Audio in eCall and Cluster

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FAE Summit 2016

Agenda

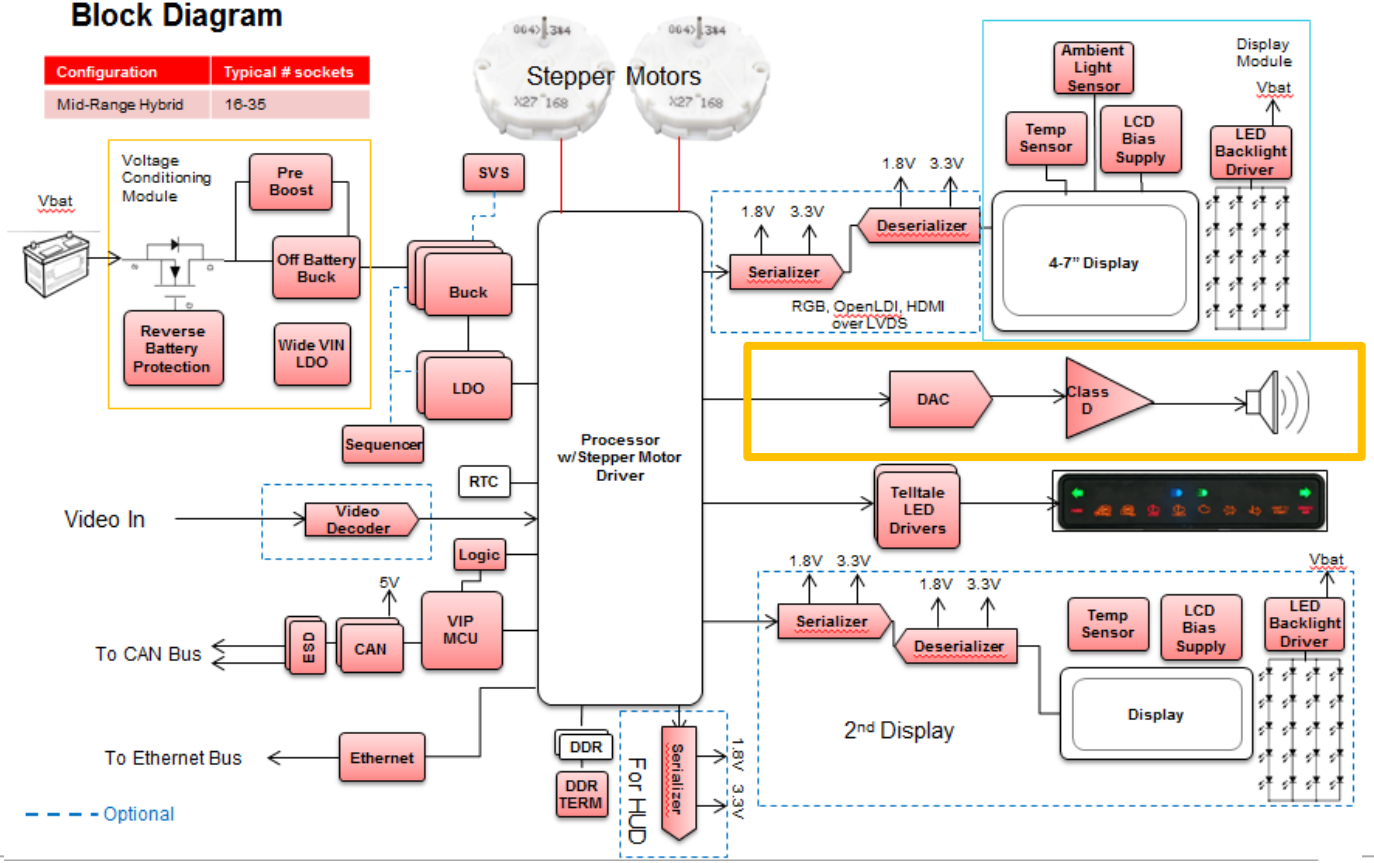
- Audio Architecture
- Audio Quality
- Diagnostics and Protection
- Efficiency
- EMI/EMC

Audio Architecture

Cluster Mid-Range Hybrid

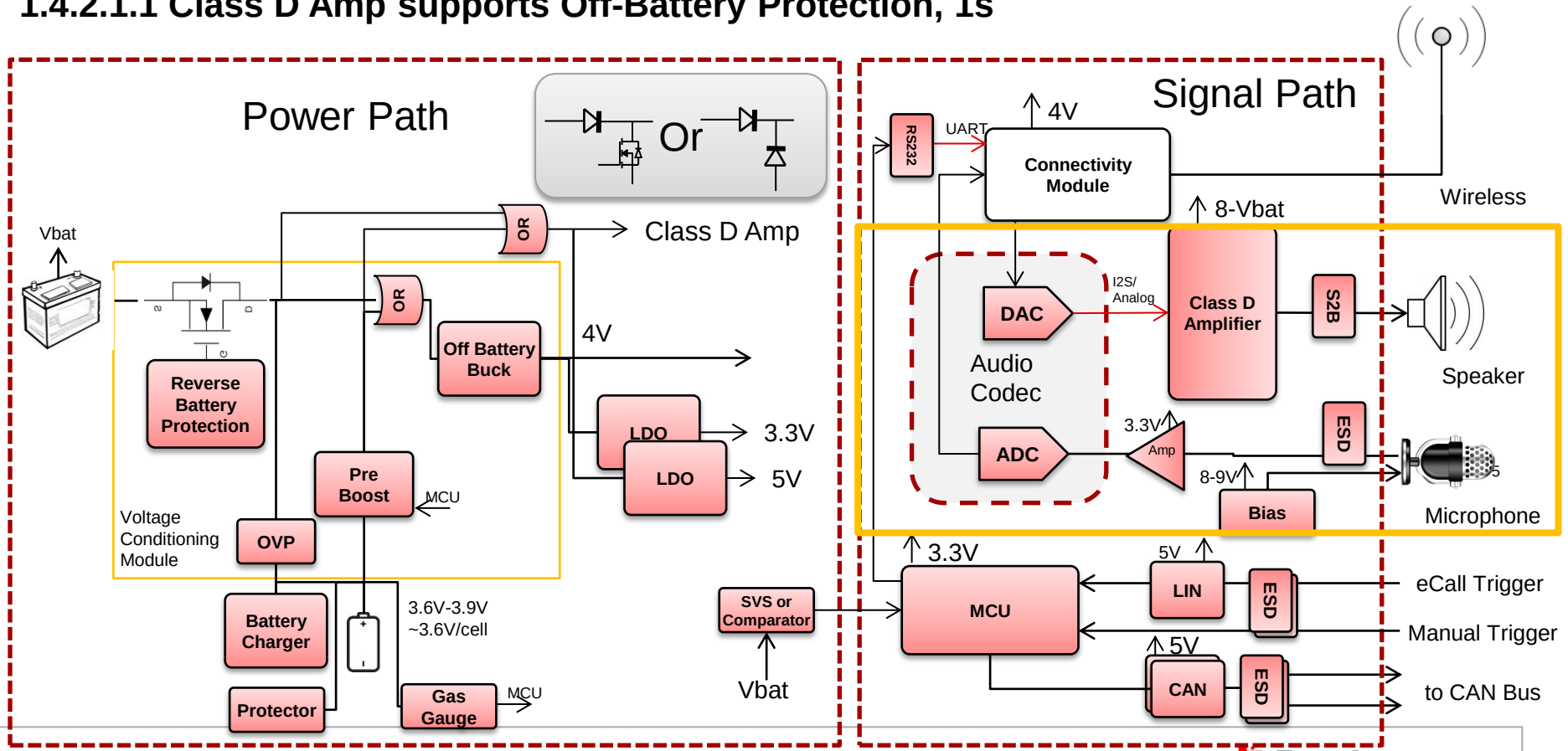
Block Diagram

Configuration	Typical # sockets
Mid-Range Hybrid	16-35

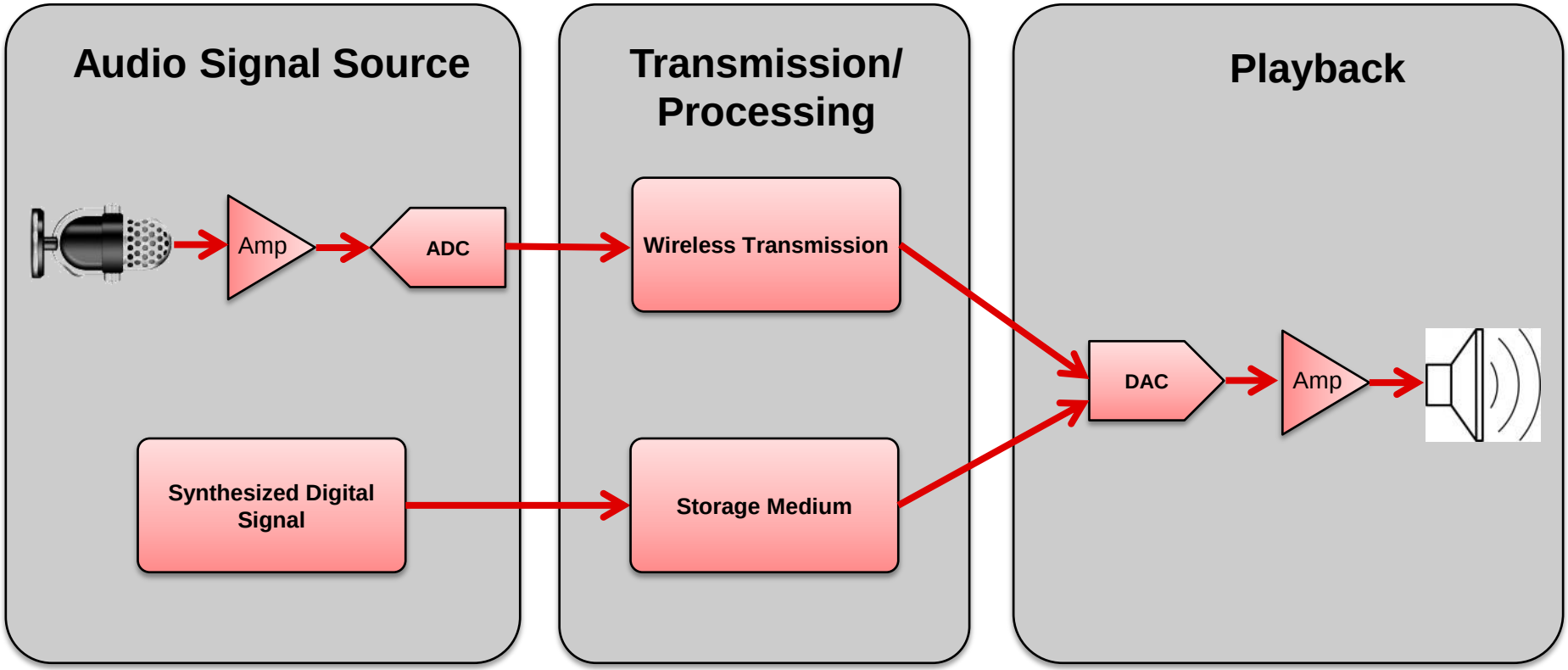


eCall with Li-Ion Battery

1.4.2.1.1 Class D Amp supports Off-Battery Protection, 1s



Audio Signal Path



eCall vs Cluster

	Cluster	eCall
Audio Source	Digital stored signal from processor	- Digital signal from wireless module - Analog input from mic to be transmitted to wireless module
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Audio Quality	Low audio, higher fidelity necessary for speech	Most of the distortion will come from the voice compression. Audio quality lower than for music
Audio SPL	Lower SPL needed	Higher SPL needed, since speech recognition must occur
Efficiency	High efficiency needed since cluster can't afford additional heat generation	High efficiency needed due to required call length on small battery
No. of channels	1	1, can re-use speakers from infotainment
Diagnostics and Protection	Needed for safety notifications: (ex. Lane departure, blind spot)	Mandatory, potential problem if shorted to battery when powered from back-up battery
Input Power	Battery or 5V	Powered from battery and/or back-up battery system
EMI/EMC	CISPR-25 or OEM specific	CISPR-25 or OEM specific

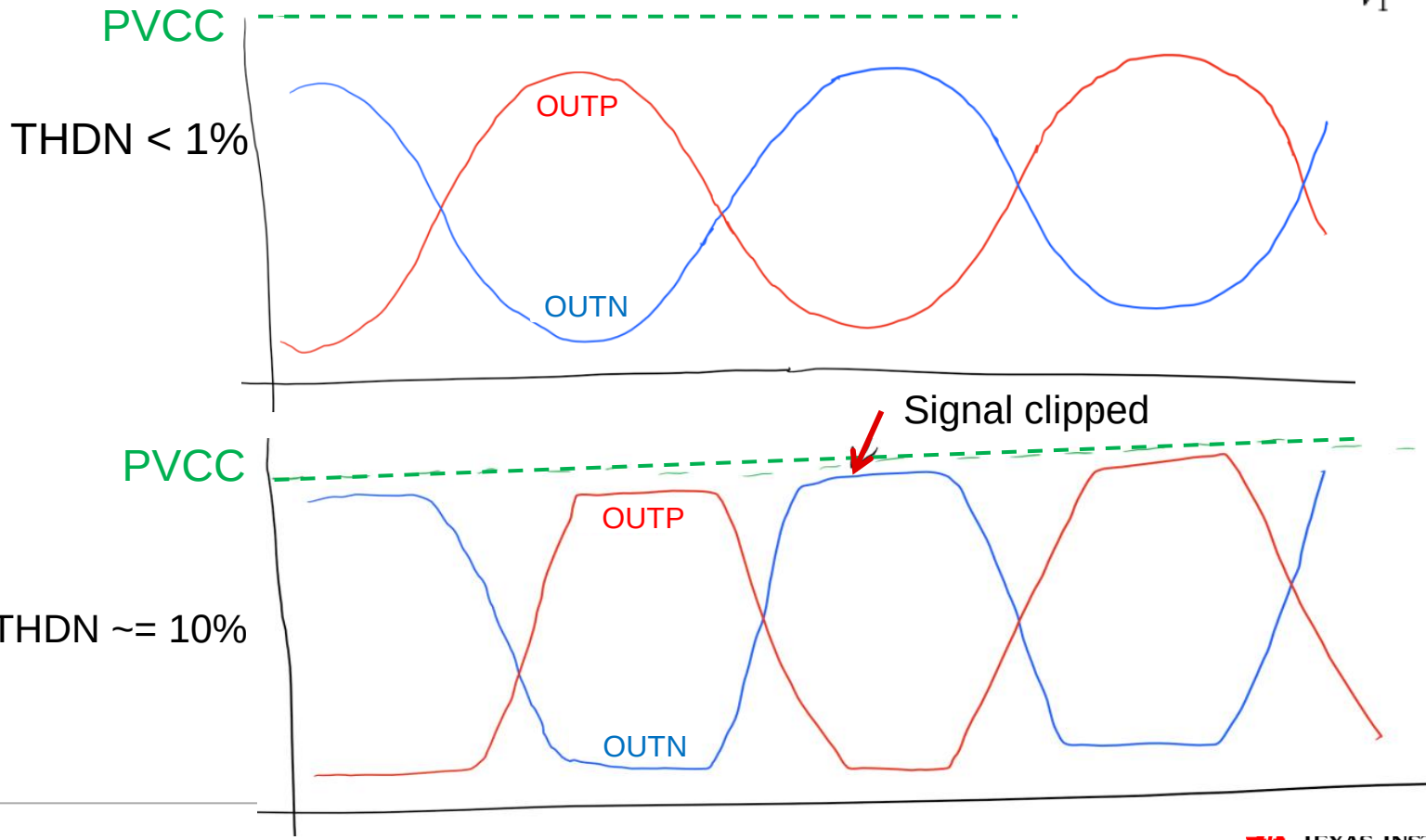
Audio Quality

Important Parameters for Audio Quality

- ADC/DAC/CODEC:
  - THD+N
  - Frequency Response
  - SNR of signal chain
    - Dynamic range
- Amplifier:
  - THD+N
  - Output Power
  - PSRR
  - Pop and Click
  - Frequency response
    - Output filter
- Speaker:
  - SPL – Sound Pressure Level, function of acoustic power from the speaker, (dB/W at 1m)

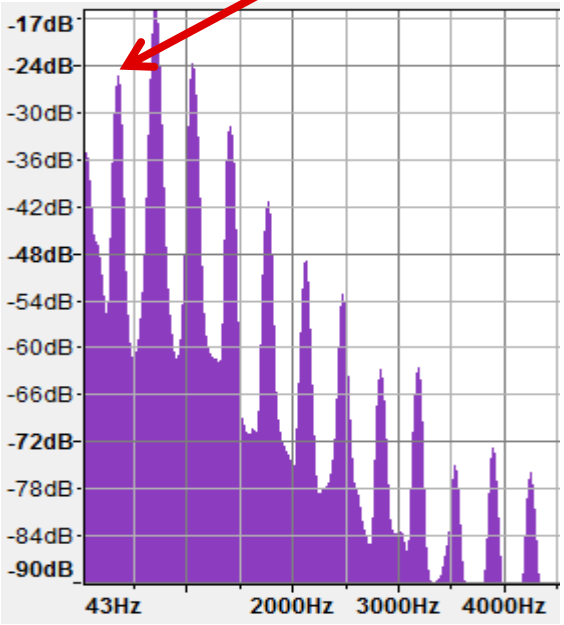
Clipping and THDN

$$\mathrm{THD_F} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1}$$



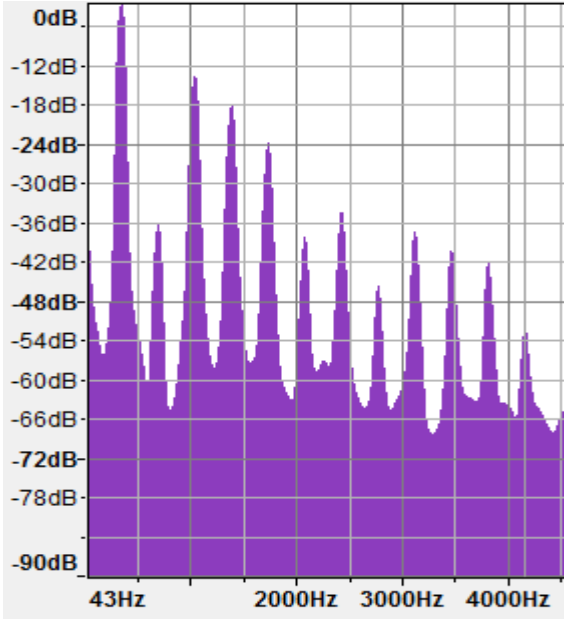
Harmonic Content of Sounds

Fundamental = 440 Hz



Trumpet – A Note

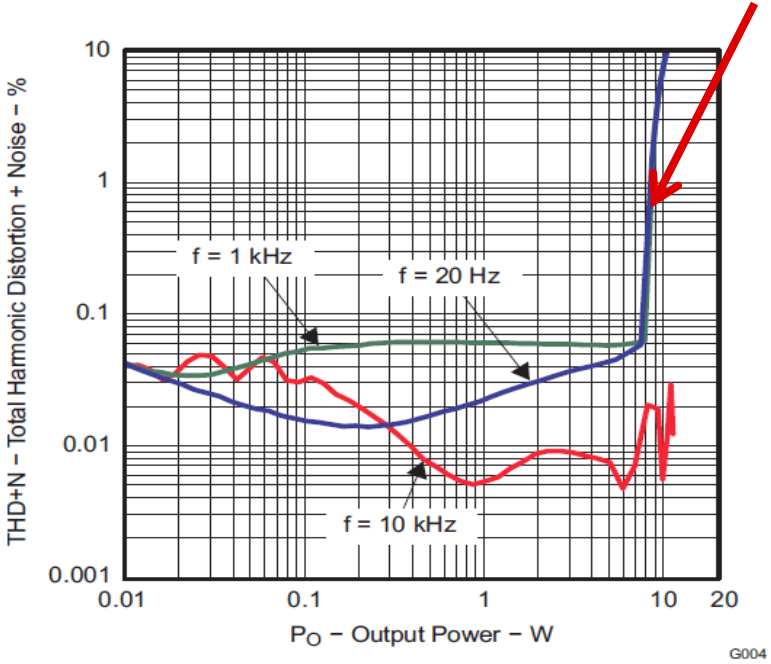
Fundamental = 440 Hz



Clarinet – A Note

THD+N Examples

clipping



Gain = 20 dB V_{CC} = 12 V Z_L = 8 Ω +66 µH

Figure 4. Total Harmonic Distortion + Noise vs Output Power

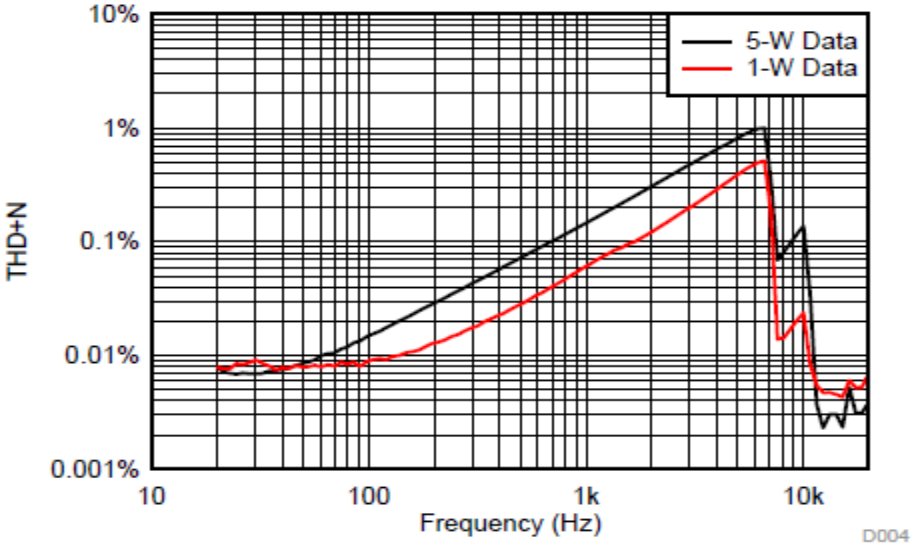
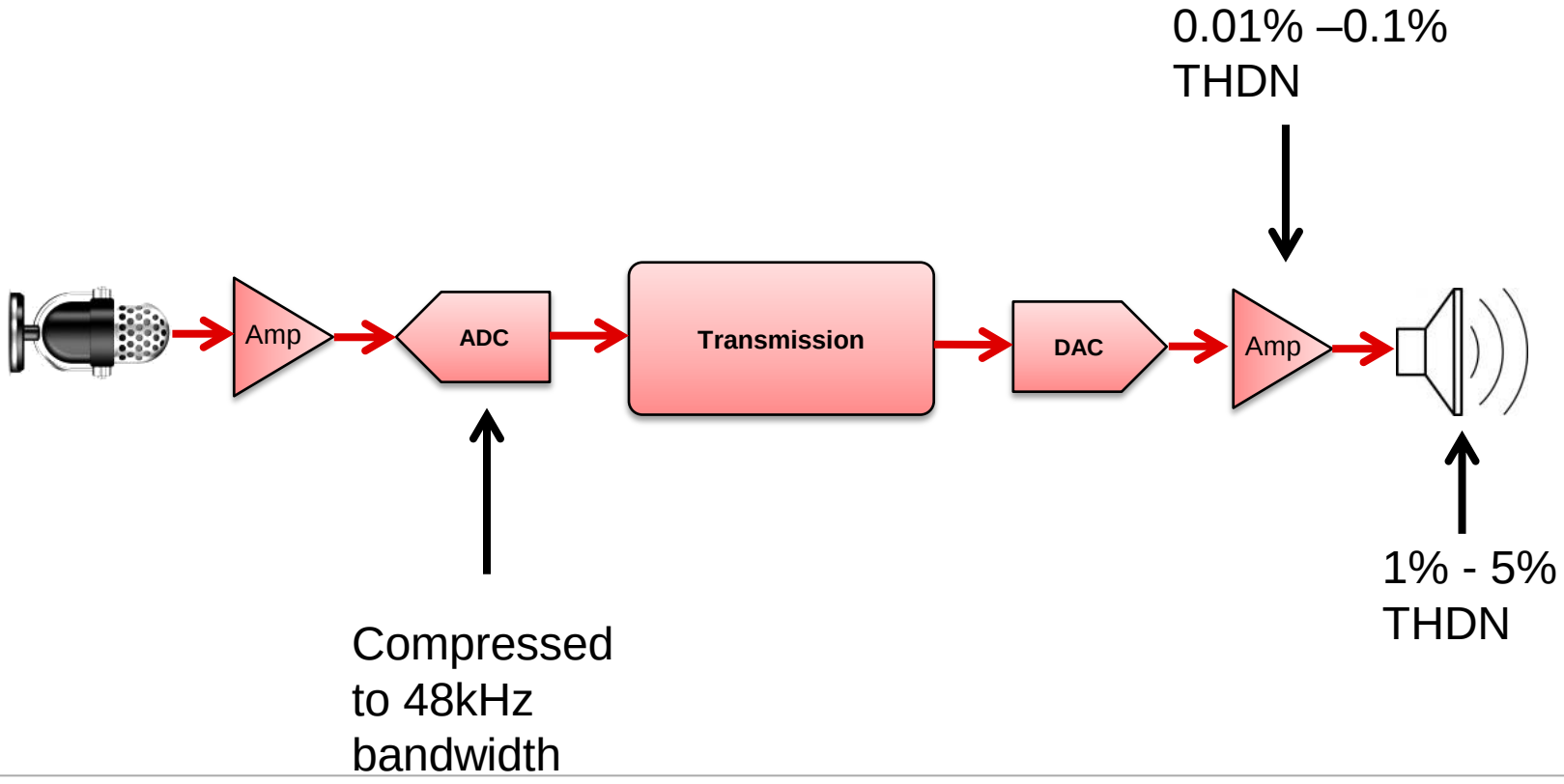


Figure 6. THD+N vs Frequency

THD+N – What Causes Distortion?

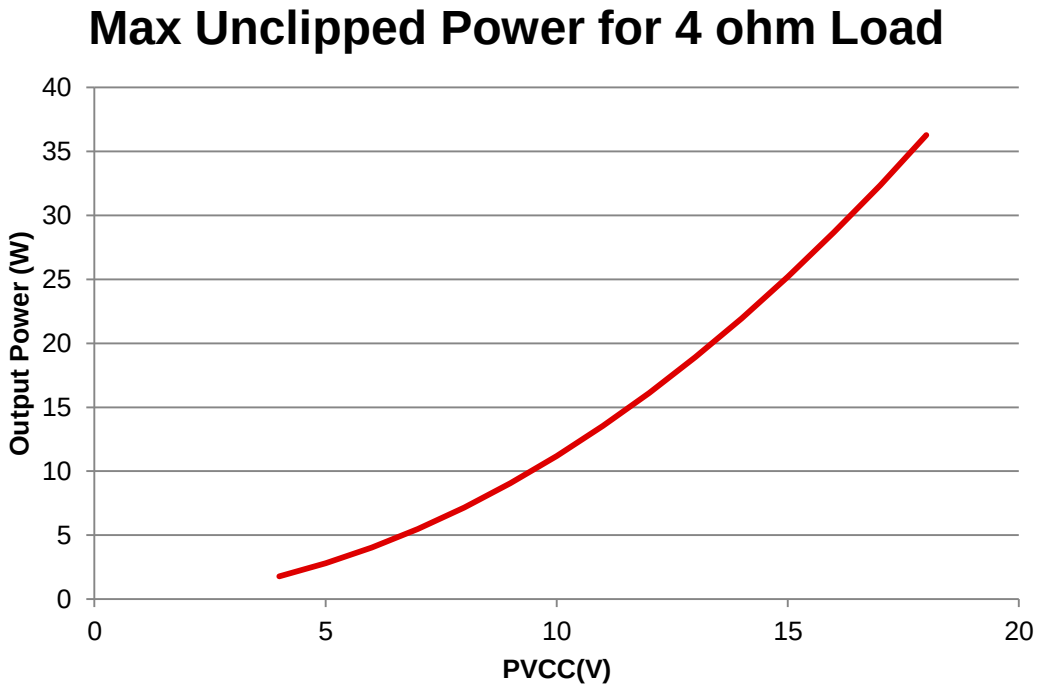


Maximum Output Power vs PVCC to Avoid Clipping

Due to clipping, the maximum output power is limited by PVCC.

$$V_{headroom} = \frac{R_{dson}}{2 * R_{dson} + R_L} * PVCC$$

$$P_o = \frac{V_{RMS}^2}{R_L} = \frac{V_{peak}^2}{2 * R_L}$$



PSRR – Power Supply Rejection Ratio

- A measure of how much of the noise from the power supply line will feed through to the output of the audio amplifier

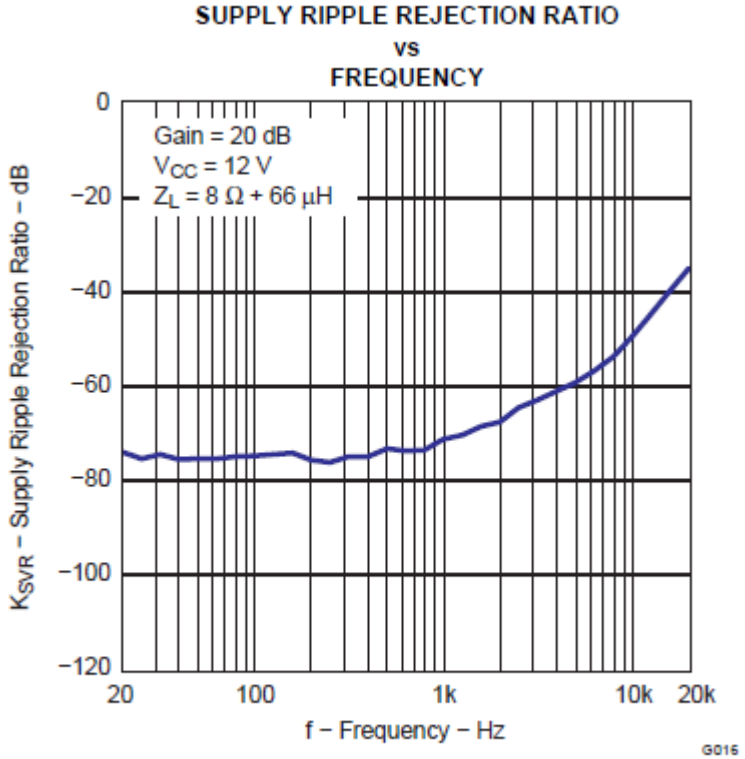


Figure 15.

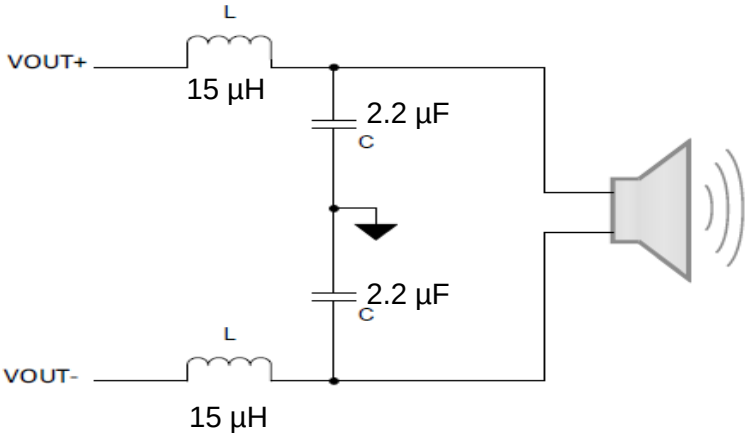
Output Filter Frequency Response

- Simple LC reconstruction filter
- fc = 27.7kHz

Design Equations:

$$Q = R_L * \sqrt{\frac{C}{L}} \qquad Q = \frac{1}{\sqrt{2}}$$

$$\omega_c^2 = \frac{1}{L * C}$$



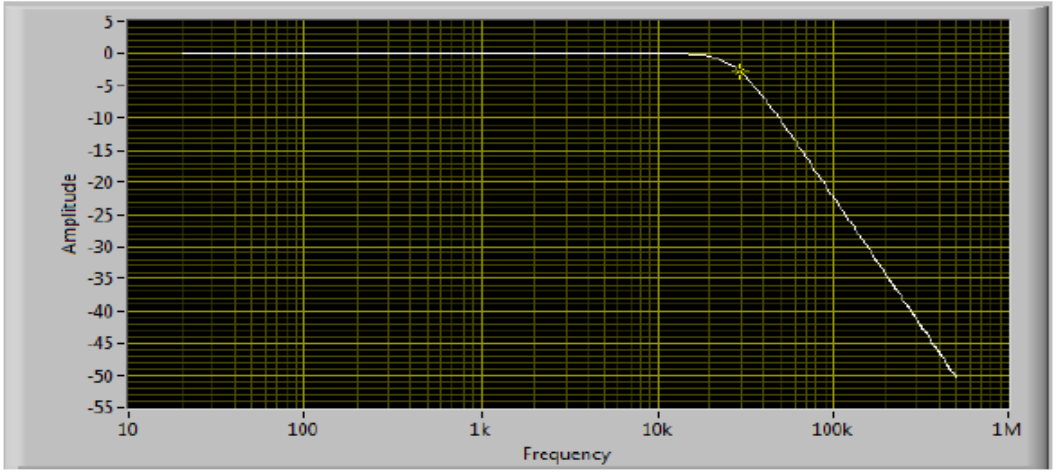


Figure 9: Frequency Response of LC Filter, L = 15uH, C = 2.2uH, R = 2 ohms Single Ended

SNR – Signal to Noise Ratio

- SNR is the ratio of the wanted signal to the background noise.

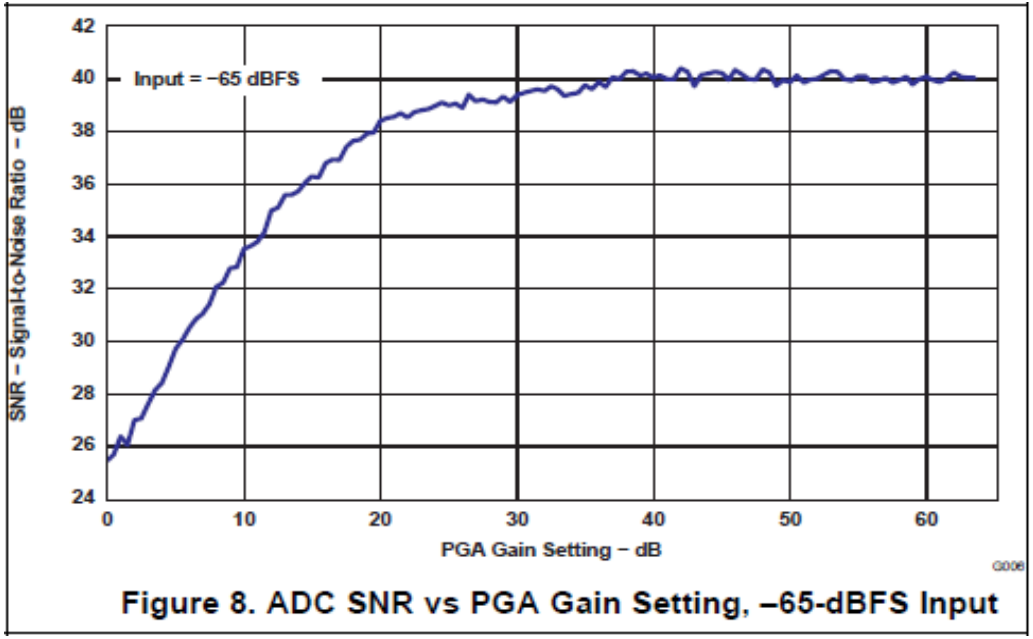


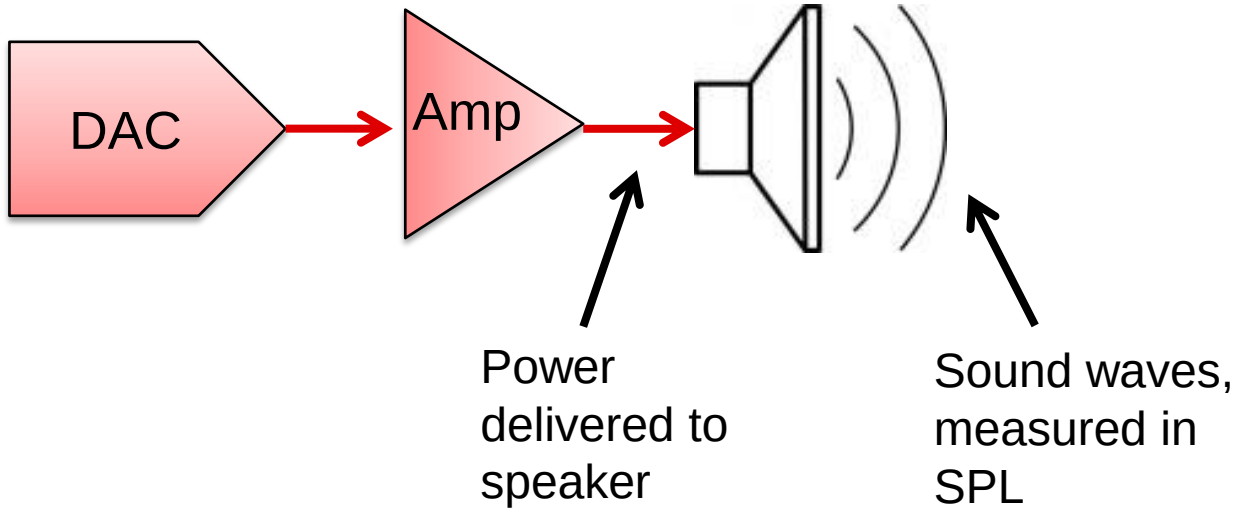
Figure 8. ADC SNR vs PGA Gain Setting, –65-dBFS Input

Pop and Click

- Pop/Click occurs due to discontinuities in the signal applied to the speaker

SPL – Sound Pressure Level

- Sound Pressure Level: The deviation from the ambient pressure level caused by a sound wave.



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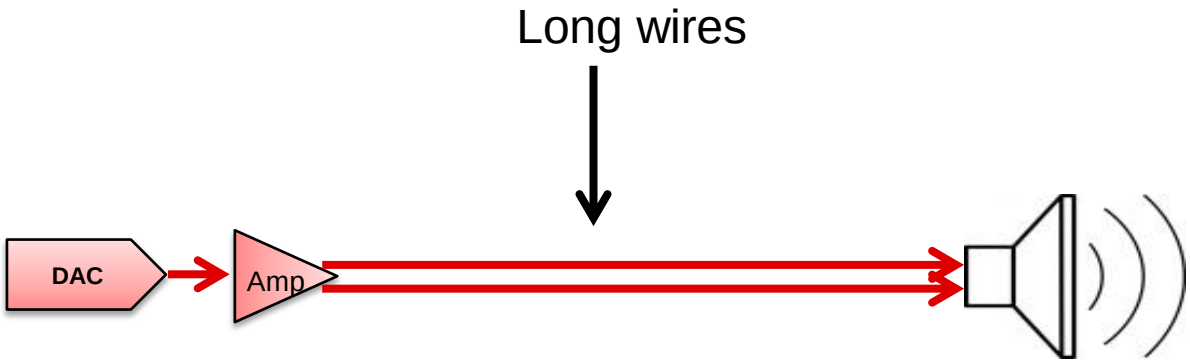
Diagnostics and Protection

Load Diagnostic Requirements

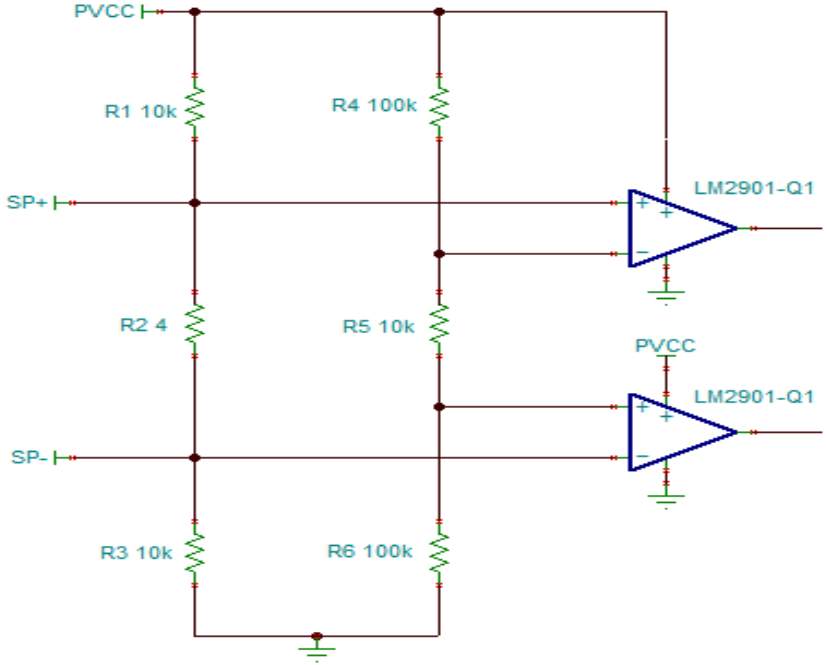
- Four types of connection problems:
  - Short to Battery
  - Short to Ground
  - Shorted load
  - Open load



External Load Diagnostics

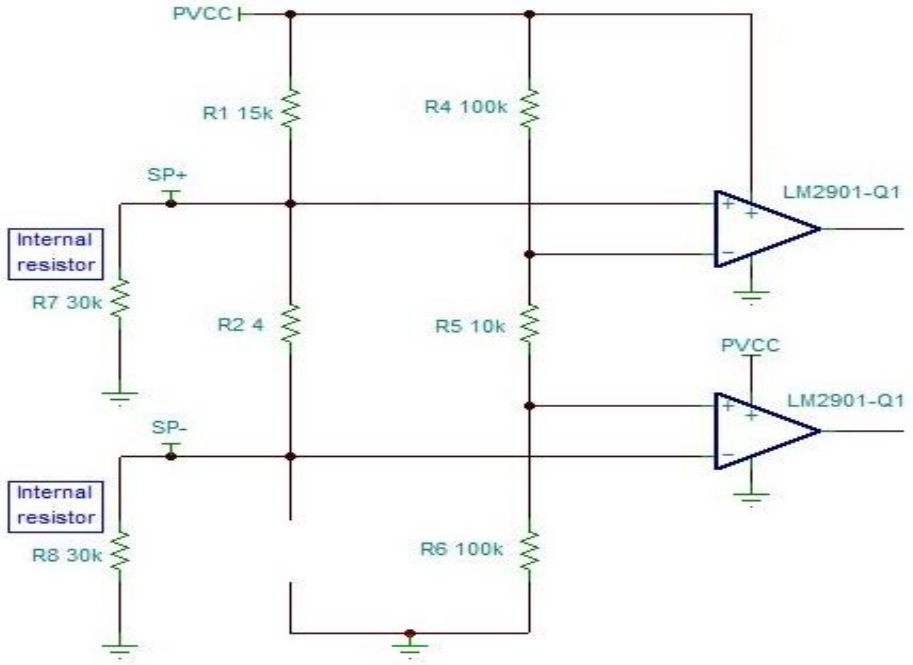
- Two comparators and a resistive network can be used to provide external load diagnostics

FAULT CONDITIONS	LEDs
No fault	Both LEDs off
Open load	Both LEDs on
Short to PVCC	LED on SP+ on, LED on SP- off
Short to GND	LED on SP+ off, LED on SP- on



External Load Diagnostics

- While a Class-D amplifier is in shutdown mode, there is an internal resistance to ground that must be accounted for

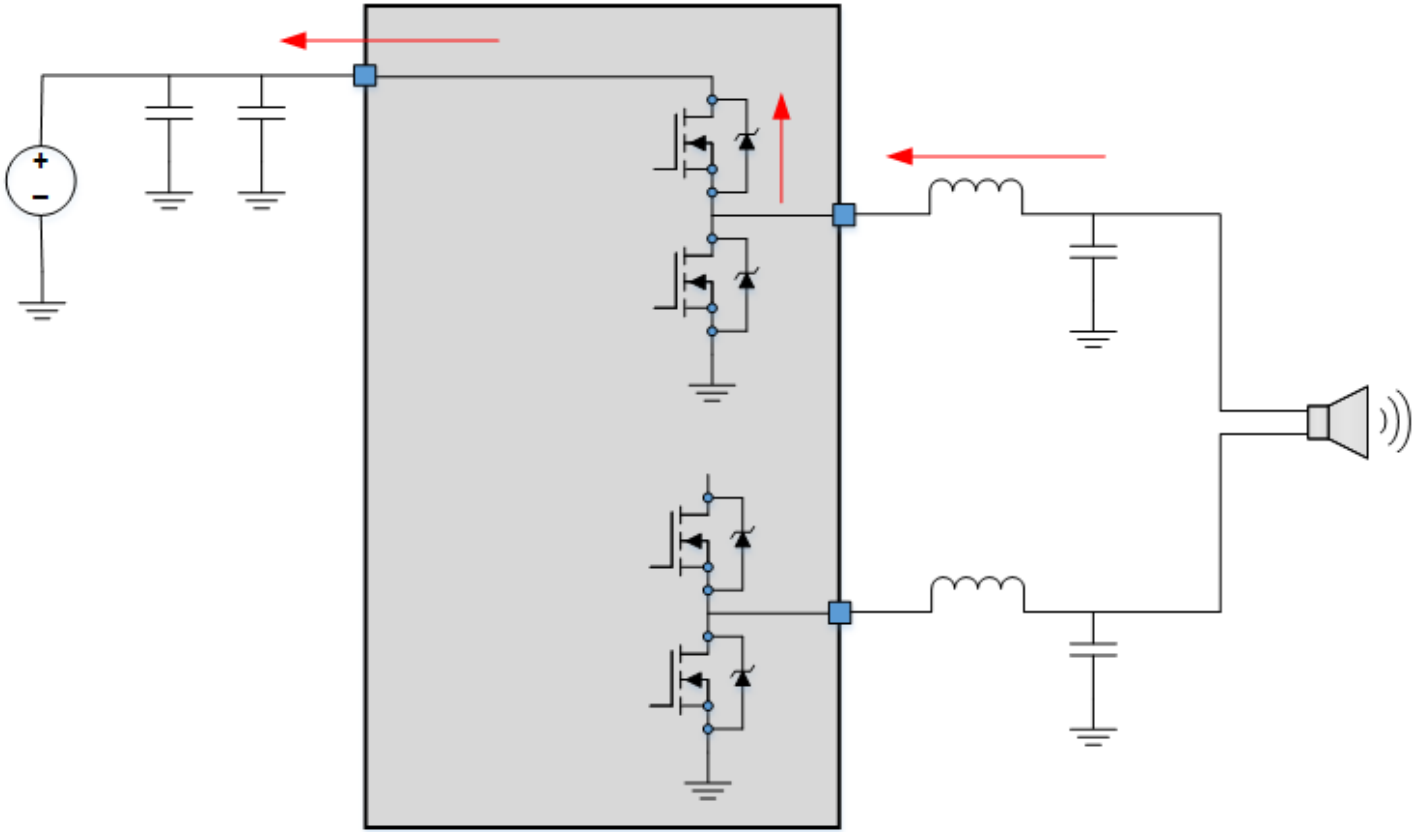


Internal vs External Load Diagnostics Cost Estimate

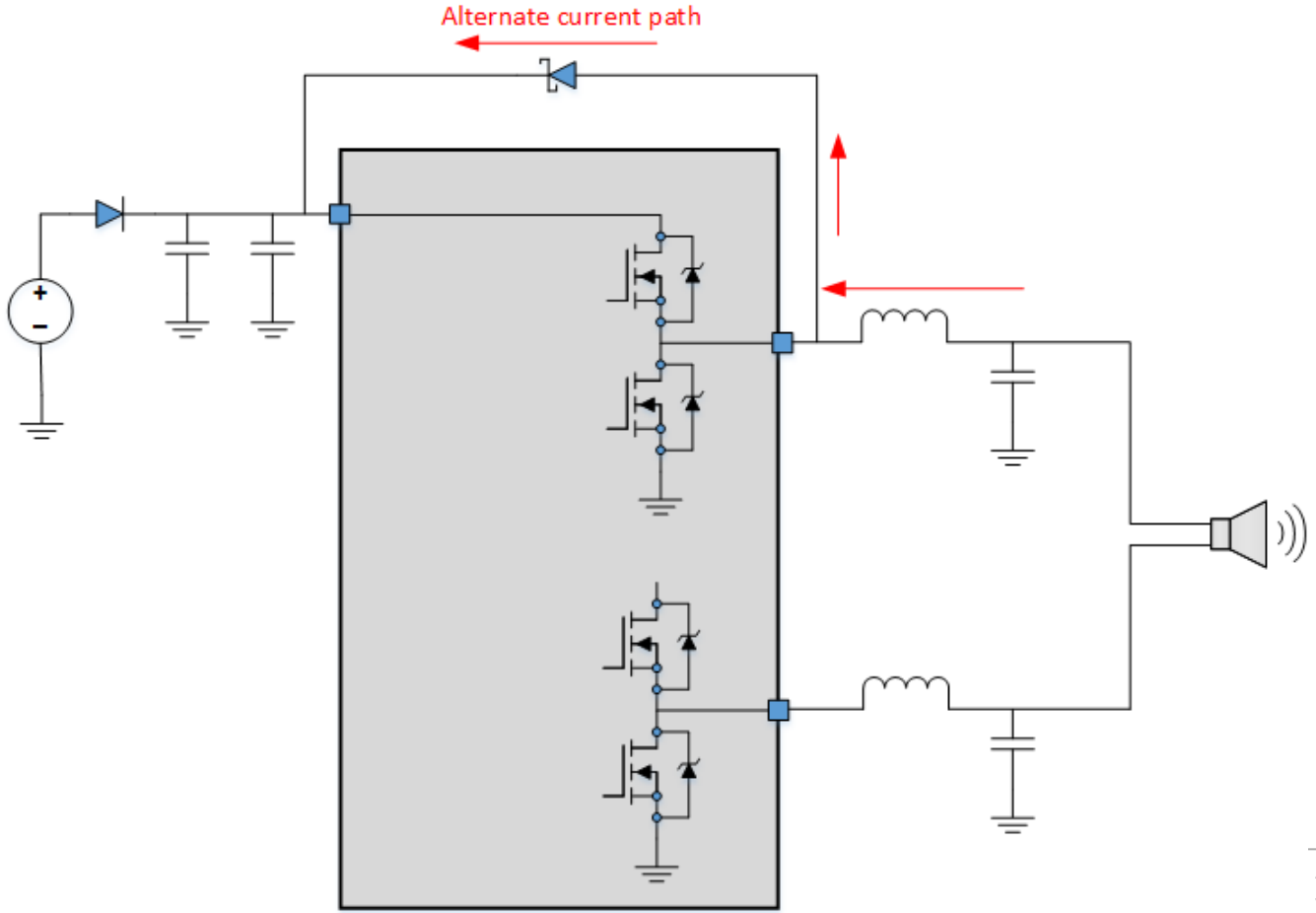
Component	1k Cost:
Comparator (2 per channel)	$0.12
2 GPIO channels on MCU	Dependent on MCU
PCB space	Affects system cost

TAS5411-Q1: Class-D amplifier with integrated load diagnostics

Short to Battery



Adding the Schottky Diode



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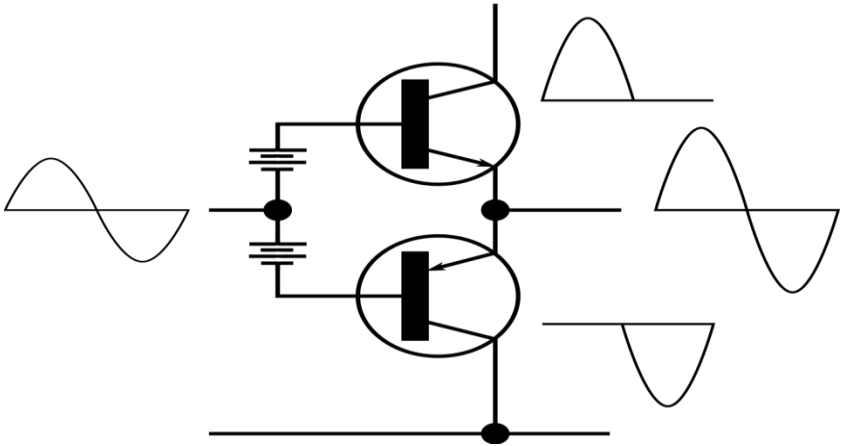
Efficiency

Amplifier Classes

- Class A
  - The output stage is always conducting and is very inefficient
- Class B
  - The output stage is conducting on ½ of the signal and if more efficient that class A, but with severe crossover distortion.
- Class AB
  - A hybrid of class A and class B. The output stage is conducting on a little more than ½ of the signal to eliminate the crossover distortion. Less efficient than Class B.
- Class C
  - Typical of RF amplifiers and will not be discussed.
- Class D
  - The audio signal is modulated with a higher frequency so the output stage can be operated very efficiently.
- Class G and H
  - These are not amplifier types but power supply types that provide power to audio amplifiers and will not be discussed.

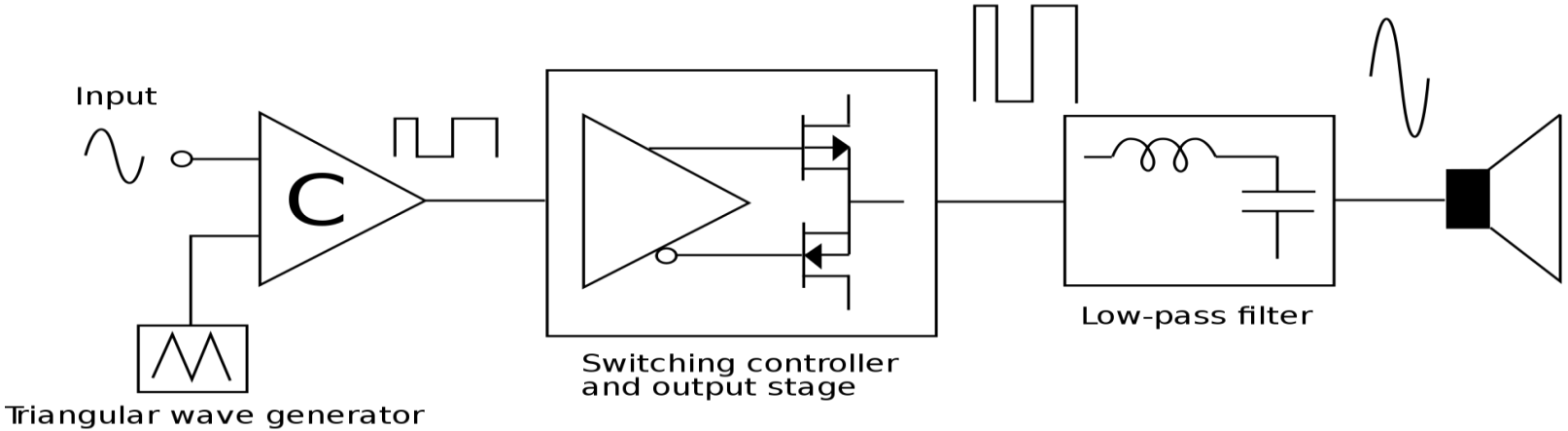
Class AB



- Typically a class B stage with additional bias to overcome the crossover distortion
- Less efficient than class B
- Most common Audio Amplifier type used in commercial applications.

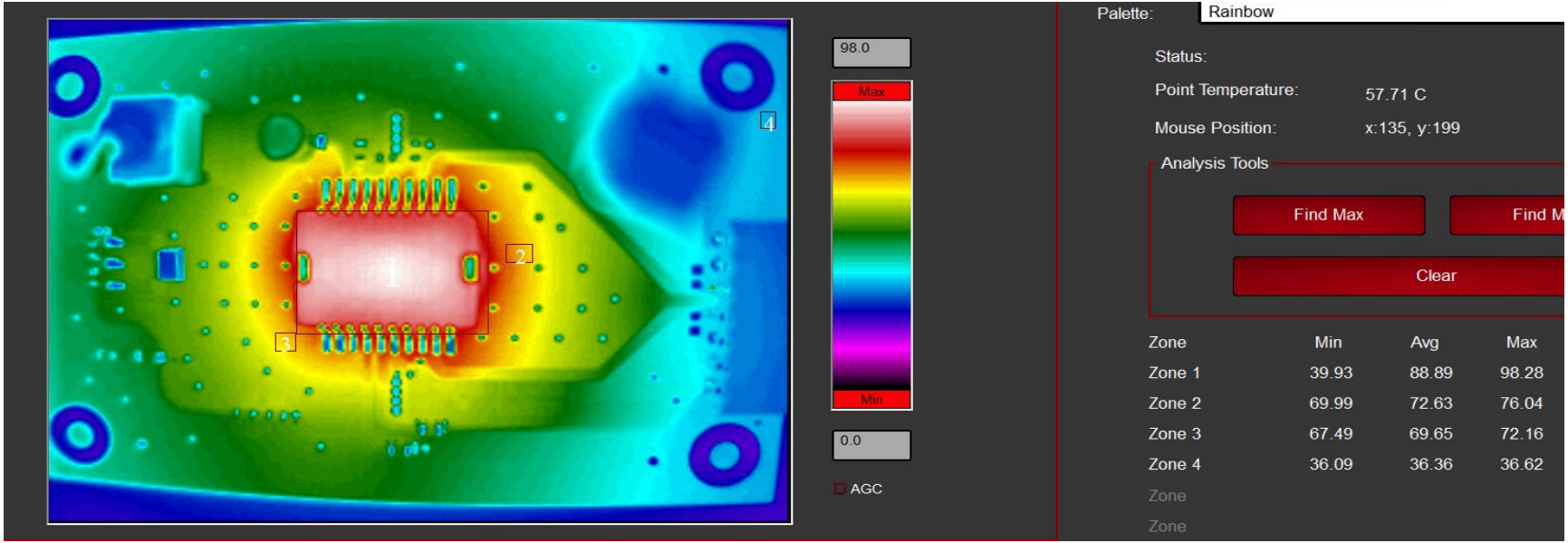
Class D

- Modulated with a high frequency signal. Typically to generate a pulse width modulated signal (PWM)
- The output transistors switch “on” to saturation and “off” to complete cut off.
- Voltage across the transistor is minimal during current flow for high efficiency.
- Typically 90% in modern PWM Class D amplifiers
- High frequency switching can be a challenge for EMC.



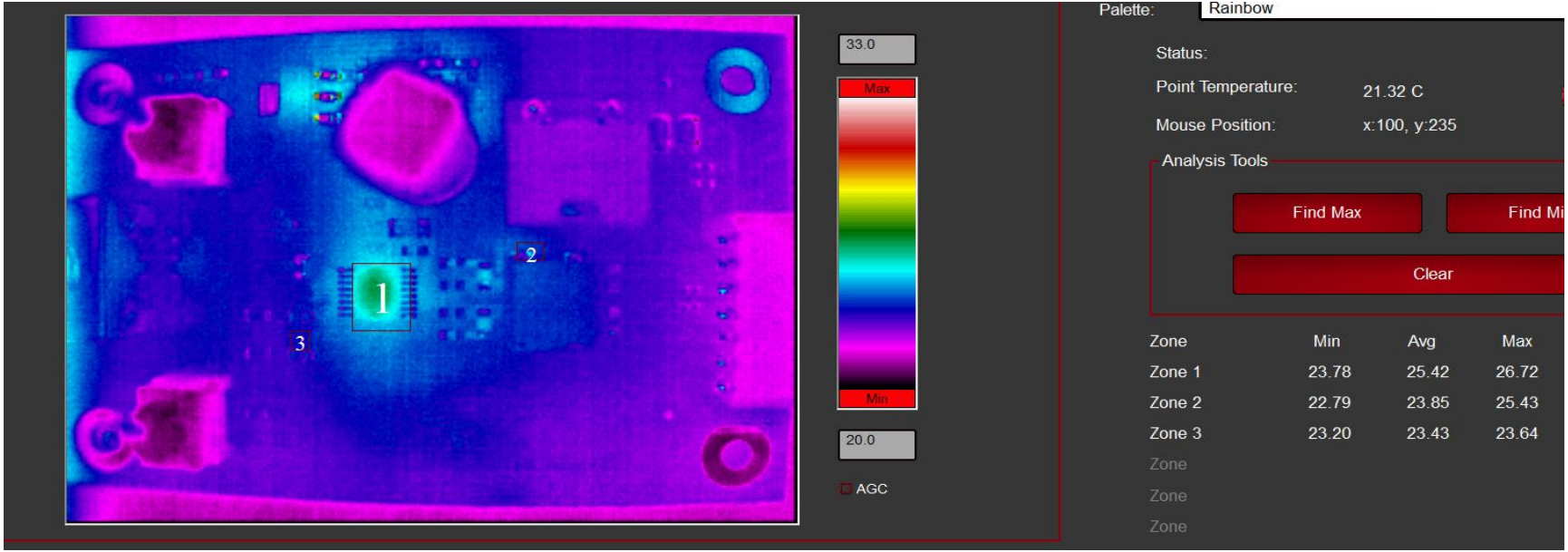
Thermal Image of PCB with Class-AB Amp

ST Power Amplifier. PVDD=14.4Vdc, 4 ohm load, 1W output



Thermal Image of PCB with Class-D Amp

TI TAS5421-Q1 Power Amplifier. PVDD=14.4Vdc, 4 ohm load, 1W output



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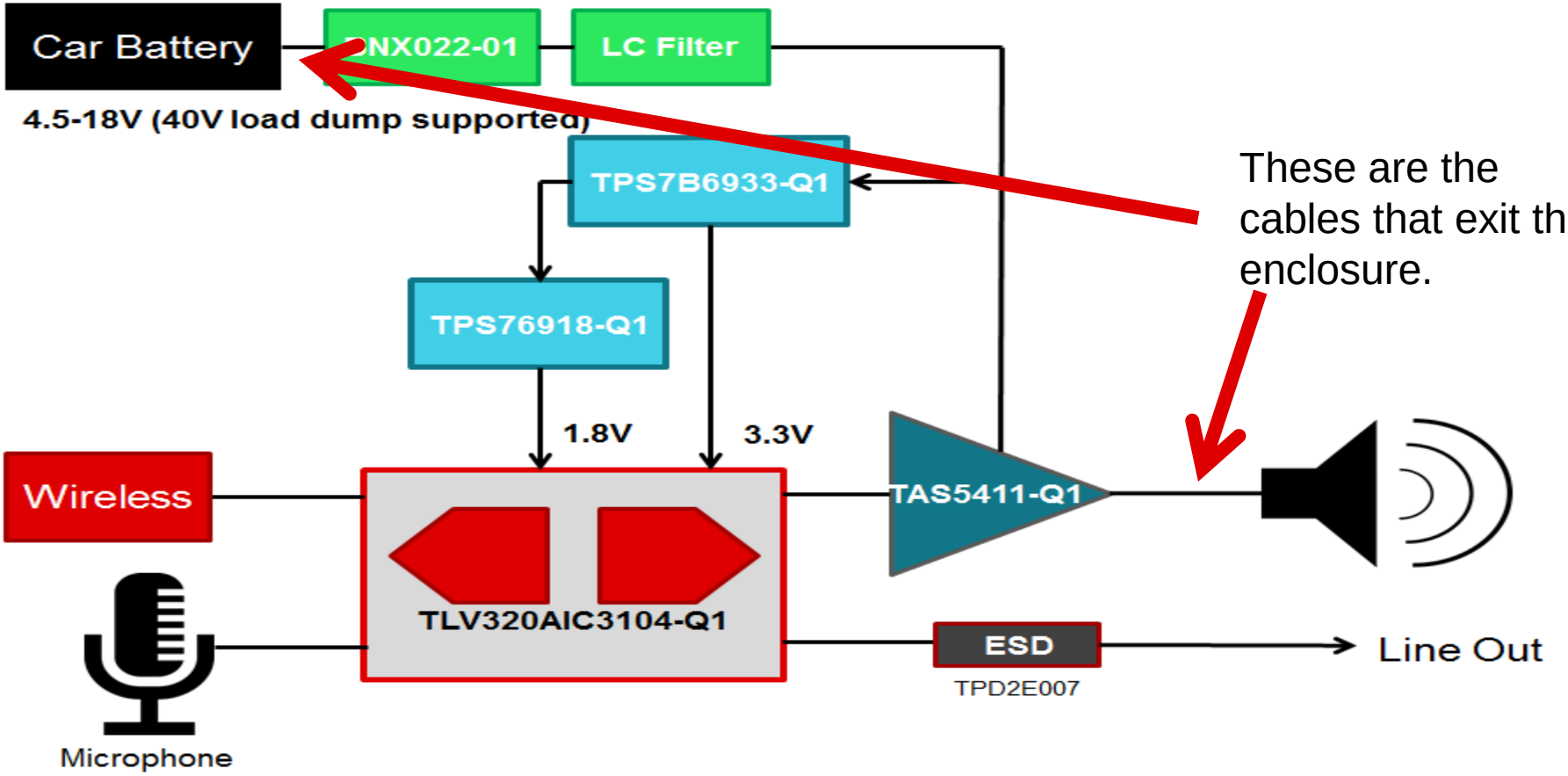
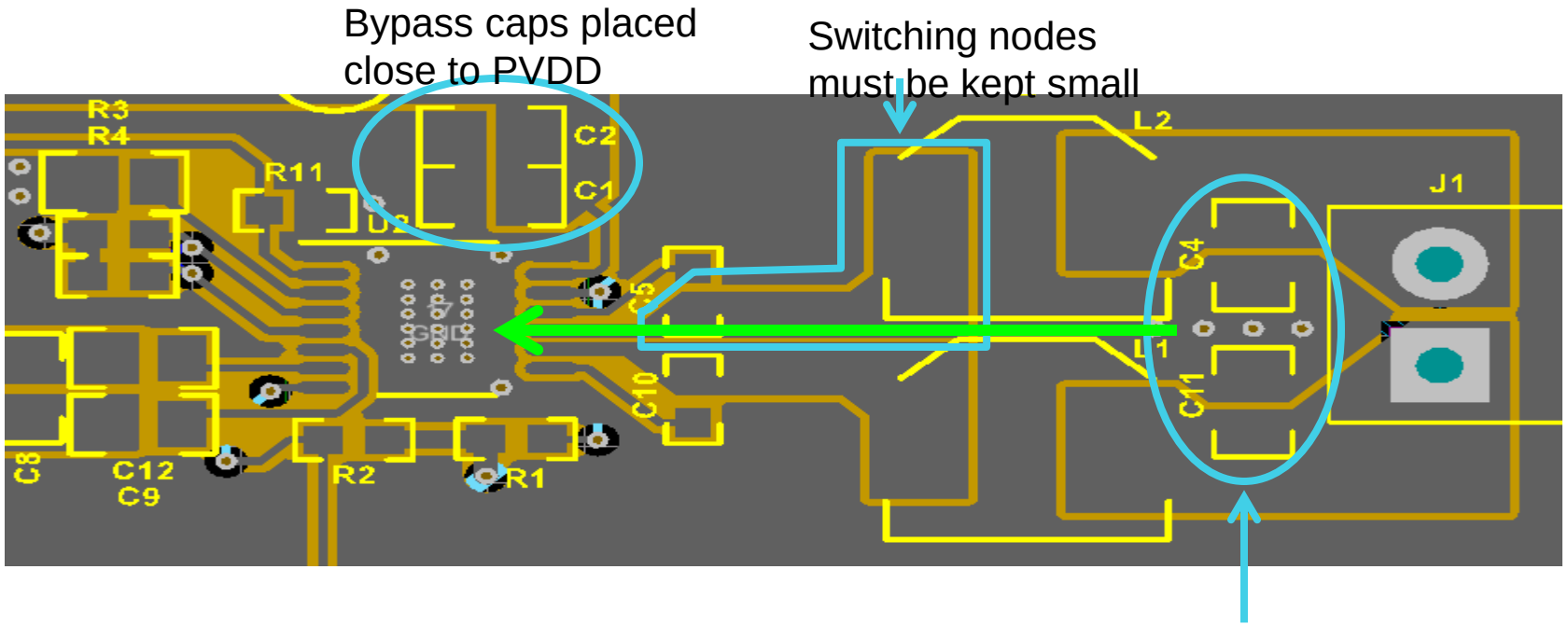
Designing for EMI/EMC

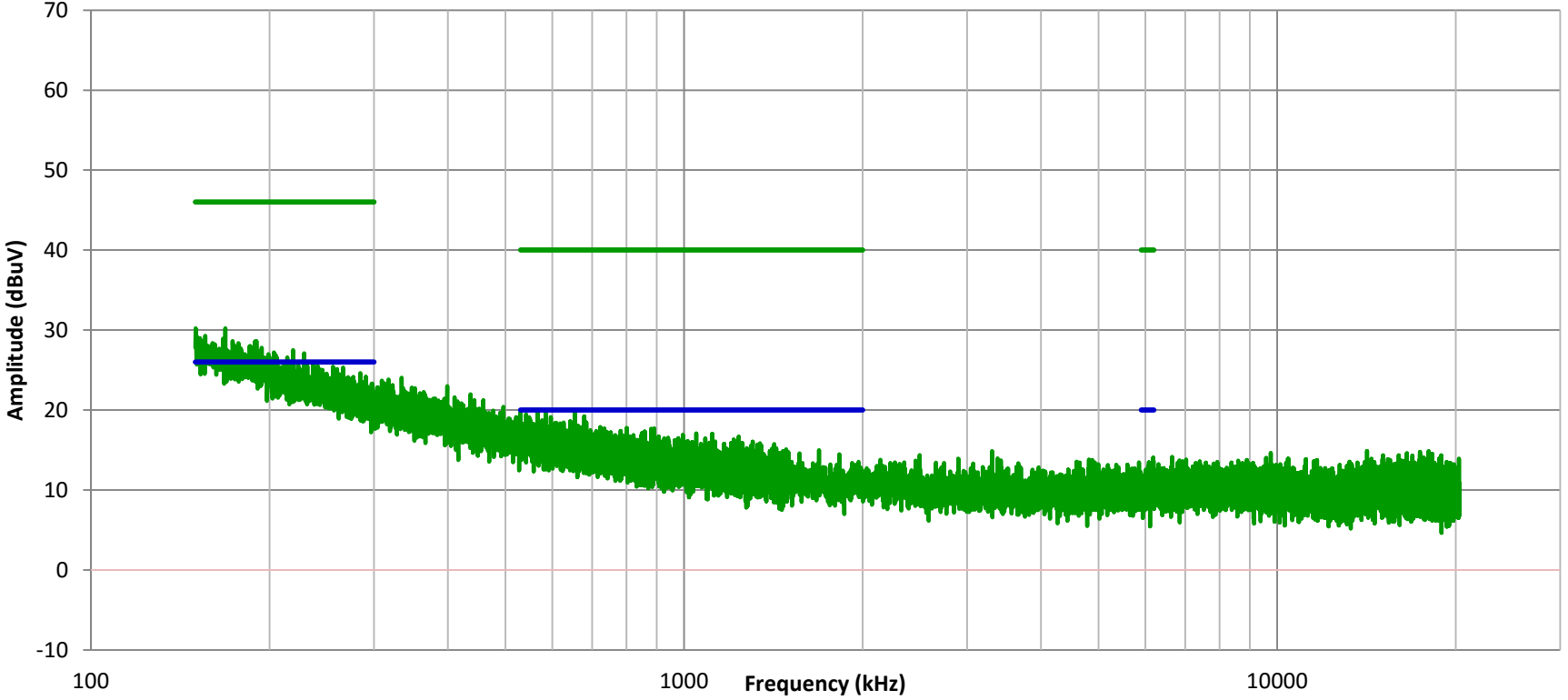
TIDA-00724 Block Diagram



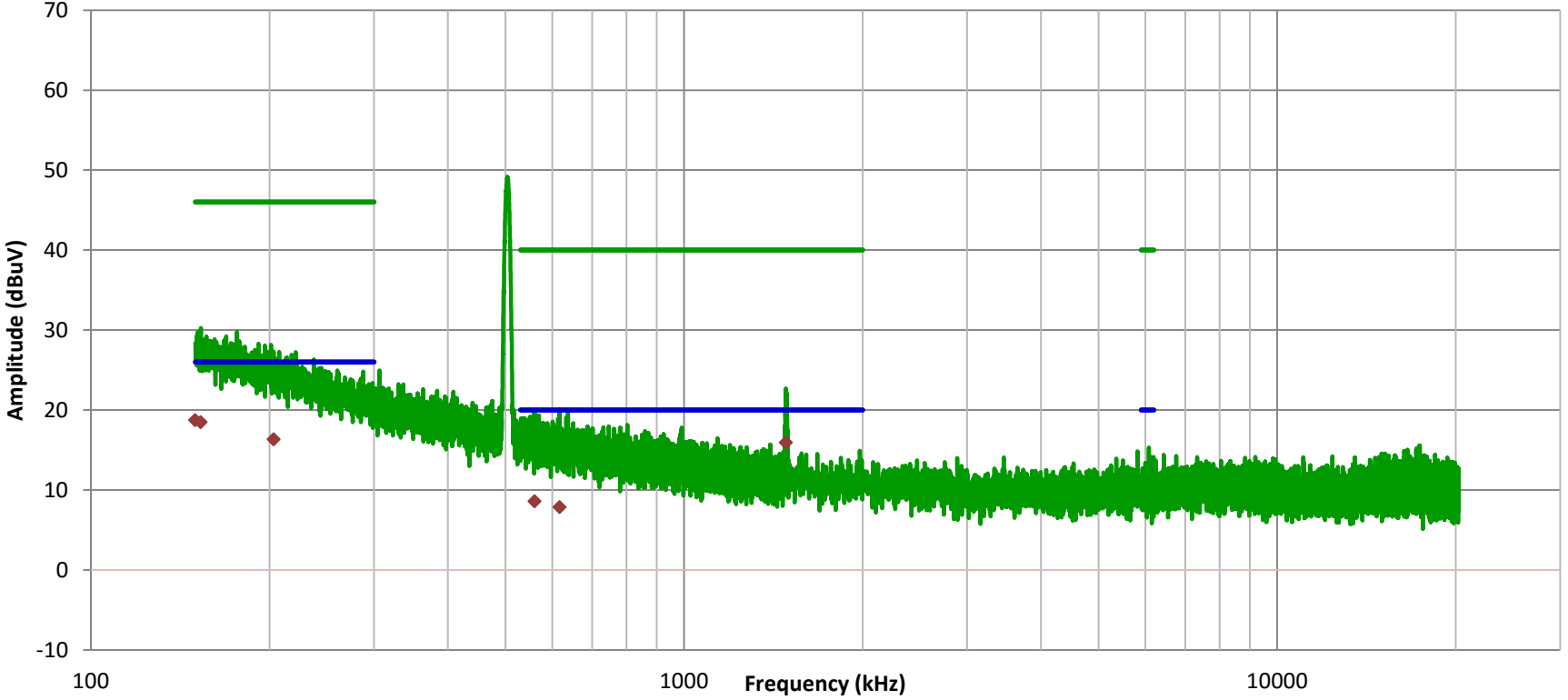
Layout Example



Monopole Antenna – Ambient



Monopole Antenna – 500kHz PWM Switching Frequency



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Collateral

Customer collateral

The following information is available for you to send for customers

Content title	Content type	Link to content or more details
TIDA-00724 eCall Audio Subsystem	TI Design for audio in eCall. Uses the TAS5411-Q1 and TLV320AIC3104-Q1	http://www.ti.com/tool/tida-00724
External Load Diagnostics Application Note	Application Note for external load diagnostics. Uses the TPA3111D1-Q1.	4Q 2016
Class-D Amplifier Short to Battery Protection	Application note describing short to battery protection options. Uses the TPA3111D1-Q1.	4Q 2016

Audio Emergency Call (eCall) Subsystem Reference Design

TIDesigns

Features

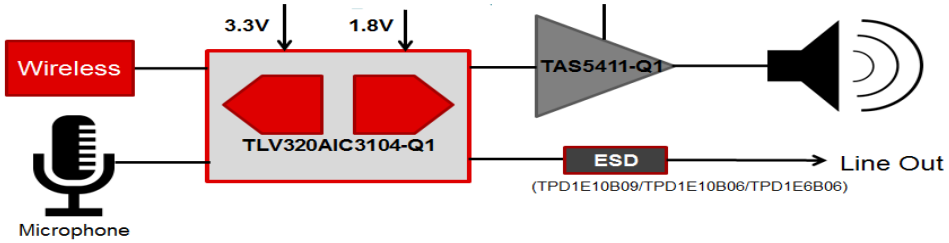
- Integrated load dump protection to withstand 40V voltage spikes
- Wide input voltage range: 4.5V - 18V
- Integrated diagnostics for output pin to pin shorts, short to ground, short to battery, and open load
- Up to 8W of output power through a 4 ohm speaker
- Dual channel TLV320AIC3104-Q1 allows for input from a microphone and audio data from a wireless module to facilitate a 2-way call
- Tested for radiated emissions according to CISPR-25
- Codec has configurable options for gain, digital audio format, PLL, and filtering

Applications

- Automotive Emergency Call (eCall)
- Telematics + eCall
- Gateway + eCall

Benefits

- The integrated load-dump protection reduces external voltage clamp cost and size
- Onboard load diagnostics report the status of the speaker through I2C, which reduces external components needed for diagnostic coverage
- TLV320AIC3104-Q1 + TAS5411-Q1 combo allows for:
  - reduced power consumption
  - reduced heat
  - reduced peak currents in the electrical system
- Loud, clear audio in an unpredictable emergency environment
- Ability to use an additional output from the codec for the head unit or other car audio needs



http://www.ti.com/tool/tida-00724

Texas Instruments

Questions