Audio in eCall and Cluster

Clancy Soehren – MSA Applications
FAE Summit 2016
Agenda

• Audio Architecture
• Audio Quality
• Diagnostics and Protection
• Efficiency
• EMI/EMC
Audio Architecture
Cluster Mid-Range Hybrid

Block Diagram

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Typical # sockets</th>
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<tbody>
<tr>
<td>Mid-Range Hybrid</td>
<td>18-36</td>
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</table>

- Voltage Conditioning Module
- Pre Boost
- Off Battery Buck
- Wide VIN LDO
- Reverse Battery Protection

- Buck
- LDO
- Processor w/Stepper Motor Driver
- Video Decoder
- Logic
- VIP MCU
- Ethernet
- CAN

- Stepper Motors
- 4-7" Display
- DAC
- Class D

- Ambient Light Sensor
- Temp Sensor
- LCD Bias Supply
- LED Backlight Driver
- Display Module

- 2nd Display
- Serializer
- Deserializer

- 1.8V 3.3V

- - - - - Optional

Texas Instruments
eCall with Li-Ion Battery

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

**Power Path**

- Vbat
- Reverse Battery Protection
- Off Battery Buck
- Pre Boost
- MCU
- Battery Charger
- Gas Gauge
- eCall

**Signal Path**

- Class D Amp
- DAC
- Audio Codec
- ADC
- UART
- RS232
- CAN Bus
- Bluetooth
- eCall Trigger
- Manual Trigger
- Lin
- Can
- ESD
- Bias
- 3.3V
- 5V
- 8-9V
- 4V
- 8-Vbat
- Speaker
- Microphone
- eCall
- 3.3V
- 5V
- 3.3V
- 4V
- 3.6V-3.9V ~3.6V/cell
- 3.6V-3.9V

**Note:**
- The diagram shows the connectivity and signal flow between various components, including power supply management, audio processing, and communication interfaces.
Audio Signal Path

Audio Signal Source

- Audio Signal Source
- Amp
- ADC
- Synthesized Digital Signal

Transmission/Processing

- Wireless Transmission
- DAC
- Storage Medium

Playback

- Amp
- DAC
- Amp
- Speaker
# eCall vs Cluster

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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

THDN $< 1\%$

THDN $\approx 10\%$

$\text{THDF} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1}$
Harmonic Content of Sounds

**Trumpet – A Note**

Fundamental = 440 Hz

**Clarinet – A Note**

Fundamental = 440 Hz
THD+N Examples

clipping

Figure 4. Total Harmonic Distortion + Noise vs Output Power

Gain = 20 dB  \[ V_{CC} = 12 \text{ V} \]  \[ Z_L = 8 \Omega + 66 \mu \text{H} \]

Figure 6. THD+N vs Frequency
THD+N – What Causes Distortion?

- Amp
- ADC
- Transmission
- DAC
- Amp

Compressed to 48kHz bandwidth

0.01% – 0.1% THDN

1% - 5% THDN
Maximum Output Power vs PVCC to Avoid Clipping

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

\[ V_{headroom} = \frac{R_{dson}}{2 * R_{dson} + R_L} \times PVCC \]

\[ P_o = \frac{V_{RMS}^2}{R_L} = \frac{V_{peak}^2}{2 * R_L} \]
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.
Output Filter Frequency Response

- Simple LC reconstruction filter
- $f_c = 27.7\text{kHz}$

### Design Equations:

$$Q = R_L \cdot \sqrt{\frac{C}{L}}$$

$$Q = \frac{1}{\sqrt{2}}$$

$$\omega_c = \frac{1}{L \cdot C}$$

![Figure 9: Frequency Response of LC Filter, $L = 15\mu\text{H}$, $C = 2.2\mu\text{F}$, $R = 2$ ohms Single Ended](image)
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.
## eCall vs Cluster

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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

Long wires

DAC → Amp → Speaker
External Load Diagnostics

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

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<td>Open load</td>
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<td>Short to PVCC</td>
<td>LED on SP+ on, LED on SP- off</td>
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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

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<td>Comparator (2 per channel)</td>
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<tr>
<td>2 GPIO channels on MCU</td>
<td>Dependent on MCU</td>
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<tr>
<td>PCB space</td>
<td>Affects system cost</td>
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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 $\frac{1}{2}$ 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 $\frac{1}{2}$ 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
These are the cables that exit the enclosure.
Layout Example

Bypass caps placed close to PVDD

Switching nodes must be kept small

Return path through caps of LC filter must provide clear path to ground.
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

<table>
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<th>Content title</th>
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<th>Link to content or more details</th>
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<tr>
<td>External Load Diagnostics Application Note</td>
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<tr>
<td>Class-D Amplifier Short to Battery Protection</td>
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## Audio Emergency Call (eCall) Subsystem Reference Design

### 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

### 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

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

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