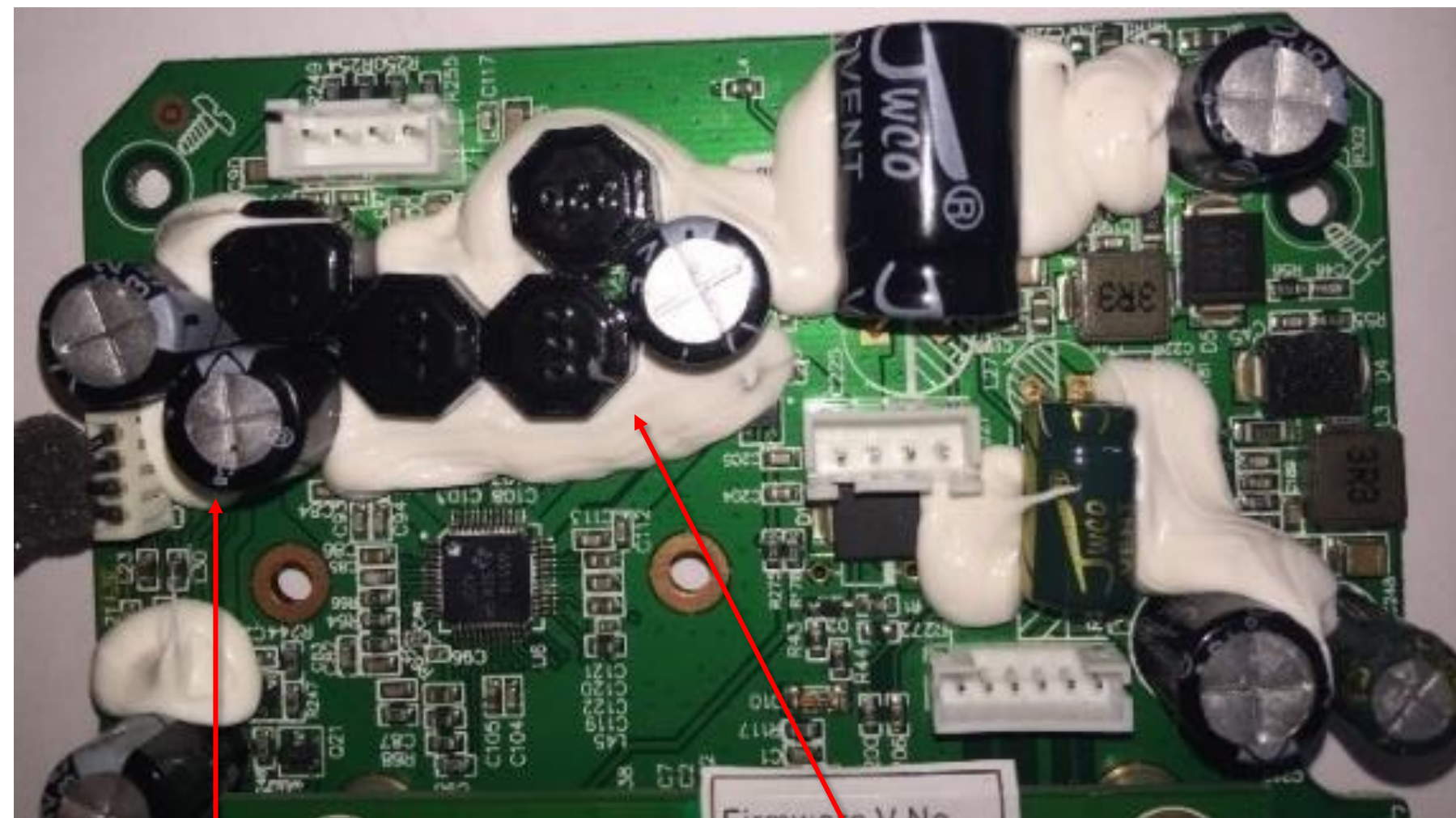




# MOST COMPACT SOLUTION

CUSTOMER EXAMPLES

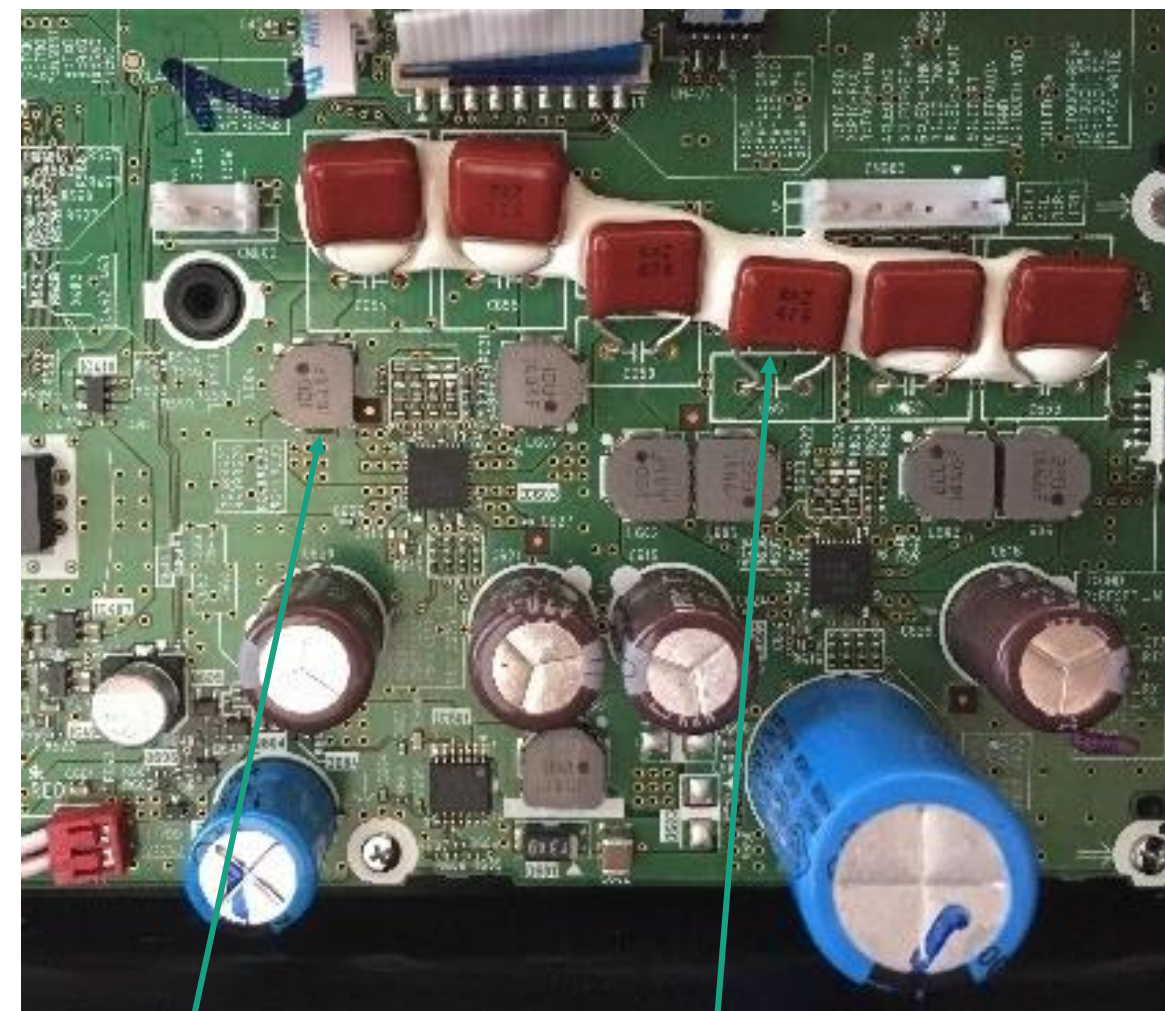
Denon  
PRODUCT NAME: Heos1



4x Input Capacitors  
for TAS5711 Amp

4 x Inductors  
for LC filter

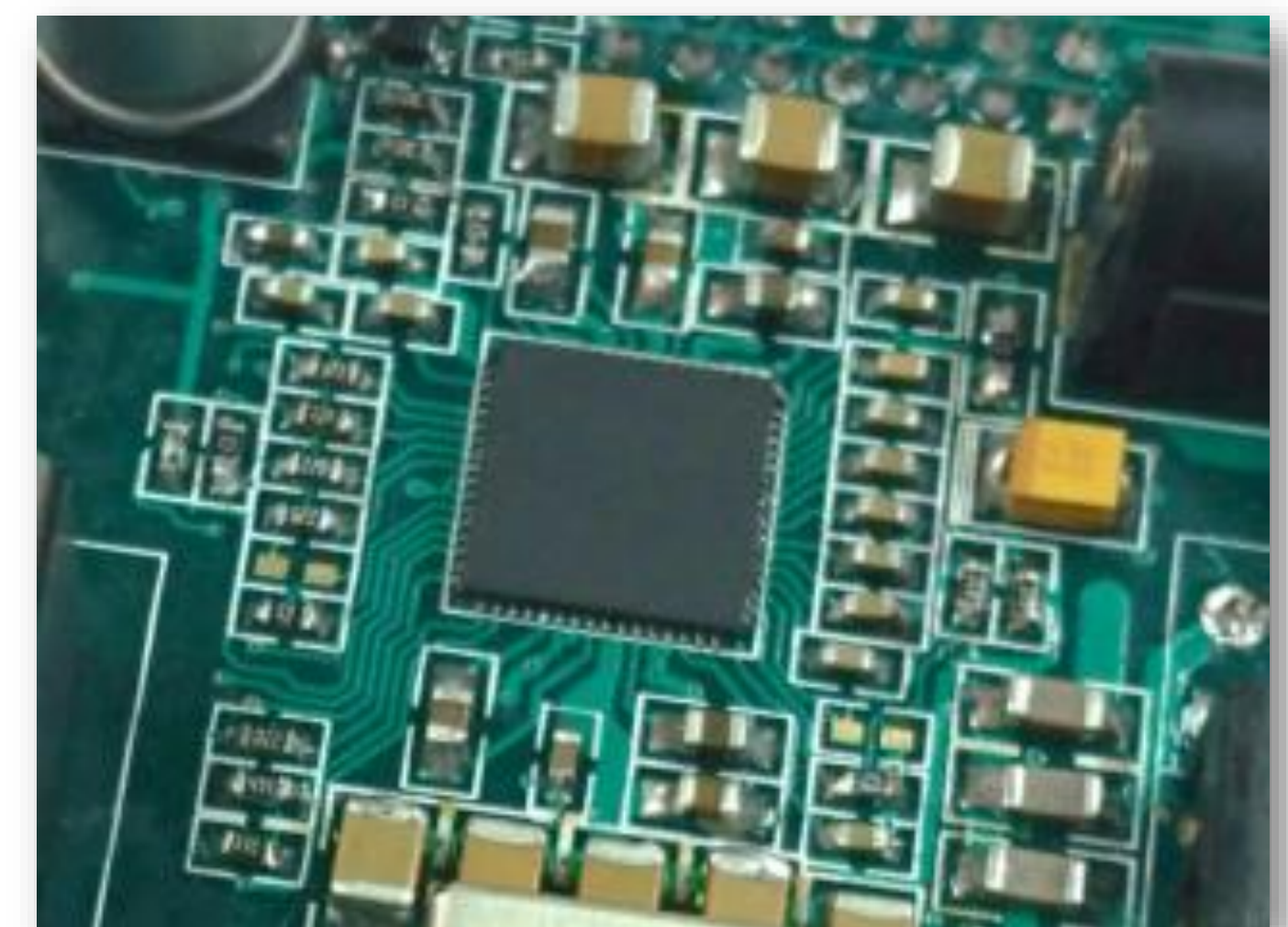
Sony  
PRODUCT NAME: SRS-X77



6 x inductors for  
LC filter

6 x Capacitors for  
LC filter

ImmersiveDSP  
PRODUCT NAME: SPK-4P



Compact design with MA12040  
– no LC components





# COFFEE BREAK

IMPORTANT!





# DEMOS

HEAR, SEE & FEEL FOR YOURSELF

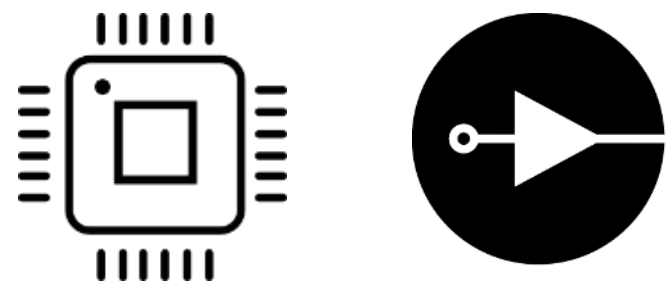
# DEMOS

HEAR, SEE AND FEEL FOR YOURSELF

- Listening Demo



- Tech Demo



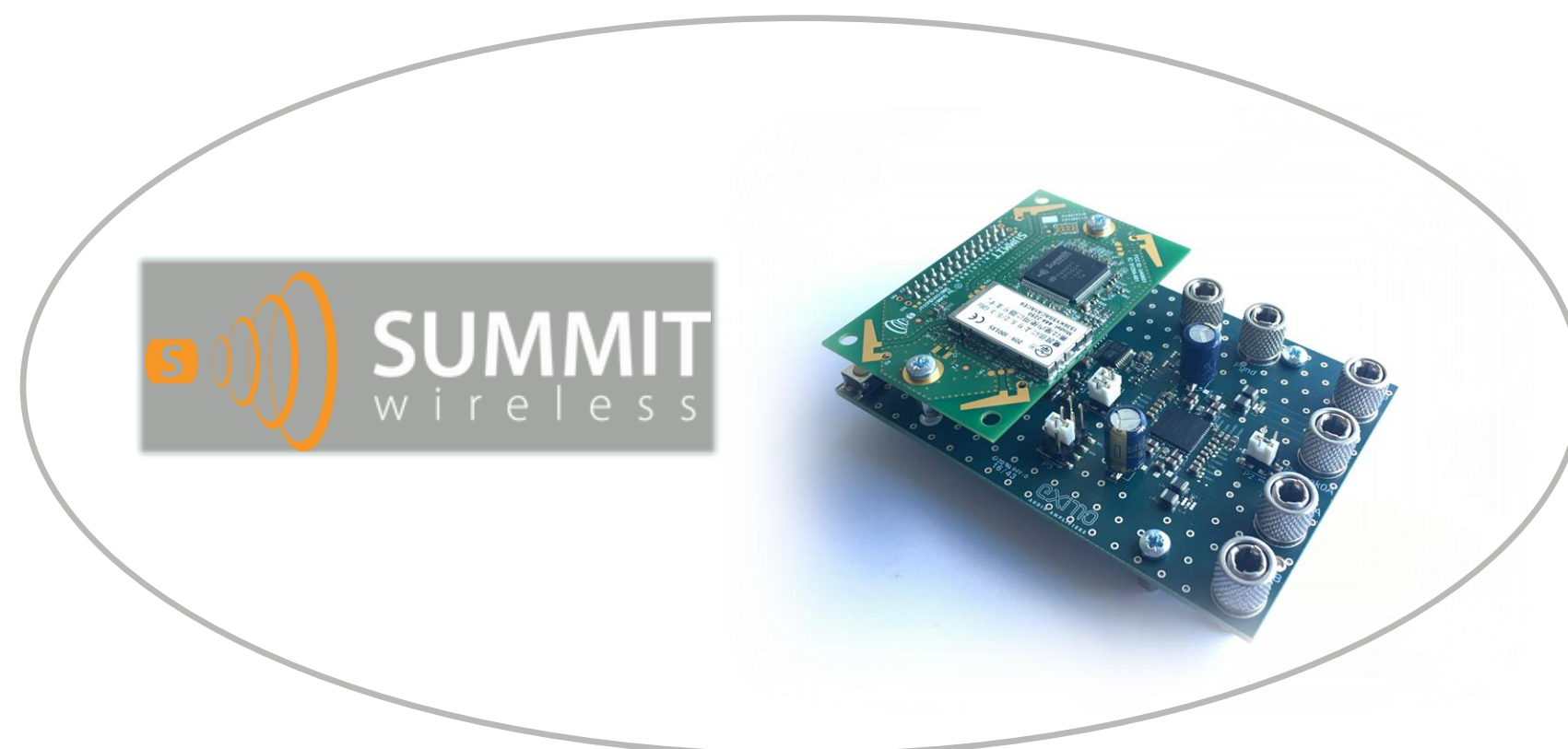
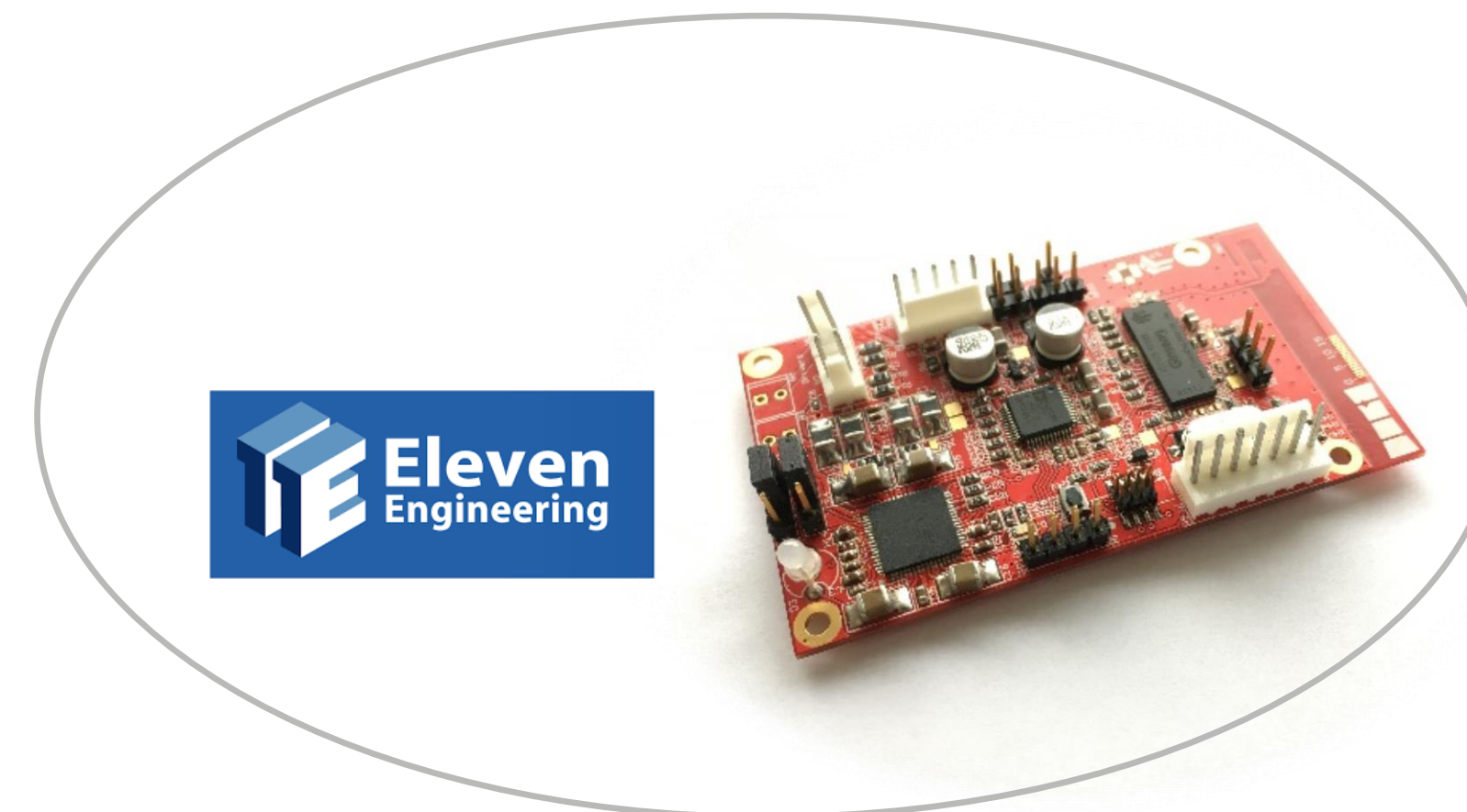
- Battery Playback Demo





# Reference Designs

HEAR, SEE AND FEEL FOR YOURSELF







# USECASES

CUSTOMER EXAMPLES



# OUR LATEST PROJECTS

CATERING TO A BROAD RANGE OF INTERNATIONAL CUSTOMERS

ARTISON<sup>®</sup>  
*the art of sound*

SAVANT

HANSONG



## BACKPACK

TV Soundbar Amplifier  
using 4xMA12070

Developed and produced  
by Hansong

ARCAM

inkel



## SOLO UNO

Mains-powered stereo  
HiFi amplifier with  
MA12070P

Manufactured by Inkel

biamp.



## PoE Project

Power over Ethernet  
Amplifier platform with  
several product  
incarnations using  
MA12070P

immersiveDSP



## SPK-4P

AVB (Audio Streaming  
through Video Bridging)  
Standard IP  
Loudspeaker using  
MA12040



# OUR LATEST PROJECTS

VARIOUS APPLICATIONS – FROM ACTIVE ON-THE-GO SPEAKERS TO TV SETS

## Platin HS Eskimo

Several audio platforms  
Including an ultra energy  
efficient on-the-go BT  
speaker using MA12040



**HANSONG**

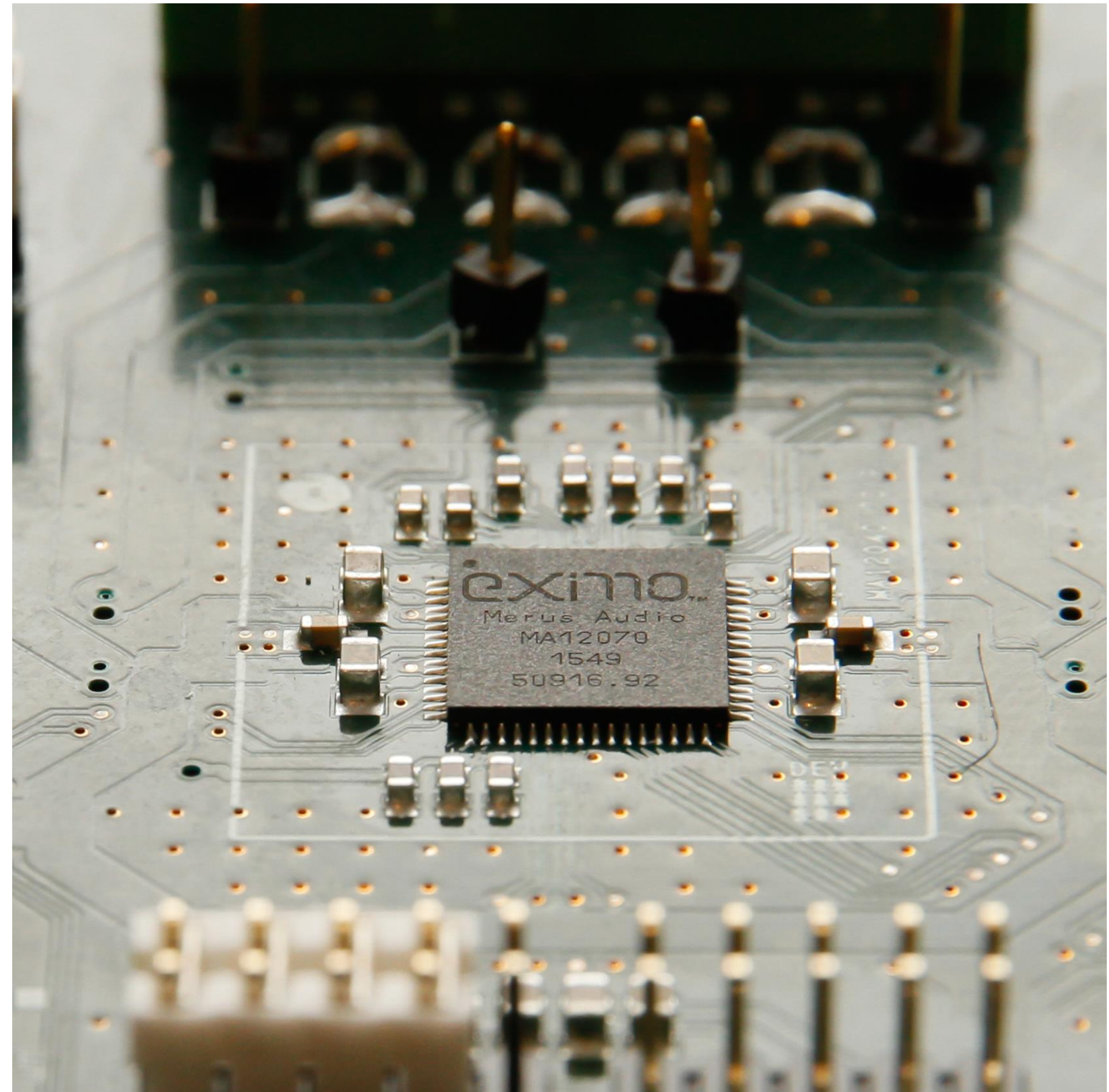


**Linnet & Larsen**



## CHEN ZHAO

Project with independent  
design house Chen Zhao  
using MA12070  
for TV Audio System  
designed for Linnet &  
Larsen brand





# CUSTOMER EXAMPLE CASE

## SOUNDBOKS



**SOUNDBOKS II**  
“THE WORLDS LOUDEST  
PORTABLE SPEAKER”



SOUNDBOKS I LAUNCHED IN 2016.

Keywords: Party – Outdoor – Loud – Durable – Long Battery Life



# SOUNDBOKS

LOWER POWER CONSUMPTION AND EXTEND BATTERY LIFE

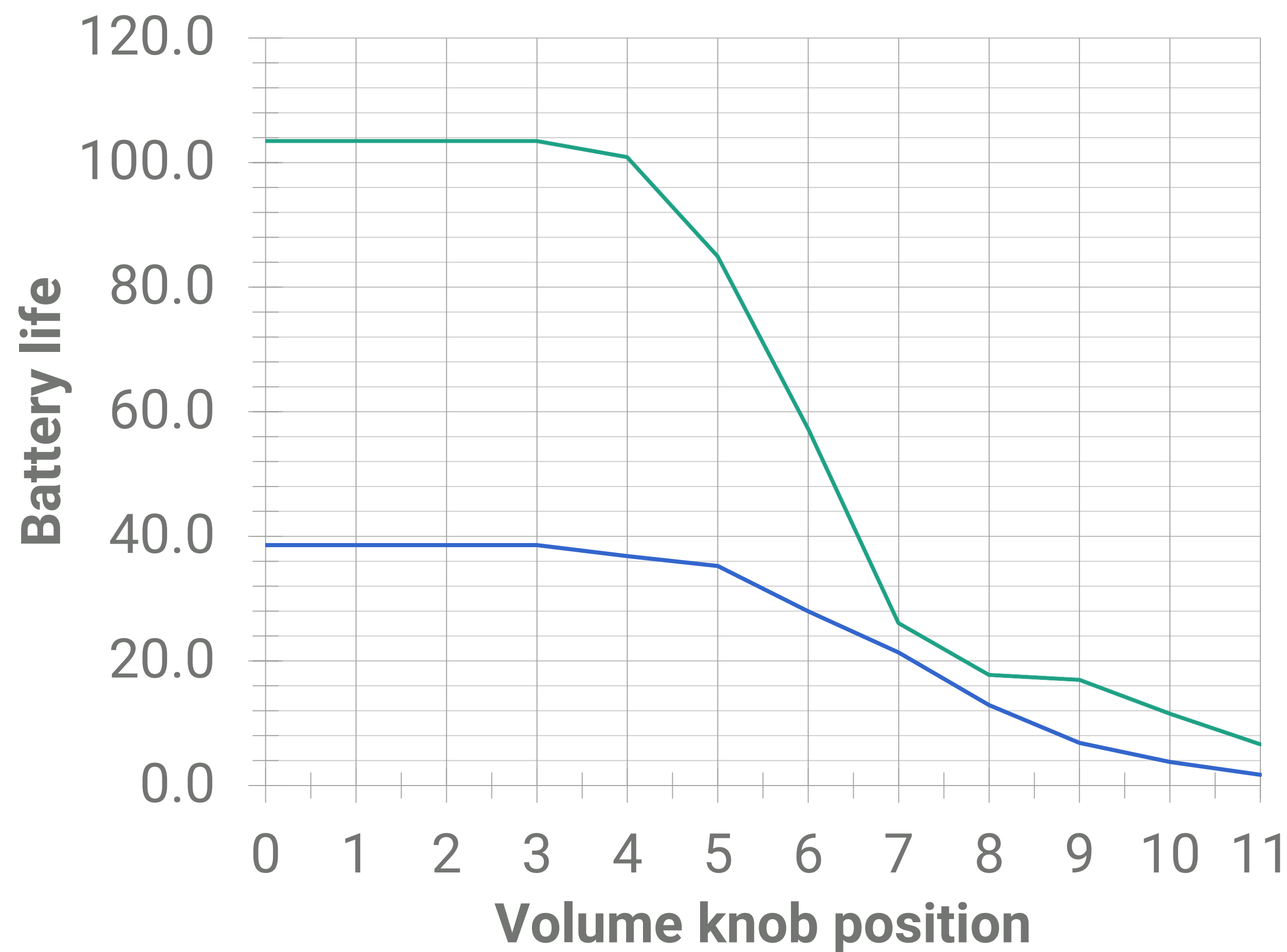


Soundboks 2:  
~ 40 hours



Soundboks 1:  
~ 30 hours

## BATTERY LIFE VS. AUDIO VOLUME

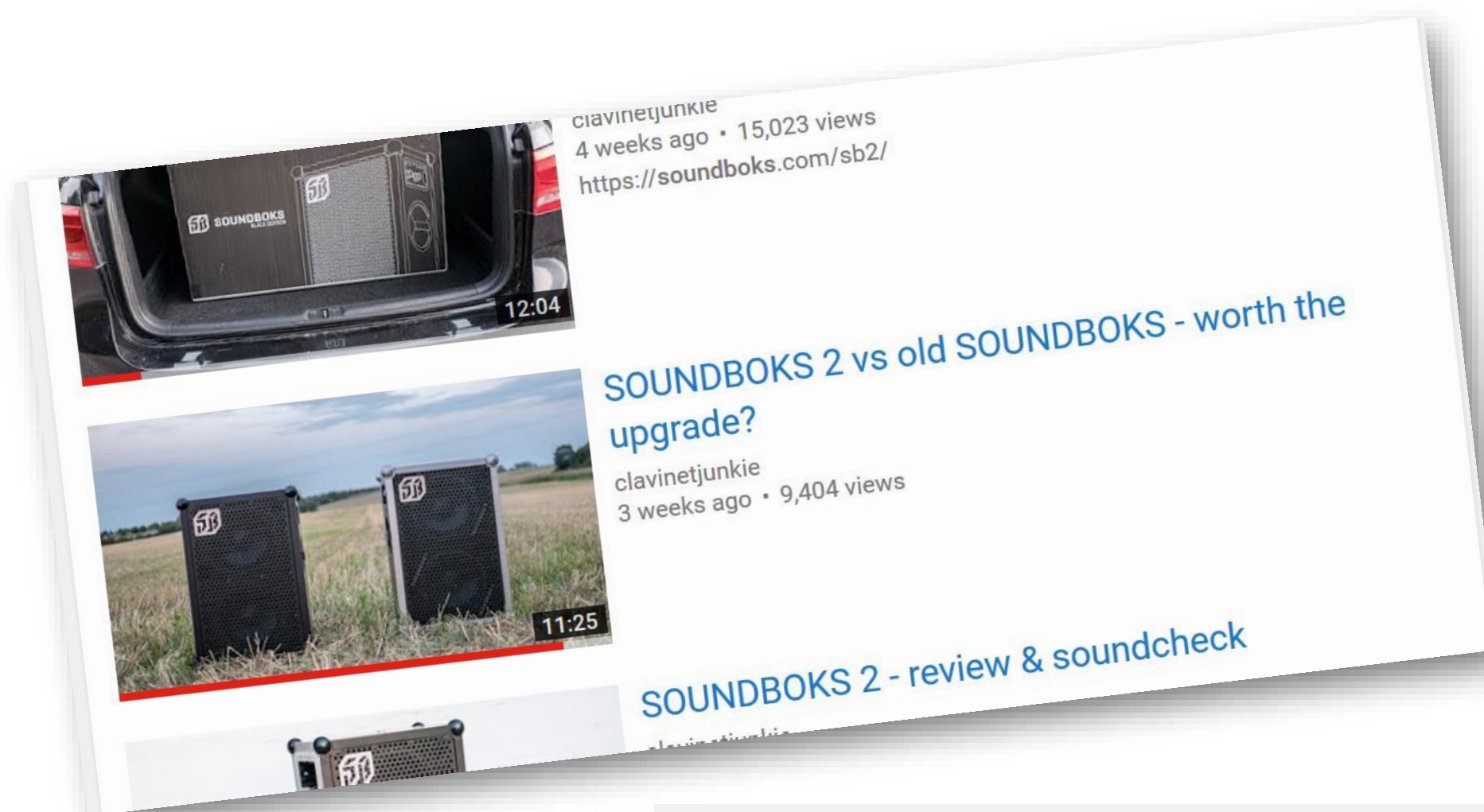




# SOUNDBOKS

IMPROVED SOUND QUALITY

Best in class audio performance  
Down to 0.005% distortion



*"the new Soundboks is in a completely different class"*

*"much more mature"*

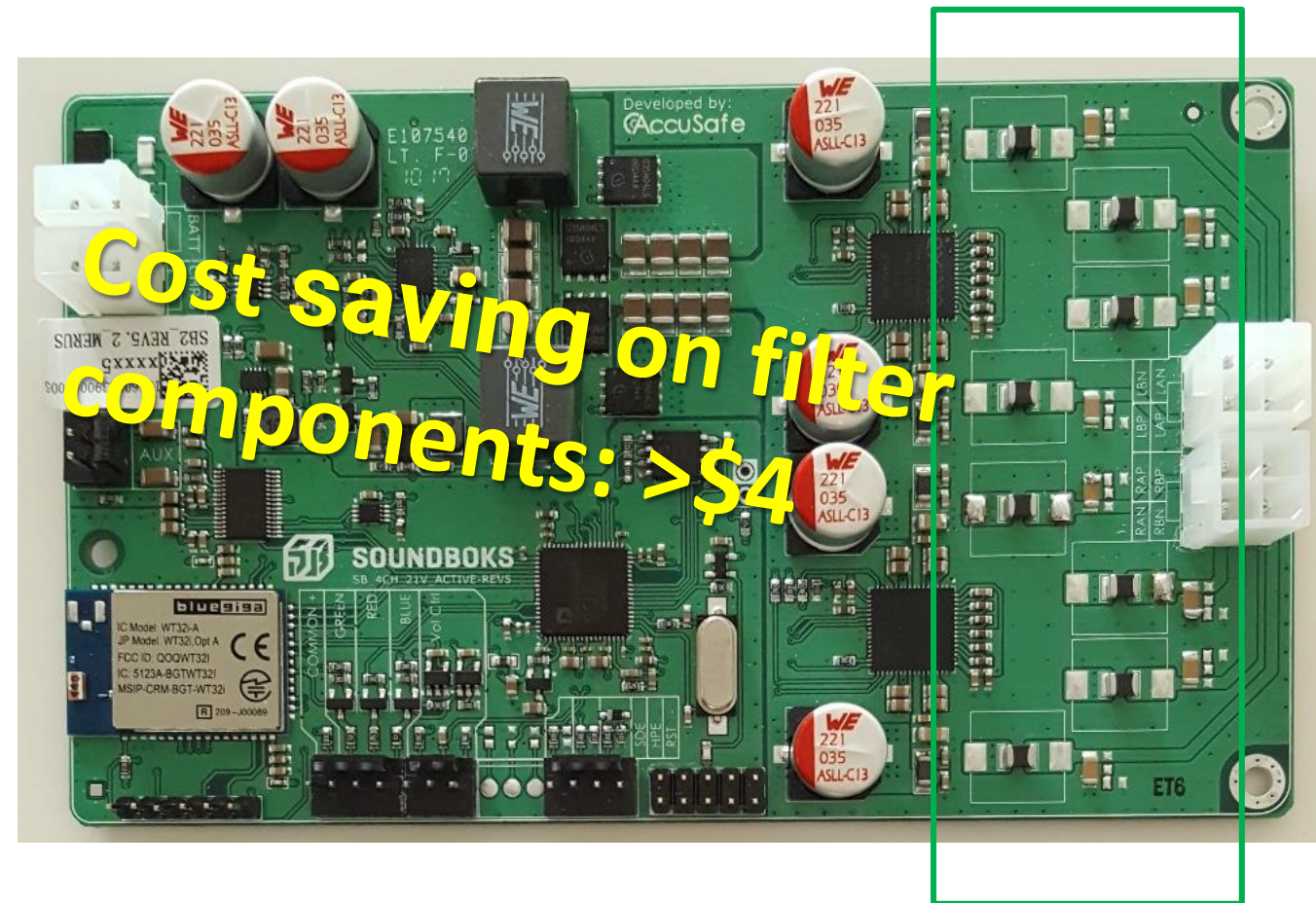
*"definitely a huge difference"*





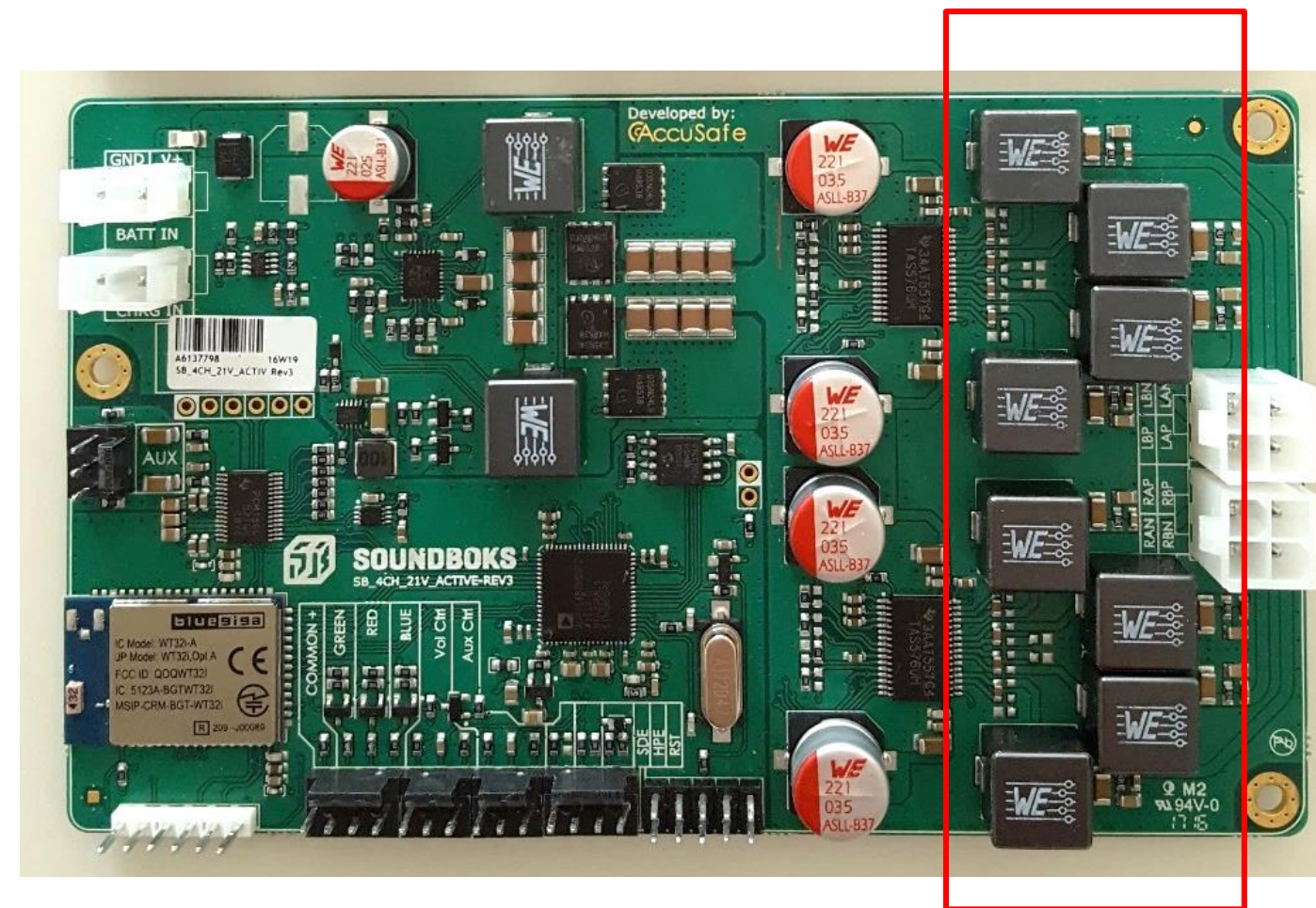
# SOUNDBOKS

REDUCED BOM CONTENT AND COSTS



## SOUNDBOKS 2 design

- 2 x MA12070P (Merus Audio)
- No LC filter
- EMC ferrites filter cost (total): <\$0.6



## SOUNDBOKS 1 design

- 2 x TI TAS5760M (Texas Instruments)
- 8x inductors for LC filter
- Inductor cost (total): \$4.6





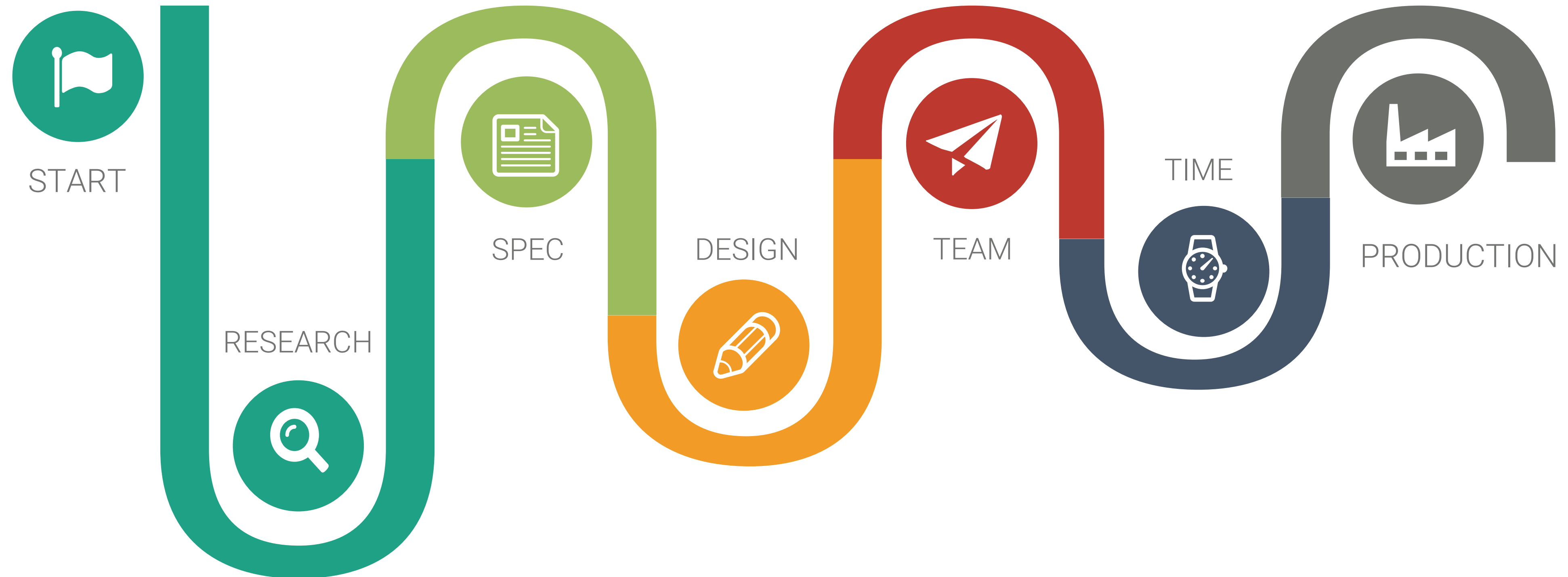
# PROJECTS

YOUR REQUIREMENTS



# YOUR PLANS?

RELEVANT PROJECTS THAT MIGHT BE RELVANT FOR US TO DISCUSS?





# STAY IN TOUCH

CONTACT DETAILS FOR REFERENCE







Singapore Office

Phone

Email / Website

info@merus-audio.com  
www.merus-audio.com





Backup slides



# CONVENTIONAL CLASS D AMPLIFIERS

ONLY POWER EFFICIENT AT HIGHEST OUTPUT LEVELS

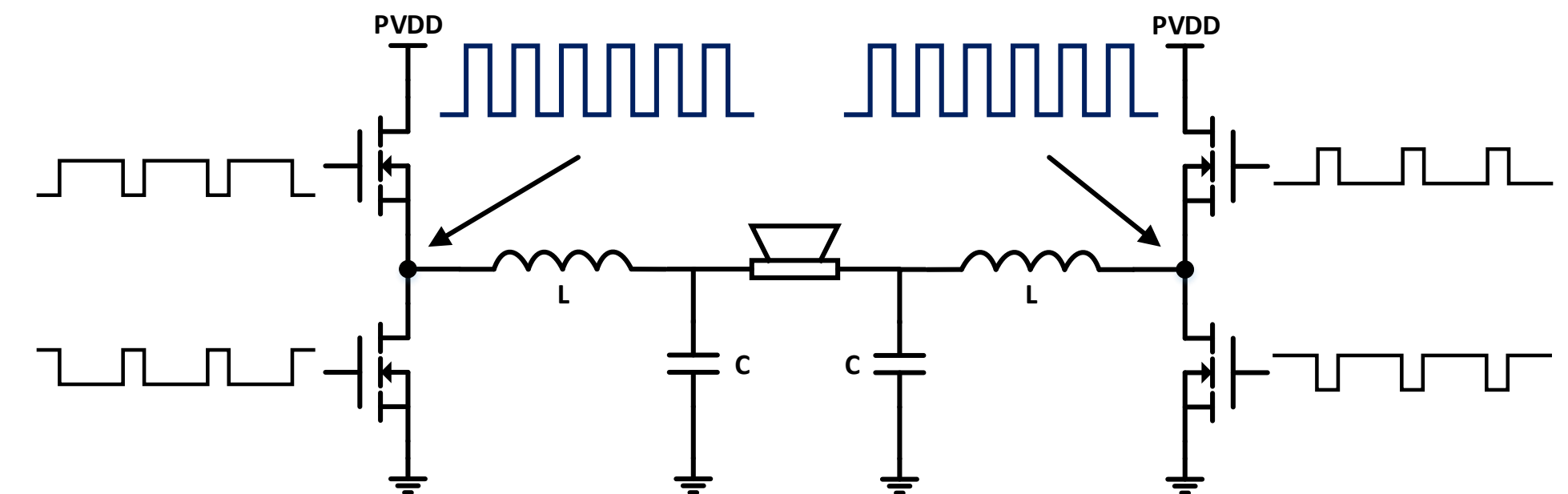
## Basic operation:

- The incoming audio signal is converted to PWM (pulse-width-modulated) signals and amplified through the output stage.
- A power source (power rail) delivers the voltage (Pvdd) and current for the amplification
- 2 MOSFETs on each side switches and the output differential drives the speaker in typical BTL (bridge-tied load) topology, as illustrated
- This Amplifier is capable of providing maximum of 3 level switching in differential mode: (+Pvdd, 0V, -Pvdd).

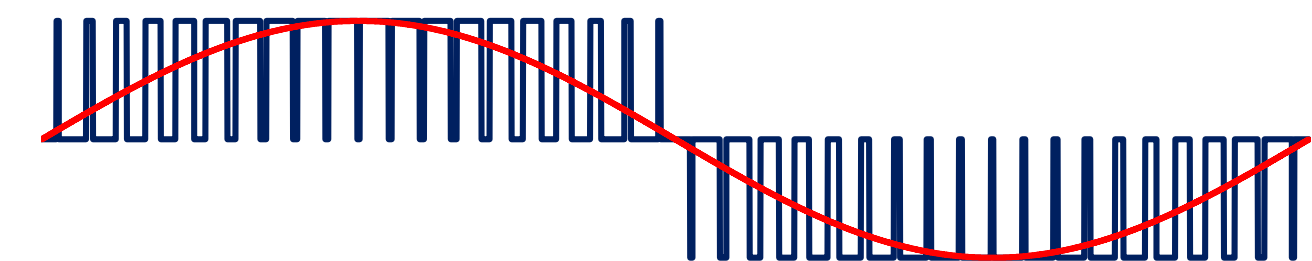
## Issues:

- Efficient at very high output levels (~ approaching 90%)
- BUT only around 50% efficient in idle or near idle mode\* because:
  - To keep speaker near idle and maintain its dynamic range,  $+\frac{1}{2} P_{vdd}$  and  $-\frac{1}{2} P_{vdd}$  is required on each side of the speaker
  - To generate  $\frac{1}{2} P_{vdd}$  on the the output of each half-bridge, the signal must be constantly changing from high to low at full voltage swing (i.e. a 50% duty cycle)
  - This constant voltage swing generates **high power losses and output ripple currents**

\* For normal audio playback the amplifier is operating near the idle stage most of the time - so this power loss is significant for overall efficiency



Left side (+)	Right side (-)	Differential
Pvdd	Pvdd	0
Pvdd	0V	Pvdd
0V	Pvdd	-Pvdd
0V	0V	0



# eximo® MULTI-LEVEL SWITCHING AMPLIFIERS

HIGHLY POWER EFFICIENT AT ALL OUTPUT LEVELS

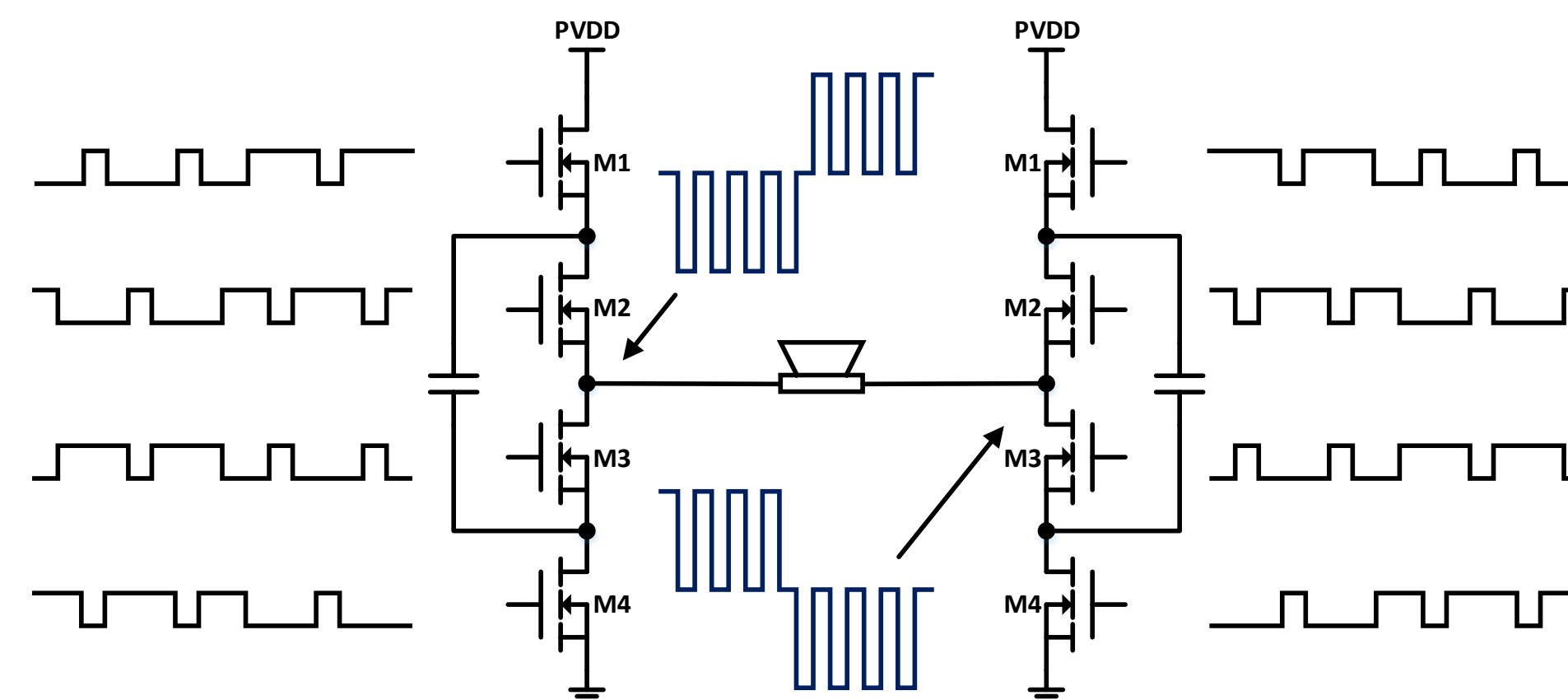
## Basic operation:

- Our patented topology uses 4 MOSFETs on each side/half-bridge with a “flying” capacitor between the top and bottom MOSFETs which provides an additional voltage supply supplying  $\frac{1}{2}$  Pvdd without switching
- The switching from the right side is phase shifted from the left side by 90 degrees
- This makes the amplifier capable of 5 level switching differential = **Multi-level**
- The switching frequency at the speaker quadruples with this design (typology)

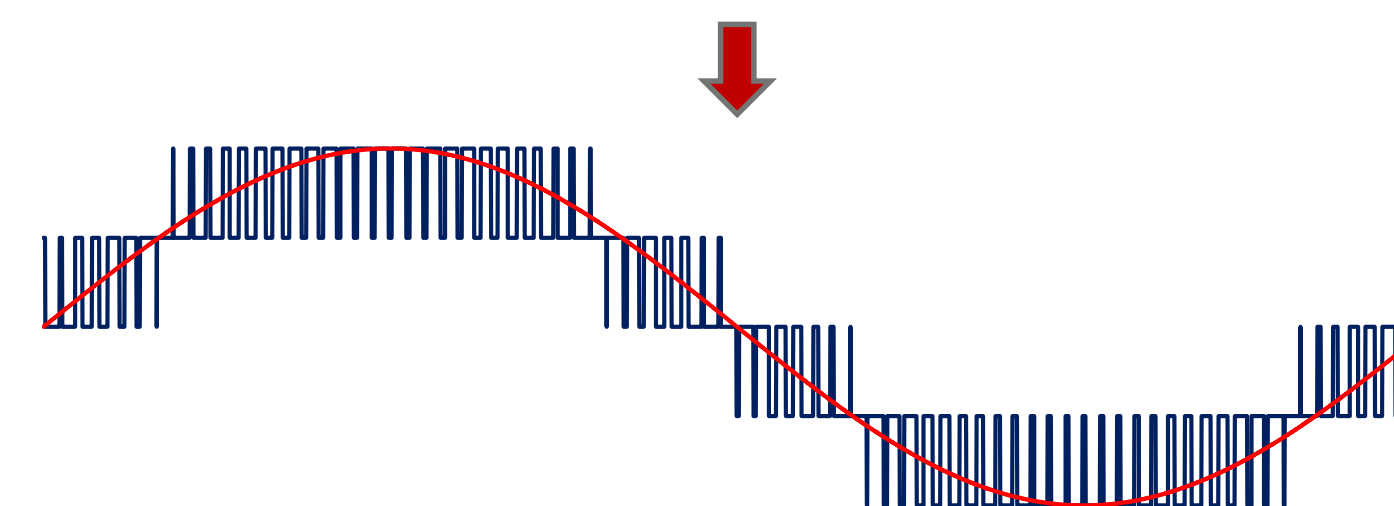
## Main benefits:

- Near Idle signals are generated without constantly changing the signal on both sides of the speaker => **substantially reduced power consumption**
- Multi-level switching resamples the incoming audio signal much closer and therefore leads to better audio quality
- The increased switching frequency of the output means less out-of-band switching residuals at the speaker => filter-less operation up to high output power levels

NOTE: the differential output (as seen by the load) has 4x frequency and  $\frac{1}{4}$  Vs amplitude) → very low ripple .



Left side (+)	Right side (-)	Differential
Pvdd	Pvdd	0
Pvdd	$\frac{1}{2}$ Pvdd	$+\frac{1}{2}$ Pvdd
Pvdd	0V	Pvdd
$\frac{1}{2}$ Pvdd	Pvdd	$-\frac{1}{2}$ Pvdd
$\frac{1}{2}$ Pvdd	$\frac{1}{2}$ Pvdd	0
$\frac{1}{2}$ Pvdd	0V	$+\frac{1}{2}$ Pvdd
0V	Pvdd	$-\text{Pvdd}$
0V	$\frac{1}{2}$ Pvdd	$-\frac{1}{2}$ Pvdd
0V	0V	0





# FOUNDERS & MANAGEMENT

WRITE YOUR GREAT SUBTITLE HERE



**Mikkel Høyerby**  
CTO & FOUNDER

#### Previous career:

- Research Engineer at **Motorola**, working on RFPA linearization, general RF/IF design as well as portable audio power amplification solutions.
- Research Assistant at **DTU**
- Research areas: high-bandwidth DC/DC converters, class-D audio power amplifiers, switch-mode control IC design, switch-mode controller modeling, RFPA systems with envelope tracking and RFPA linearization.
- *M.Sc.EE and Ph.D from the Technical University of Denmark*



**Hans Hasselby-Andersen**  
CEO & FOUNDER

#### Previous career

- General Manager & Strategic Product Development Manager at **Texas Instruments**. Business development for audio and power amplifier product lines.
- R&D Manager at **Toccata Technology**, a pioneer in switching audio amplifiers.
- Team Leader and Design Engineer at **Nokia Mobile Phones**.
- *Executive MBA from the Scandinavian International Management Institute*
- *M.Sc.EE from the Technical University of Denmark*



**Jens Tybo Jensen**  
VP Sales & Marketing

#### Previous career

- Sales Director at **Knowles Electronics**, a leading global supplier of high-performance micro-acoustic components
- Co-founder and VP Sales at Nangate, Inc.
- VP Sales & Marketing for Exbit Technology A/S, (now **Microsemi** Corporation).
- Regional sales and applications support roles for Ansoft (Now Ansys, Inc.) and Viewlogic (now **Synopsys**, Inc.).
- *Executive MBA from Copenhagen Business School*
- *B.Sc.EE from the Technical University of Denmark*



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