MPS Axign Class-D Technology Deep-Dive

February 2024

Start Time: March 5, 2024 | 1:00 AM PST | 4:00 AM EST | 10:00 AM CET | 5:00 PM CST | 12:00 PM EAT

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Introduction

- Axign is a fabless semiconductor company based in the Netherlands
- Two locations in NL:
  - Enschede (HQ)
  - Nijmegen
- Long relationship between Axign and MPS due to complementary IP
- Axign acquired by MPS at the beginning of 2024
- Presenter:
  - Olaf van der Meer
  - Business Development Mgr.
  - Background in Axign's Applications & Customer Support Team

AXIGN
An MPS Company

"Axign is excited to announce that we are now a part of Monolithic Power Systems. Our unique audio technology and expertise, coupled with MPS' manufacturing, product breadth, and system-level expertise will enable us to offer industry-leading audio solutions without compromise."

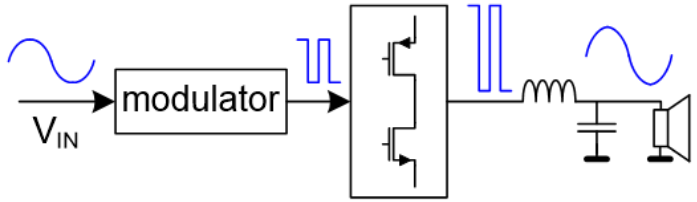
MPS

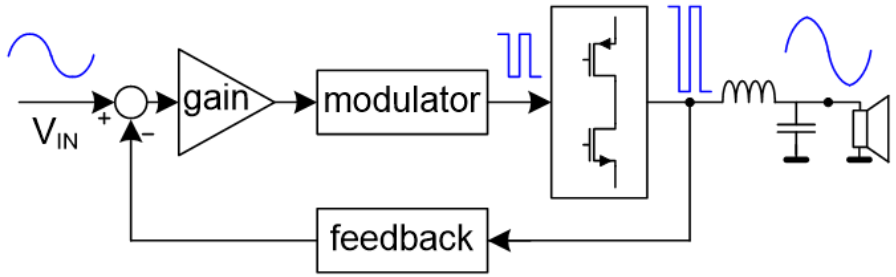
Post-Filter Feedback in Class-D Audio

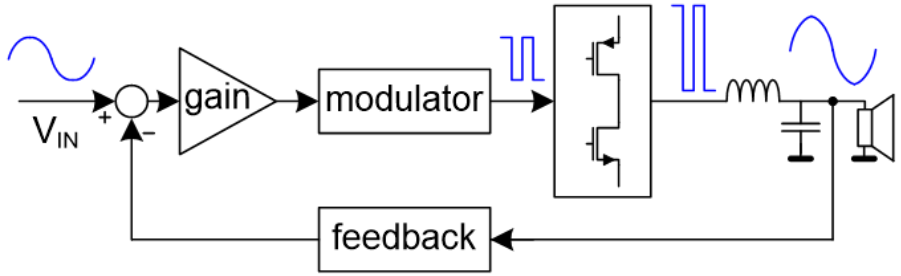
Using MPS Axign Technology

Post-Filter Feedback in Class-D Audio

- What is class-D audio?
  - Switching audio amplifier
  - Modulator creates PWM/PDM
- What is post-filter feedback (PFF) in Class-D audio?
  - PFF implies taking the feedback point after the output filter
- Feedback suppresses noise and distortion in the forward path
  - Errors in the modulator
  - Errors in the power stage
  - PFF corrects errors in the output filter as well
- THD+N in the feedback path cannot be corrected
  - High-quality feedback is key

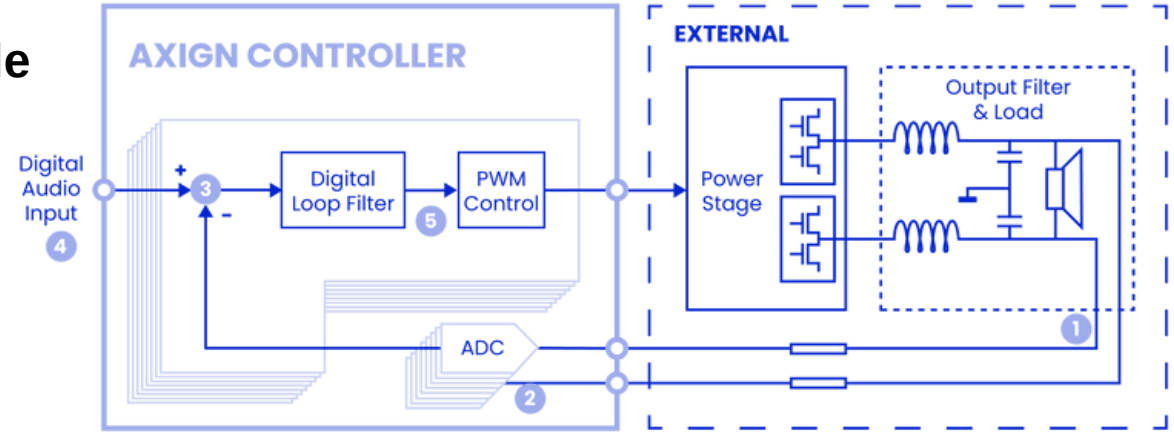






Post-Filter Feedback in Class-D Audio

- In the analog domain, parameter spread will present a limitation
  - High-order designs will have smaller margins of stability
- Digital feedback loops are **consistent** and **programmable**
  - Digital coefficients are loaded on start-up
- Programmable feedback loops can be fine-tuned to:
  - Performance requirements
  - Lowest power dissipation



- Ultimately, quality of a feedback system is limited by the quality of the feedback path
  - High-resolution analog-to-digital converter (ADC) is required
  - Patented ADC technology is cornerstone of Axign technology solutions

Post-Filter Feedback in Class-D Audio

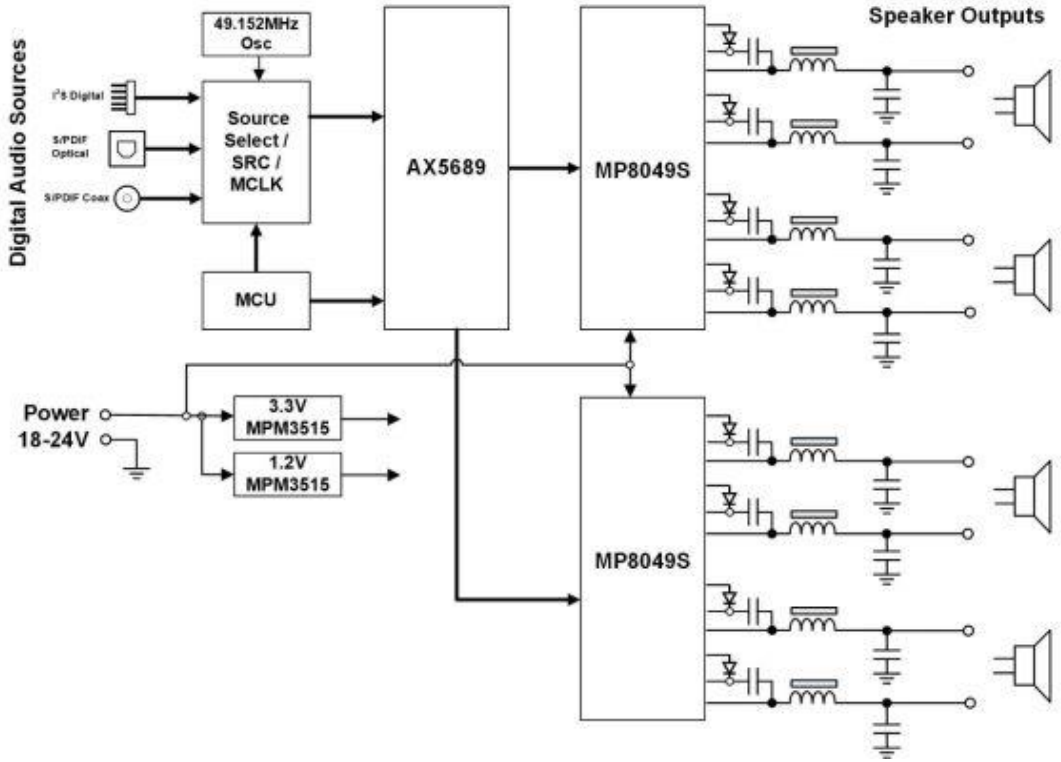
- 2-CH and 4-CH controllers for post-filter feedback available now
- Power-stages and DC-DC available from MPS
- AX5688 and AX5689 are power-stage agnostic
- More MPS Axign products are in development

AX5688

Digital Audio Converter and Amplifier Controller (2-ch BTL / 1-ch PBTL)

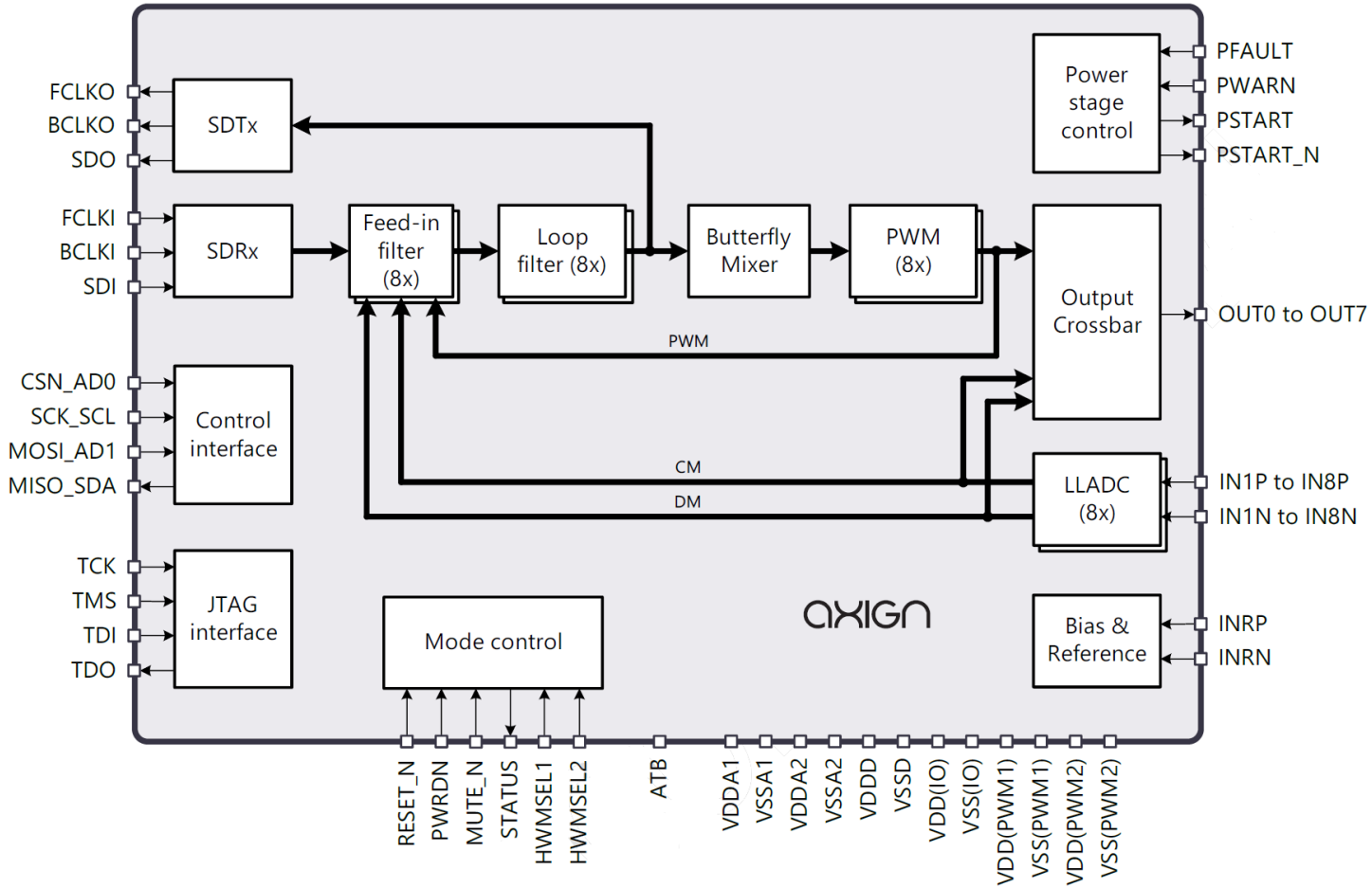
AX5689

Digital Audio Converter and Amplifier Controller (4-ch BTL / 2-ch PBTL)



Post-Filter Feedback in Class-D Audio

- AX5689 Block diagram shows more detail
- AX5689 contains
  - PWM x8
  - Low-latency ADC x8
  - Loop Filter x8
- DM and CM separated
- Possibility for PWM feedback
- Low-latency ADC has two inputs



Low-Latency ADC (LLADC)

Low-Latency ADC (LLADC)

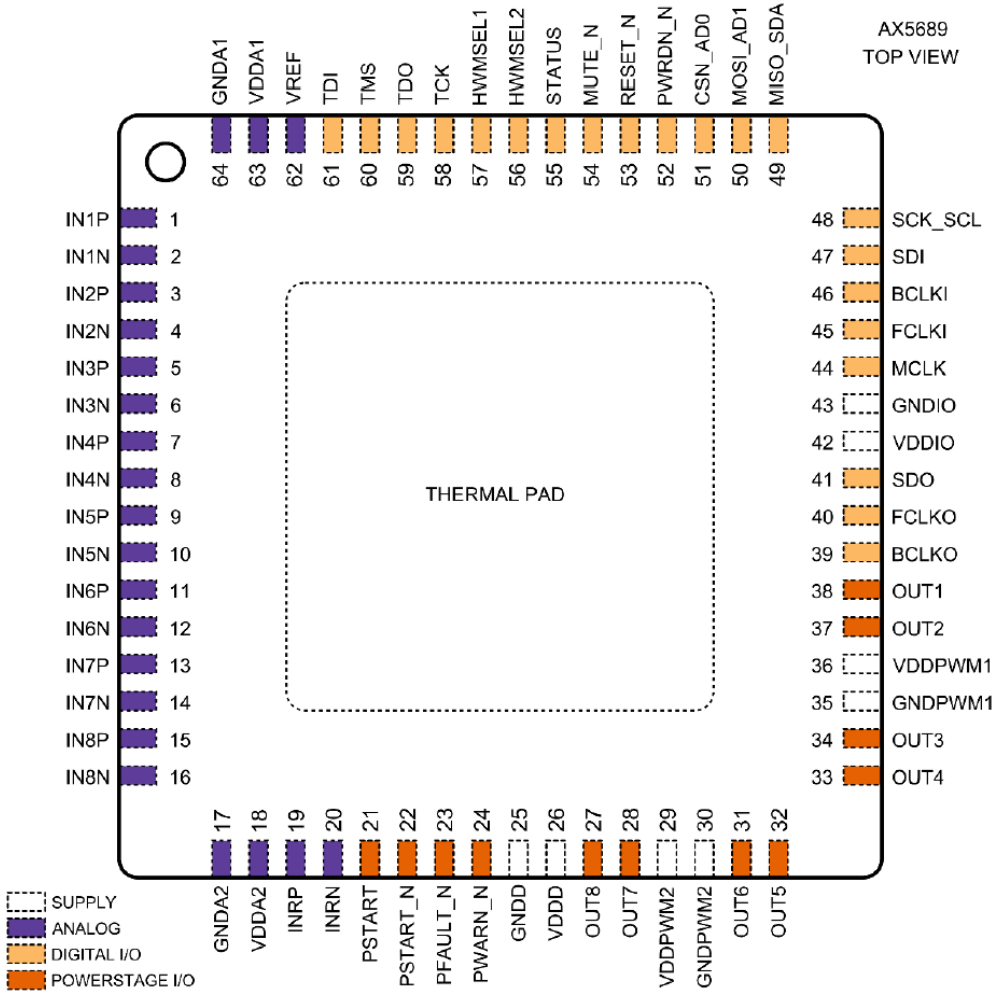
- AX5688 contains 4x LLADC
- AX5689 contains 8x LLADC
- LLADCs in parallel gives higher performance

AX5688

Digital Audio Converter and Amplifier Controller (2-ch BTL / 1-ch PBTL)

AX5689

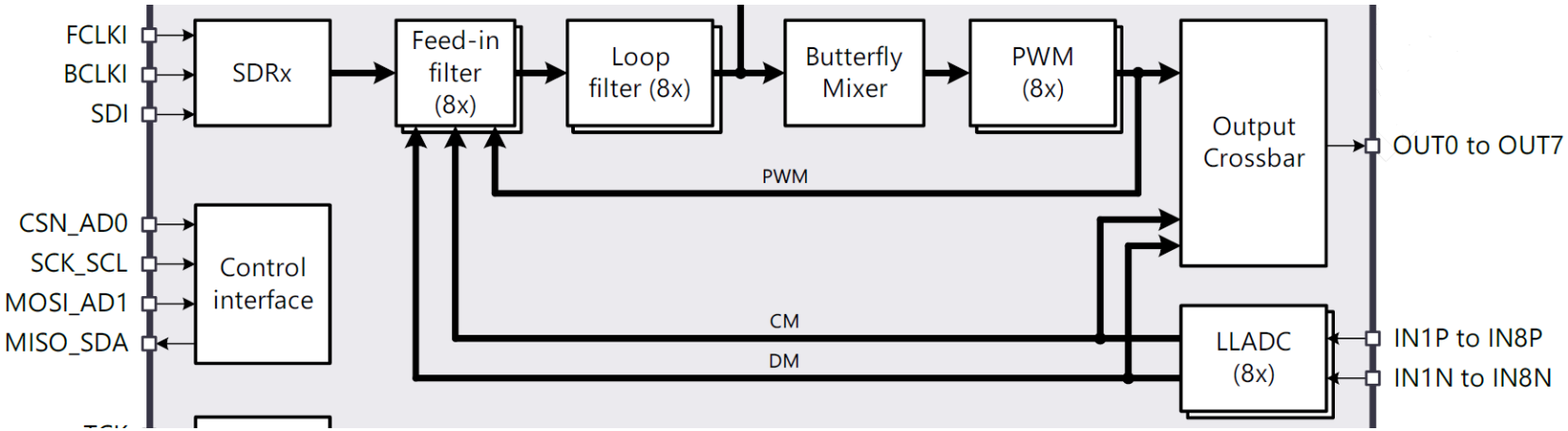
Digital Audio Converter and Amplifier Controller (4-ch BTL / 2-ch PBTL)



Low-Latency ADC (LLADC)

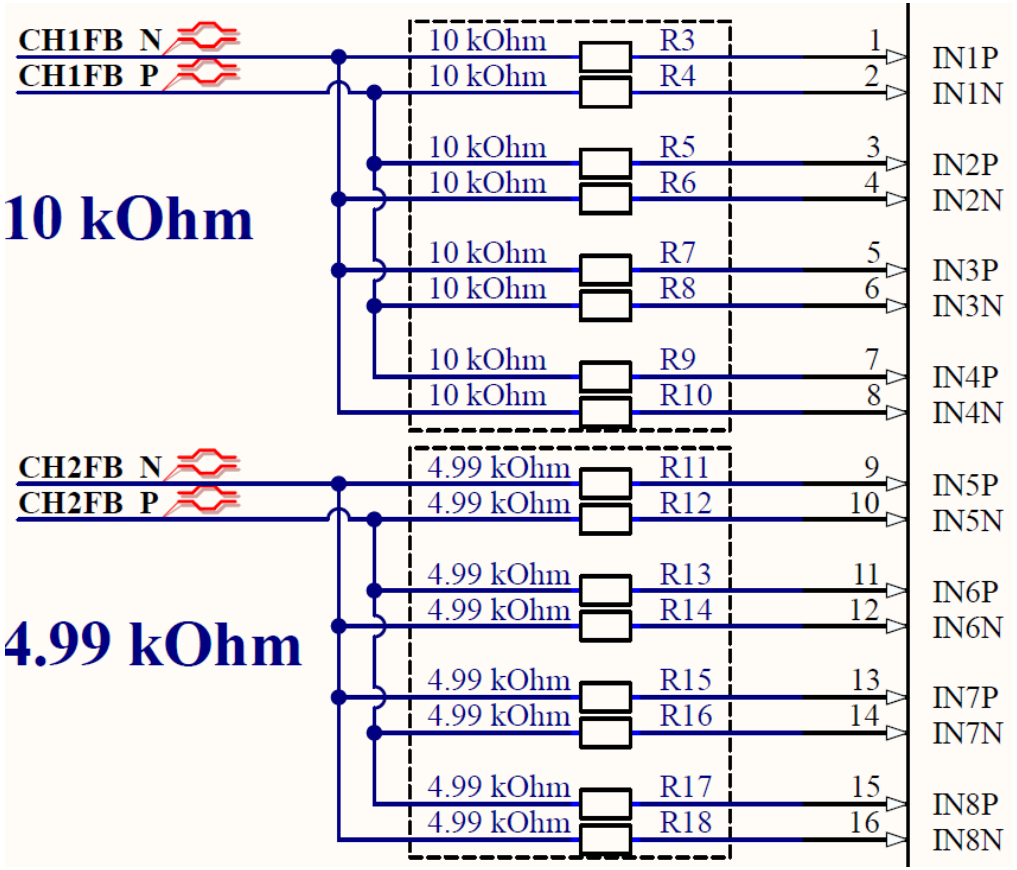
- Differential input ADC
  - Optimized for bridge-tied load (BTL) operation
  - Larger signal swing with two signals in anti-phase
  - Differential design eliminates even-order distortion

- DM and CM Split
  - Common-mode determined by average of input currents
  - Differential-mode determined by difference of input currents
  - DM and CM have different performance requirements → DM is what we hear



Low-Latency ADC (LLADC)

- Current input ADC
  - ADC resistors convert output voltage into ADC current
  - Scalable for all levels of PVDD
- Usable with multiple different power stages
  - E.g. woofer/tweeter split
  - Woofer at high PVDD
  - Tweeter at low PVDD
- Digital control system acts on digital ADC output
  - Easily scale design to higher output power
  - ADC resistor proportional to maximum output voltage
  - Noise performance correlates with ADC resistors
  - Power/Noise trade-off → dynamic range (DR) is constant

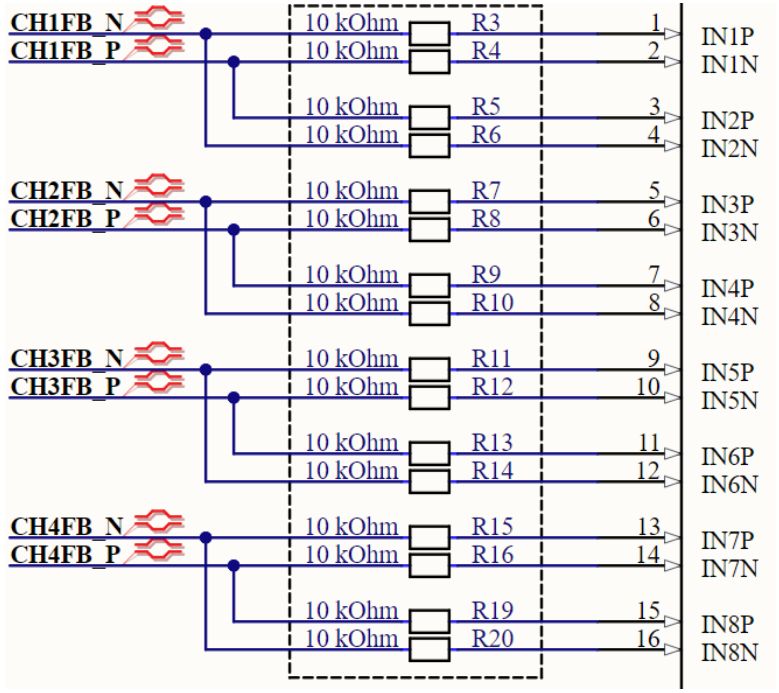


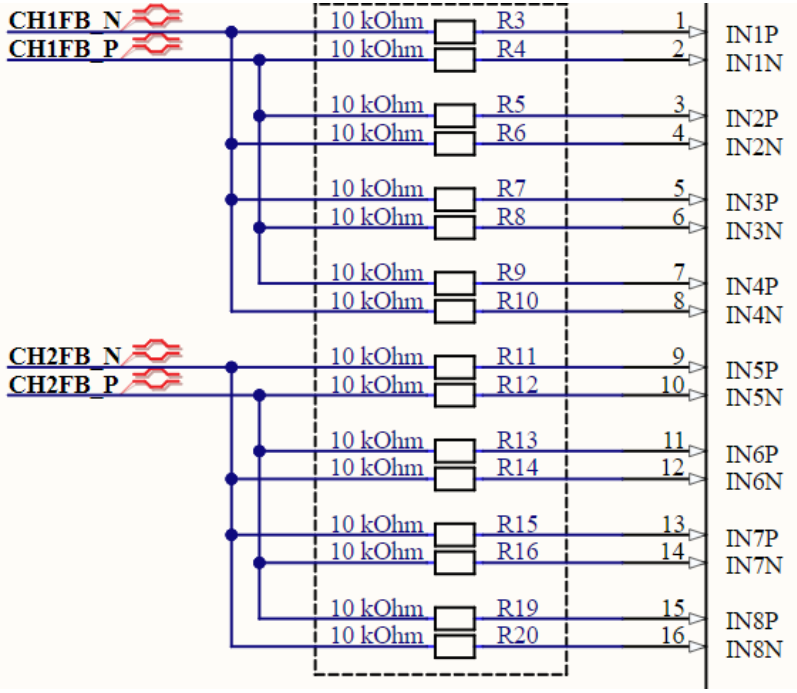
Configurable Digital Feedback Loop

Using the AX5688 and AX5689

Configurable Digital Loop – ADC configuration

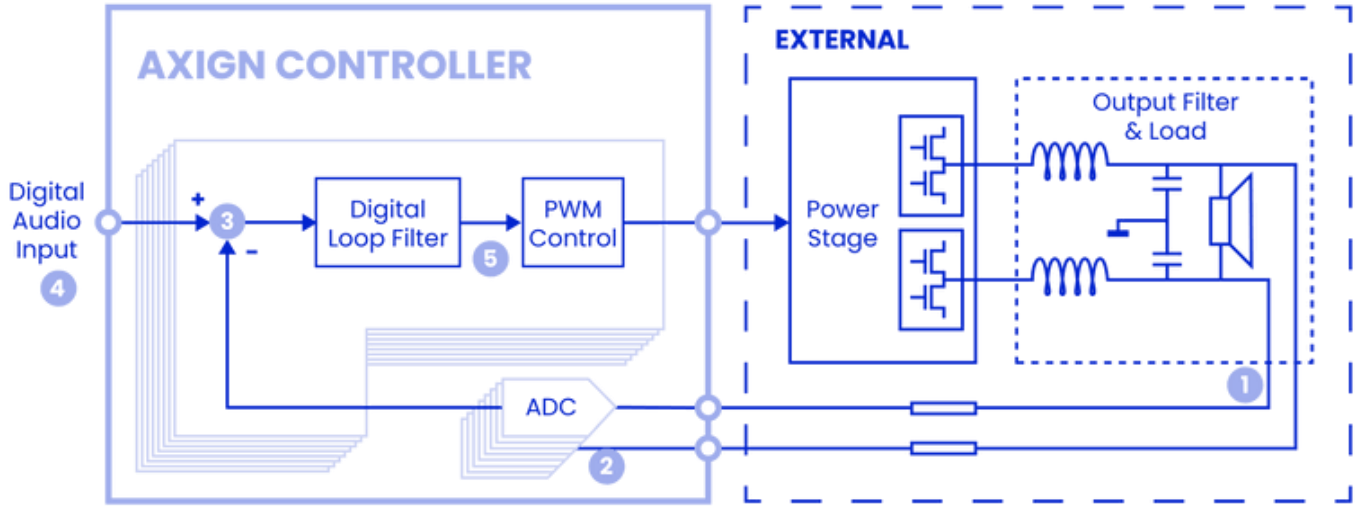
- Flexible ADC configuration to leverage all the hardware for a chosen topology
- Configurable ADC options example:
  - 4x2 ADCs or 2x4 ADCs
  - 6 ADCs to tweeter & 2 ADCs to woofer
  - 3 dB boost to dynamic range for every doubling of parallel ADCs





Configurable Digital Loop – Loop filters

- 8 configurable Digital Loop Filter slices
- Loop filter slices can be used to form several digital DM and CM feedback loops
- Common-mode feedback loops damp the output filter resonance
  - Common-mode LC response is not damped by the differential load
  - Eliminate RC snubbers/Zobel networks
- Differential-mode feedback loops suppress audible distortion and noise

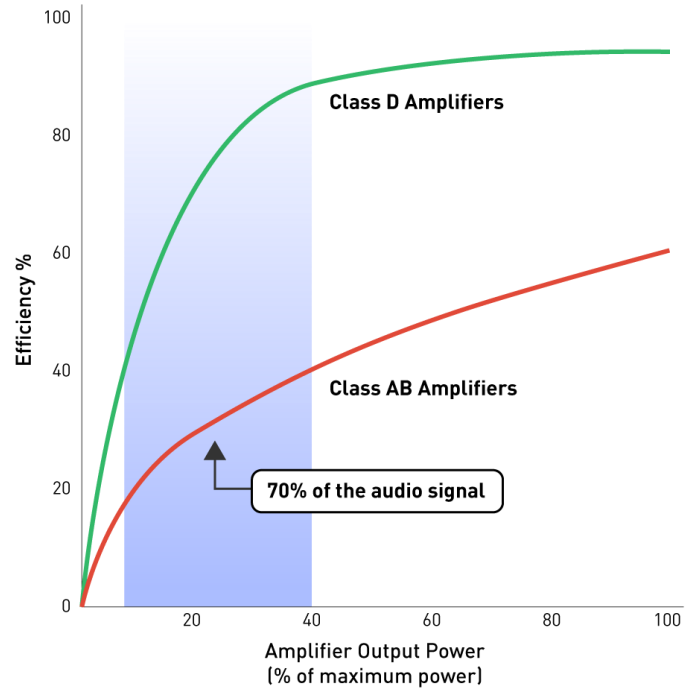


Pulse Width Modulation

Using the AX5688 and AX5689

Pulse Width Modulation

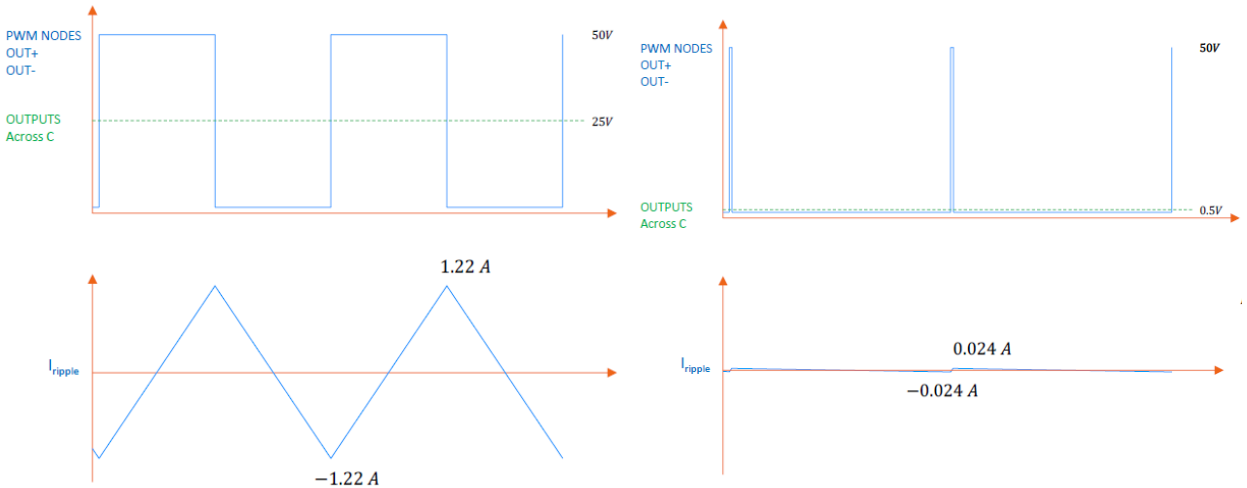
- Class-D is traditionally popular due to its high efficiency
- Typical audio content contains very low average power
- Losses at normal listening levels are largely determined by:
  - Switching losses
  - Ripple losses



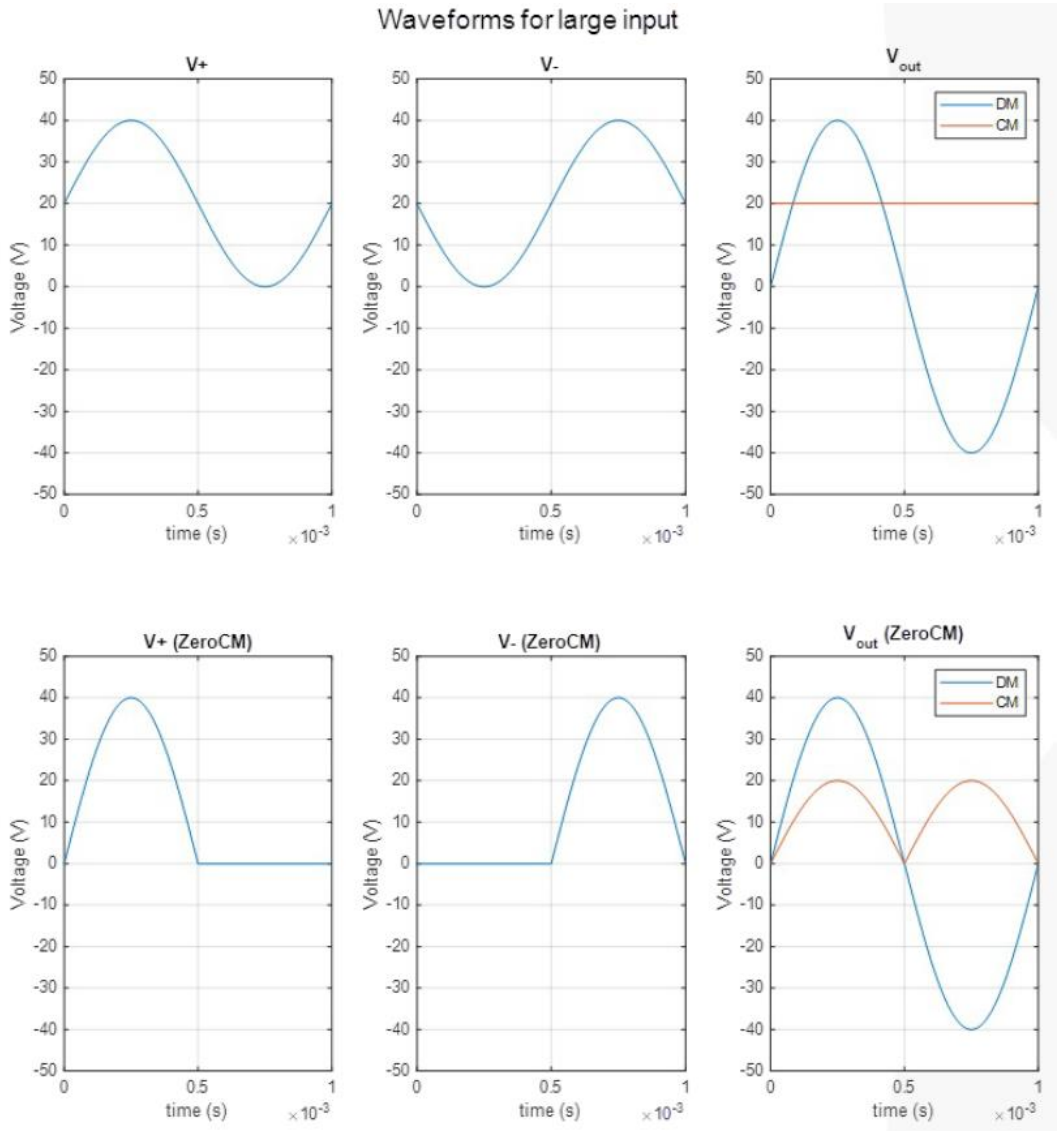
- Switching losses largely occur due to the (parasitic) capacitance charging and depleting
- Ripple currents run through the power stage and output filter inductors
  - Maximum ripple at low outputs in traditional Class-D amplifiers
- **This means wasting the most energy while at realistic listening levels!**

Pulse Width Modulation - ZCM

- Fix both switching losses and ripple losses with one solution:
  - **Zero common-mode (ZCM) switching**
- Only one side switches, reducing switching losses drastically
- Eliminates ripple currents for very small signals

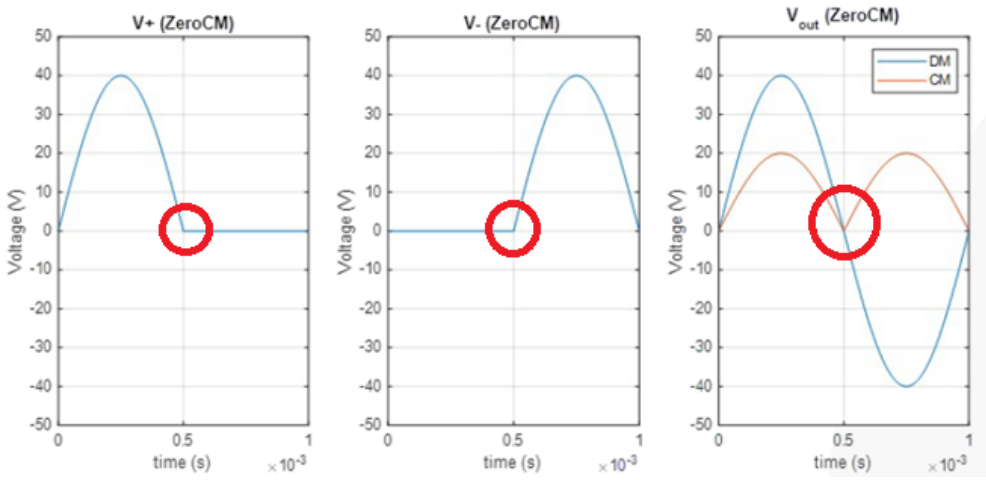


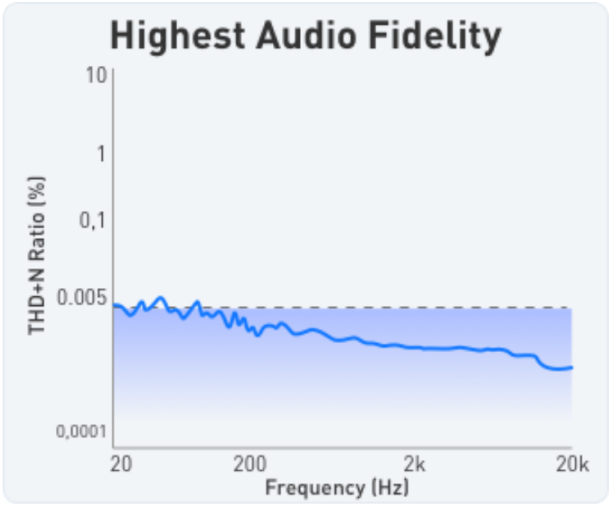
BD Modulation ZCM Modulation



Pulse Width Modulation - ZCM

- Traditionally causes significant (crossover) distortion
- Distortion in the audio band is eliminated by high loop gain
  - > 60 dB loop gain makes crossover distortion negligible
- THD+N well below 0.005% is possible
  - Frequency independent
  - Load independent

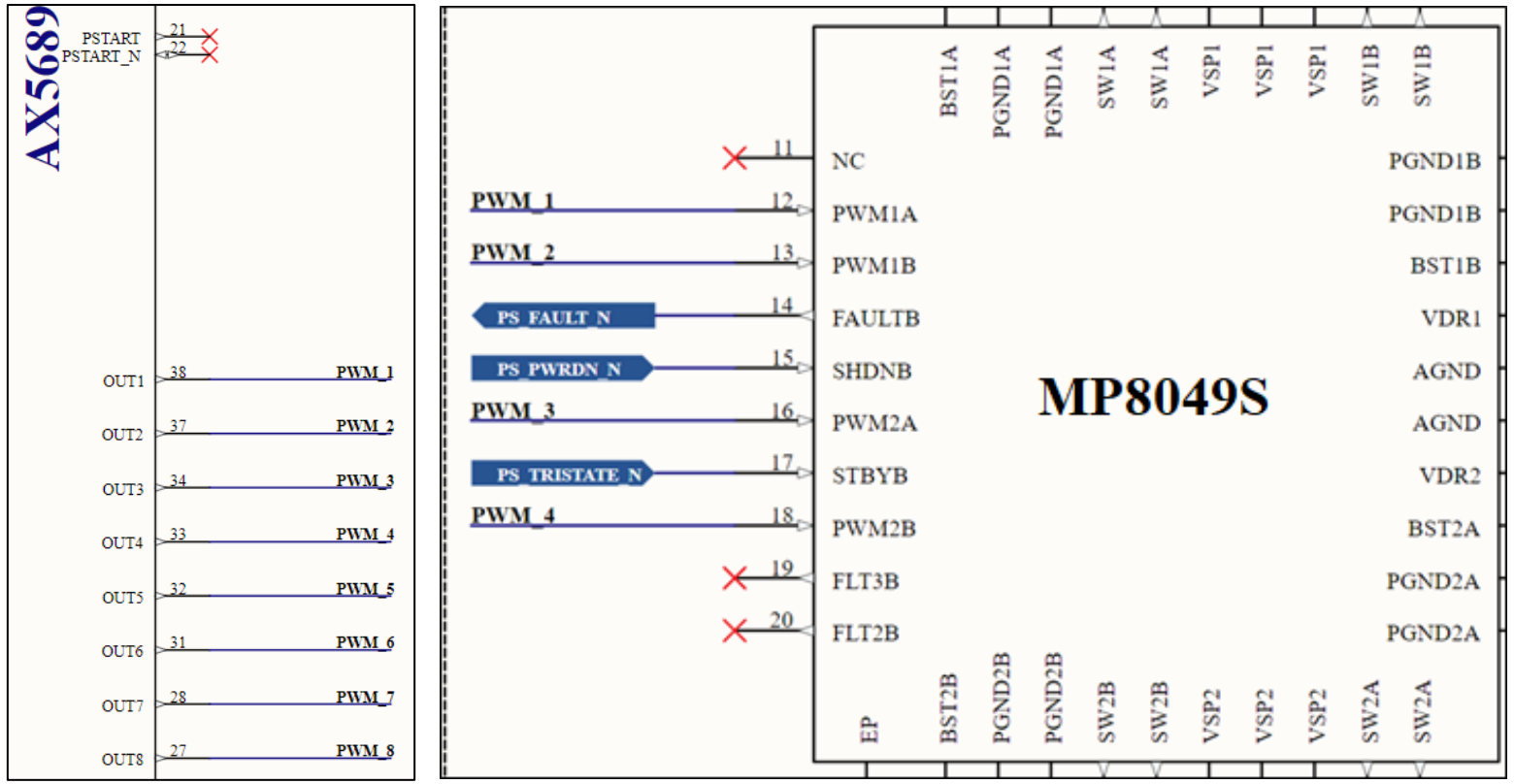




Combining extremely low losses with high audio quality, no compromise

PWM Configuration

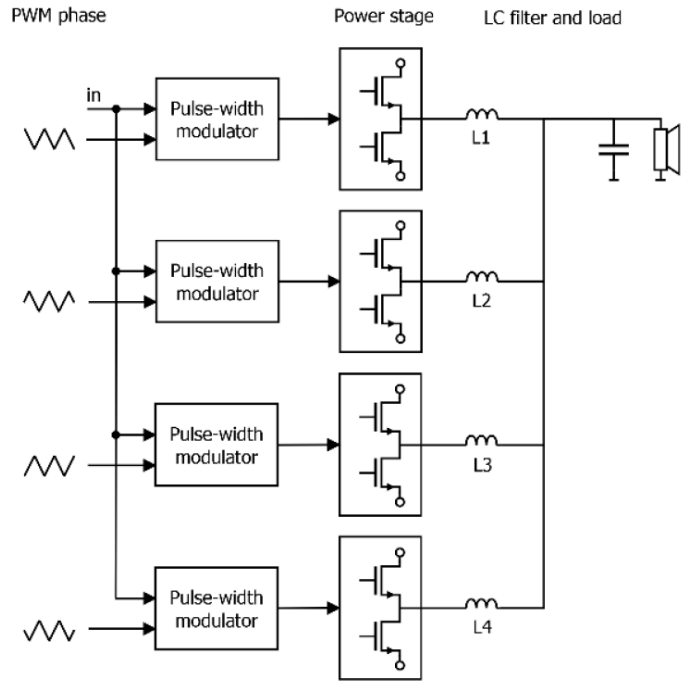
- 8 configurable PWM outputs
- Flexible PWM configurations
  - 4x Bridge-tied load (BTL)
  - 2x Parallel BTL (PBTL)
  - 2x BTL + 1x PBTL
- PBTL is typically chosen for higher output power

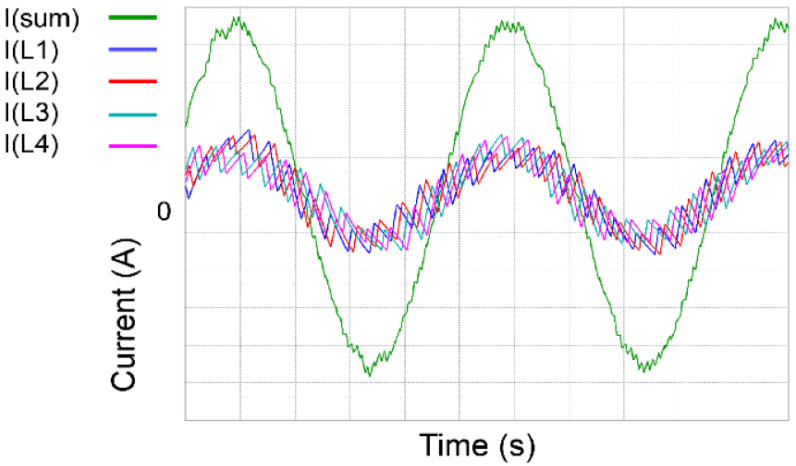


- When using 4 PWM outputs, we can use 2-phase or even 4-phase modulation
  - Advanced option for highest performance
  - Only possible for PBTL

PWM Configuration

- For 4-phase modulation, generate 2 more digital PWM carriers that are 90° out of phase
- 4-phase results in higher performance
- Downside → Inductor per half-bridge
- 2-phase PBTL modulation sums currents before the inductor
  - Still have double available current
- 4-phase only possible with 4 PWMs
  - AX5689 contains 8 PWMs → 2x 4-phase or 4x 2-phase
  - AX5688 contains 4 PWMs → 1x 4-phase or 2x 2-phase





Summary & Conclusion

Summary & Conclusion (1/3)

- Fully digital feedback loops have distinct advantages over analog feedback loops
  - Consistent (No component spread)
  - Configurable & Programmable

- Both DM and CM output are controlled using digitized feedback
  - DM feedback loop used to suppress audible noise and distortion
  - CM feedback loop used to control LC resonance → No snubbers/Zobel network needed

- Zero common-mode (ZCM) modulation allows for extremely low losses
  - High-order feedback loop guarantees exceptionally high audio performance
  - Highest performance possible using 4-phase modulation, at higher system cost

Summary & Conclusion (2/3)

- Highly configurable digital architecture
- Configurable LLADC configuration
  - Parallel ADCs for higher performance
  - Easy to meet performance requirements
- Configurable Loop filter Slices
  - DM and CM control loops
  - AX5689 (4CH) → 4DM feedback loops and 4CM feedback loops
- Configurable PWM modulators and outputs
  - Zero common-mode PWM for extremely high efficiency
  - 2-phase or 4-phase modulation possible

Summary & Conclusion (3/3)

- High configurability creates high potential for optimization
- How to easily leverage configurability for your application?
- MPS Axign reference designs
  - Copy-ready designs
  - Optimized for thermal performance, audio quality and cost
  - MPS reference designs available soon

Stay tuned:

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