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# PurePath® Digital Audio Power Amplifiers

## Application Overview

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# Topics

- Target Markets
- Signal Path/Device Examples
- DSP Interface Example
- Power Supply Considerations
- Thermal Overview
- PCB Layout
- Key Components – Critical Parameters
- Putting it all together

# Target Markets

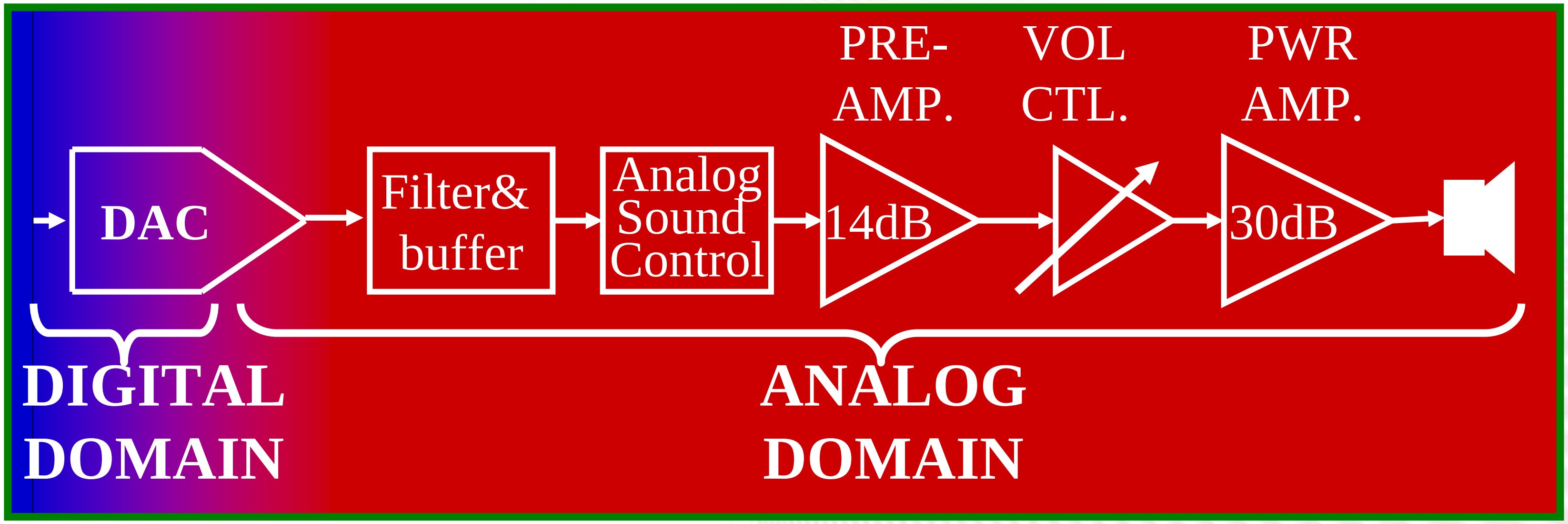
| EE | DVDR/HTIB | Mini/Micro Component | AVR |
|---|---|---|---|
| |  |  |  |
| Price | $200 to $1000 (w/ speakers) | $50 to $300 (w/ speakers) | $200 to $500 (stand-alone) |
| # of ch's | 5.1 to 7.1 | 2.0 to 2.1 | 5.1 to 7.1 |
| Power per ch | 50W-200W/3-6Ω/10%THD | 10W-300W/3-6Ω/10%THD | 70W-150W/8Ω/<0.09%THD |
| Sources | DVDR, Tuner, (VCR) | CD, Tape, (DVD), (HDD) | FM Tuner, (XM) |
| Appearance | "Sleek and stylish" | "Reincarnation of the '80's rack systems" | "Big/heavy, bells and whistles" |
| Other | Power often rated as PMPO;<br>SMPS is default; | Power often rated as PMPO;<br>Typically SMPS; (sometimes linear) | Typically FTC power and THD rating;<br>Advanced audio proc. features (DSP); |
| Care-abouts: Primary… | Cost; development time;<br>Form factor/weight<br>Efficiency (small heat sink) | Cost; development time;<br>robustness | Audio performance; features;<br>Lots of I/O's |
| Secondary… | Audio performance; features | (Form factor); audio performance | (cost); efficiency; |

# Conventional Signal Path

DAC needed
- Analog processing
- Complex & long analog signal path:

**Sound degradation!!!**

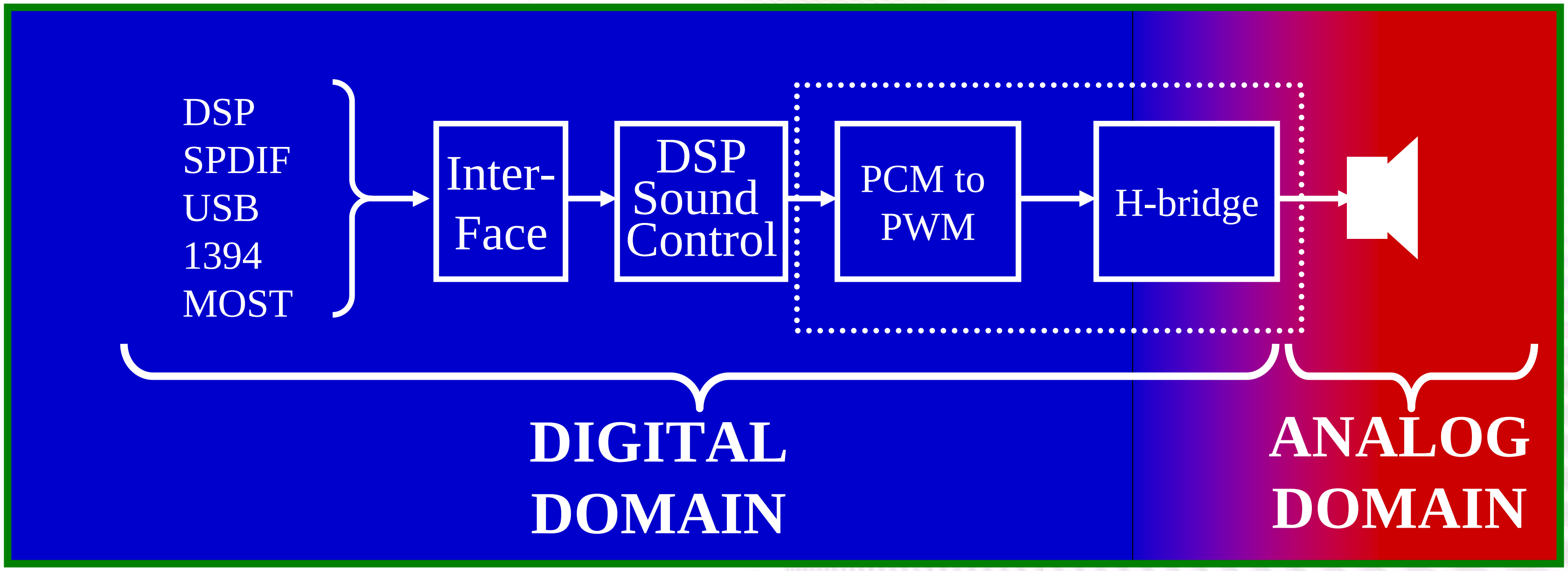
High Analog Gain:
- Sensitive to noise & Hum pick up
- SNR at speakers is much lower than theoretical DAC spec



# PurePath® Modulator Signal Path

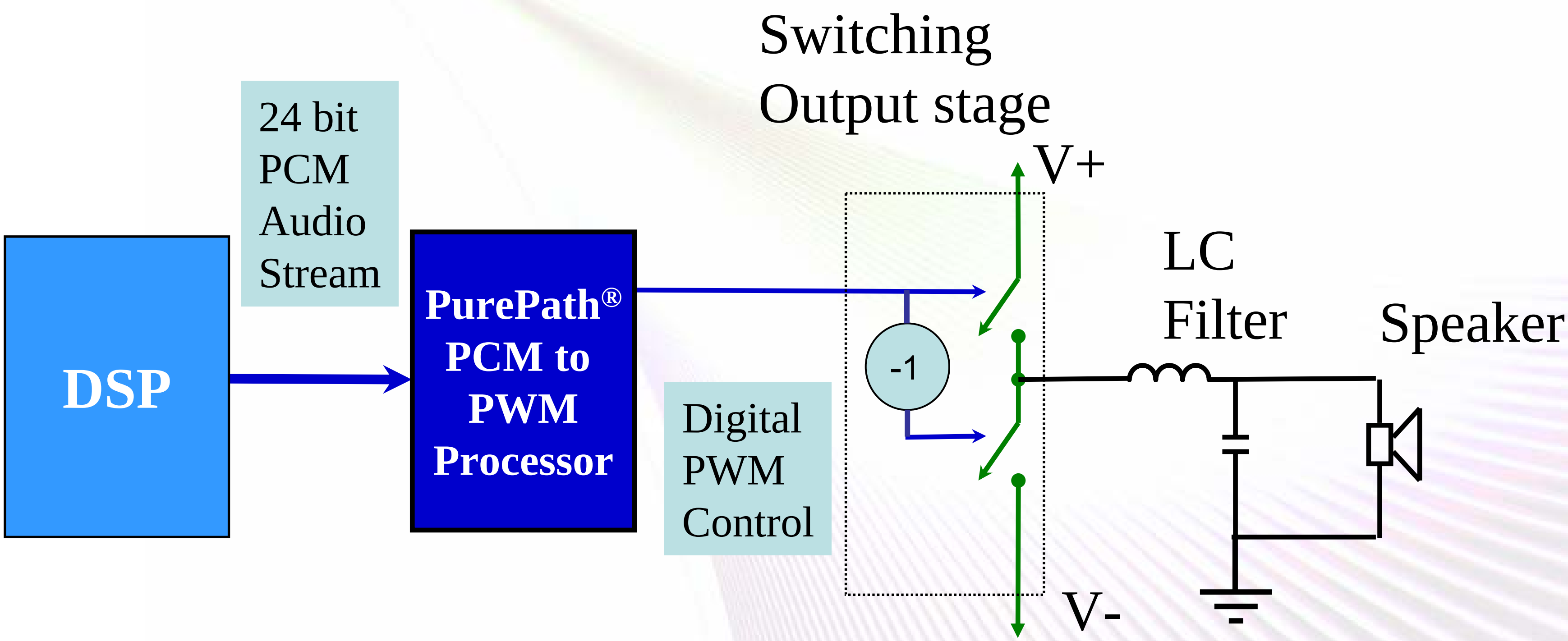
- True digital path
- Only digital processing
- No analog processing
- No D/A converter used

- No-loss DSP sound control
- No gain or amplification
- Digital is immune to noise/ hum pick-up



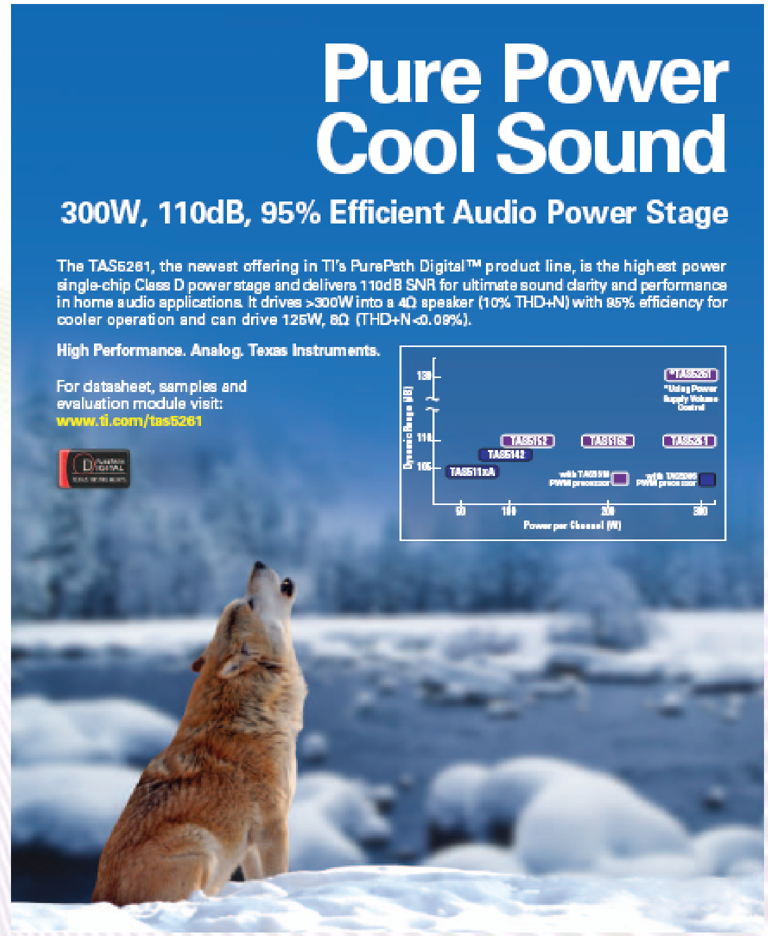
# PurePath® Modulator

(Basic Principle)



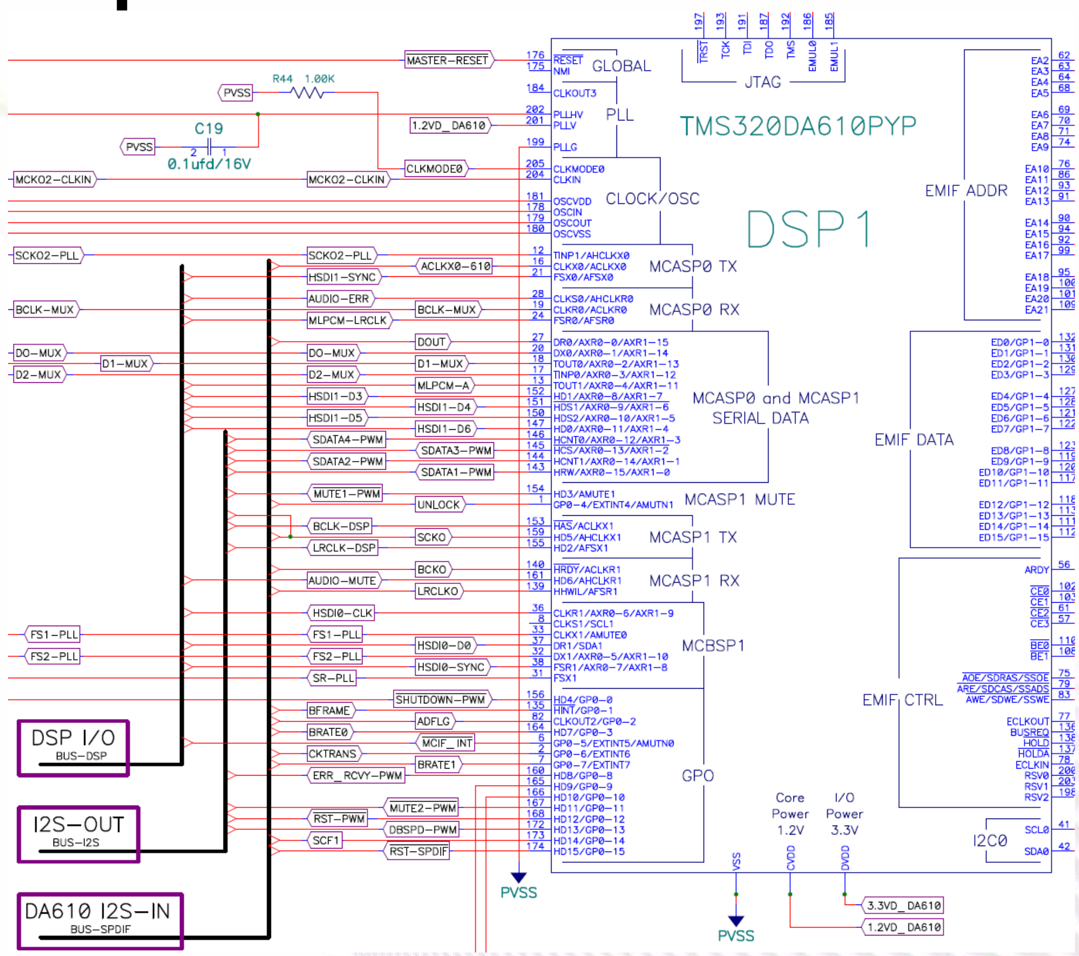
# Examples of Devices

- **PCM to PWM Modulators**
  - **TAS5086**
  - **TAS5508B**
  - **TAS5518A**
- **Power Stages**
  - **TAS5142 (2x100W)**
  - **TAS5152 (2x125W)**
  - **TAS5186A (5x25W + 1x50W)**
  - **TAS5261 *NEW (1x300W)***
  - **TAS5132 *NEW (2X25W)***
  - **TAS5162 *NEW (2X210W)***



# DSP Interface Example

# DSP/Amplifier Interconnect




Interface Port to Amplifiers

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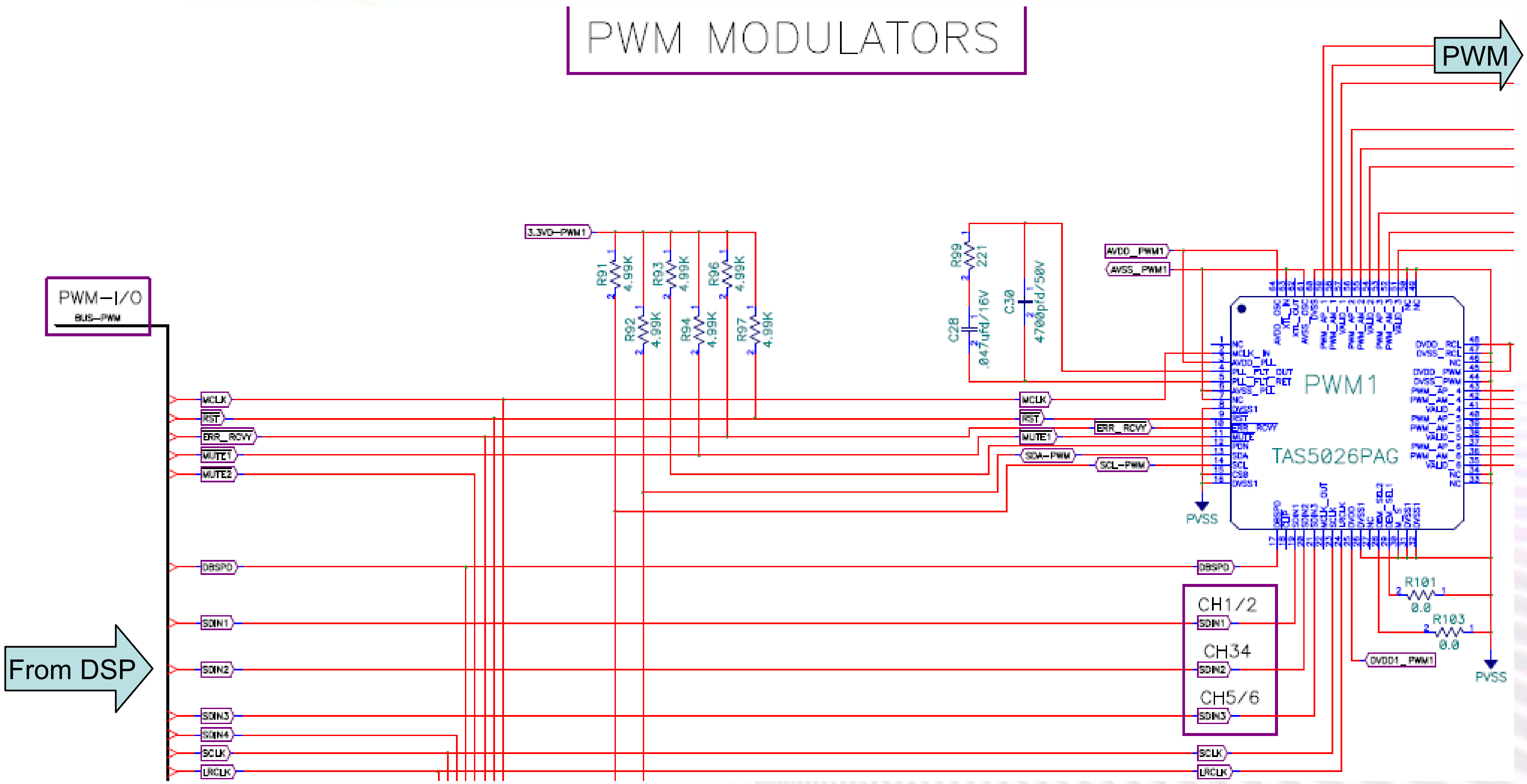
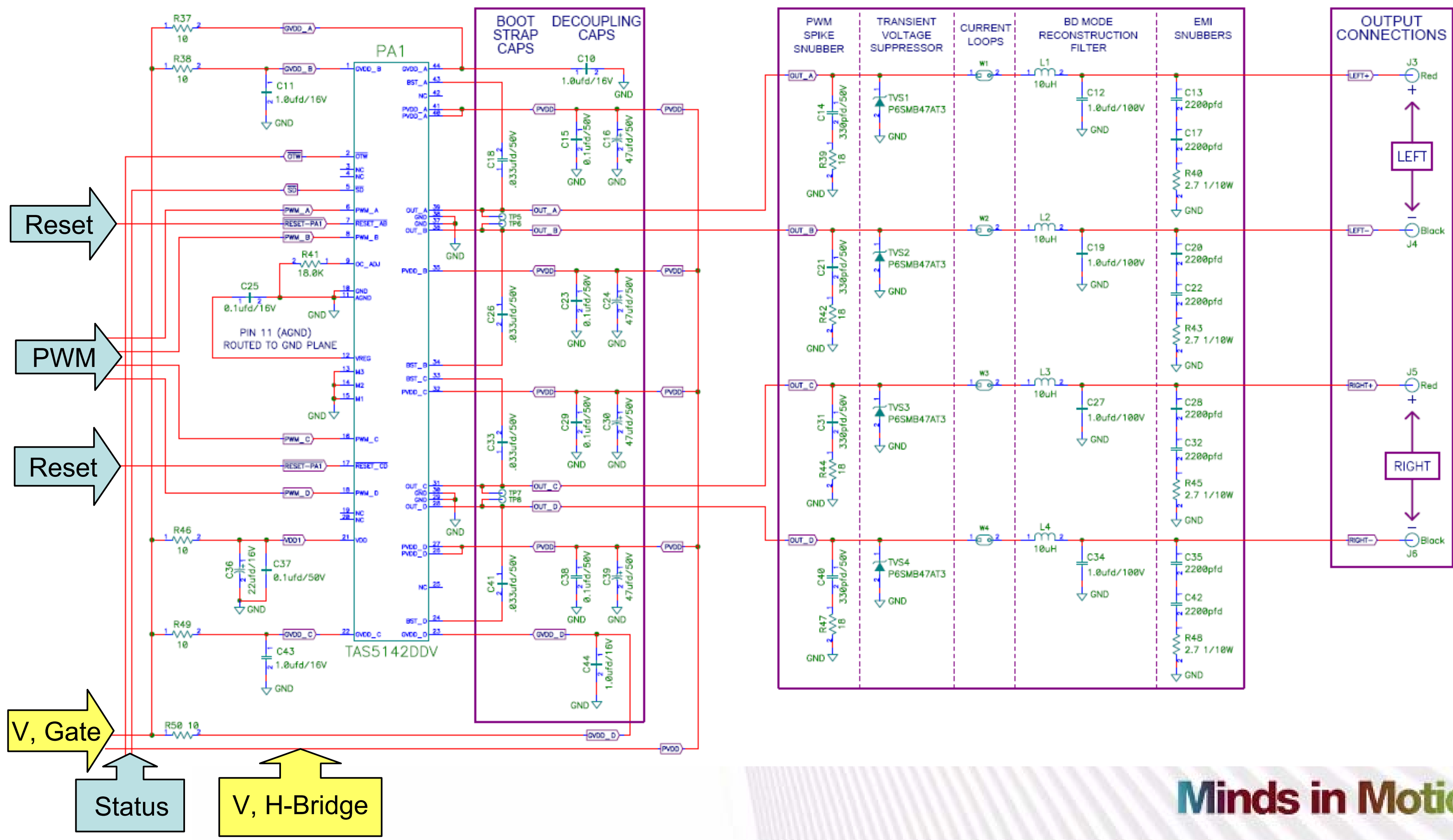
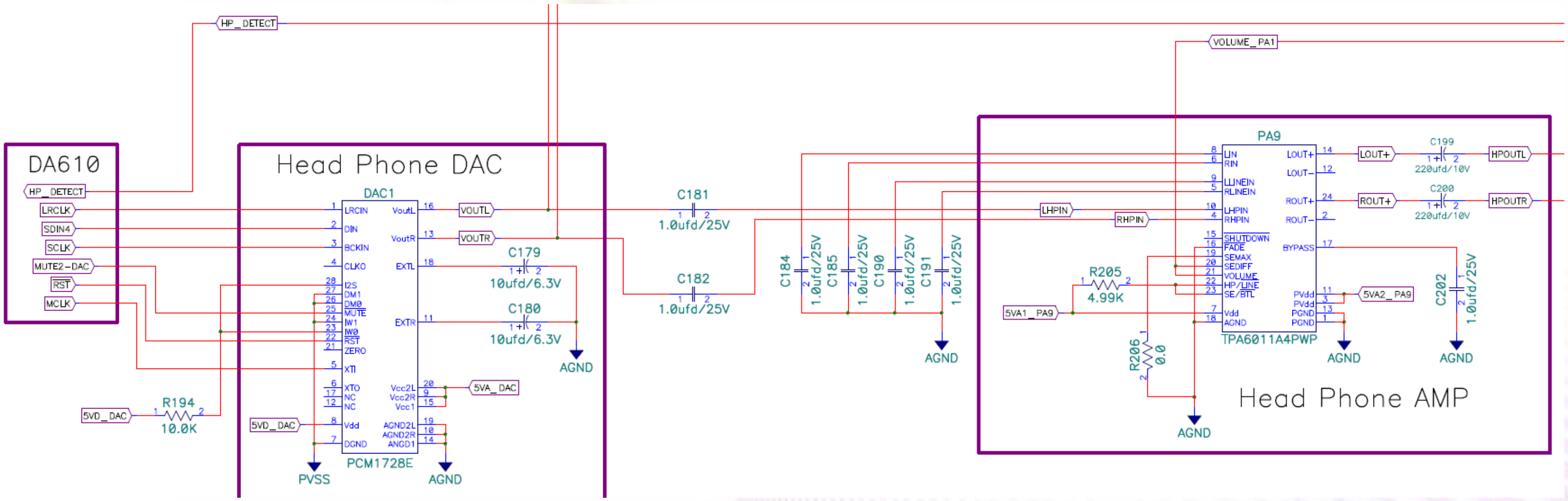
# DSP Connection to Modulator



# Modulator to Power Stage



# DSP to DAC and Headphone Amp



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# Power Supply Considerations

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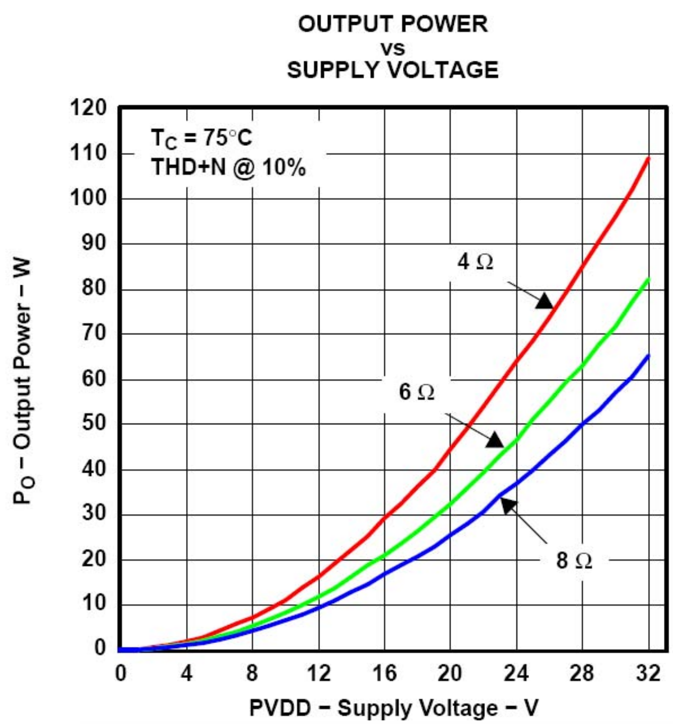
# Voltage Requirement

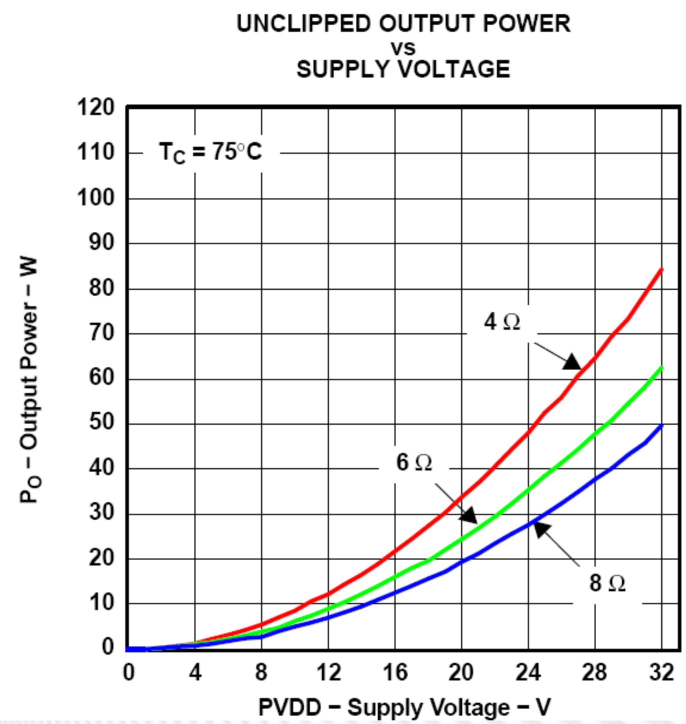
- **Using following equation:**
  - **Voltage needed for an application can be calculated as:**

$$V_{PSU} = \frac{\left(R_{LOAD} + 2 \cdot \left(R_{DSon} + R_{INDUCTOR}\right)\right) \cdot \sqrt{\left(2 \cdot P_{MAX} / R_{LOAD}\right)}}{M}$$

# Voltage Requirement

- Graphs from TAS5142 datasheet:



# Power Requirement

- Typical music and movies have 12-15dB headroom from average power to peak power.
- This corresponds well with normal requirement of testing all channels at 1/8 power for 1 hour.
- Different government regulations and company preferences require higher power for shorter periods of time.

| Specification | Preconditioning (Warm-Op) | Time at Continuous Rated Power |
|---|---|---|
| DIN EN 61305-3 | None | 600 seconds |
| EIA/CEA-490-A | 1/8 power for ½ hour | 5 minutes (1) |
| FTC 16 CFR Part 432 | 1/8 power for 1 hour | 5 minutes (2) |

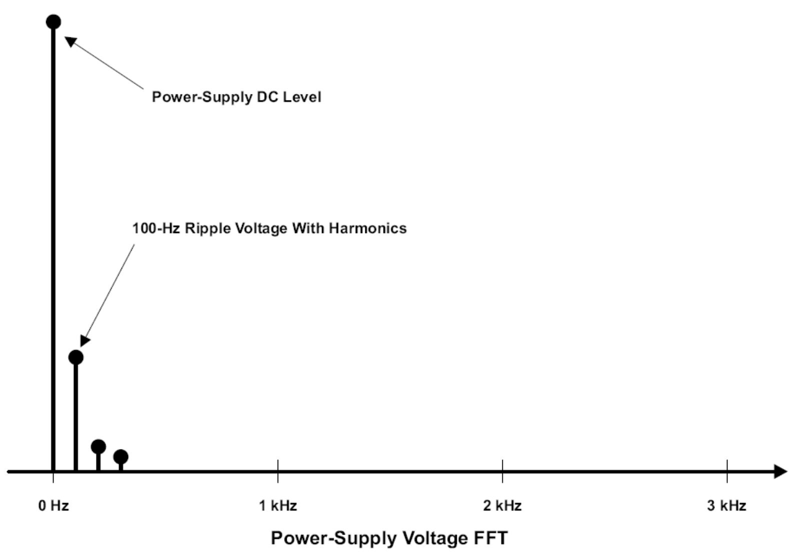
(1) Each channel is tested individually with the other channels at 1/8 power.
(2) Channels in same frequency range test at full power. The subwoofer test is separately.

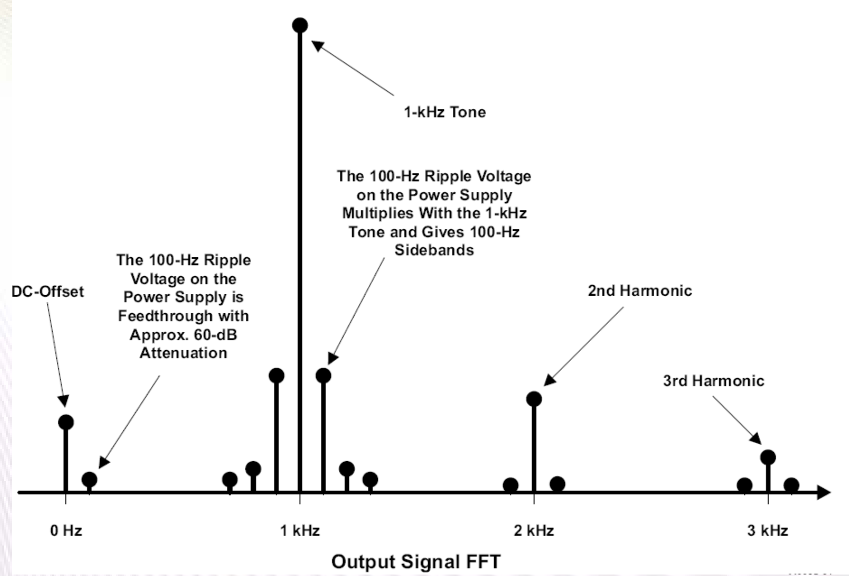
# Power Supply Rejection Ratio

- PSRR is well known for class AB amplifiers.
- Normal definitions of PSRR also apply for Class D amplifiers using feedback.
- PurePath® digital amplifiers do not use feedback; PSRR term is slightly different:
  - Vout(t) = Vpsu(t) x d(t)
- Conventional mains transformer supply will have 100Hz/120Hz ripple.
- Common Switch Mode Power Supplies (SMPS) switch in the 100KHz to 200KHz range; therefore, their ripple is out of the audio band *and* they are regulated.

# Power Supply Rejection Ratio

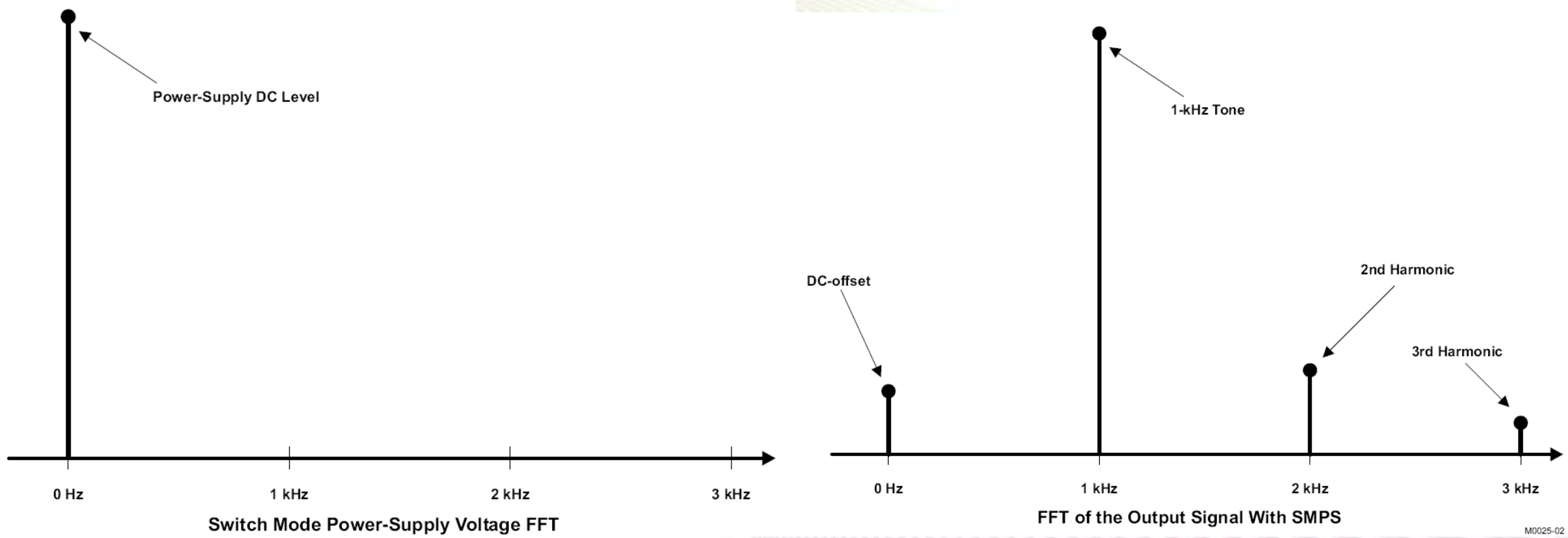
- Conventional mains transformer supply will have 100Hz/120Hz ripple.



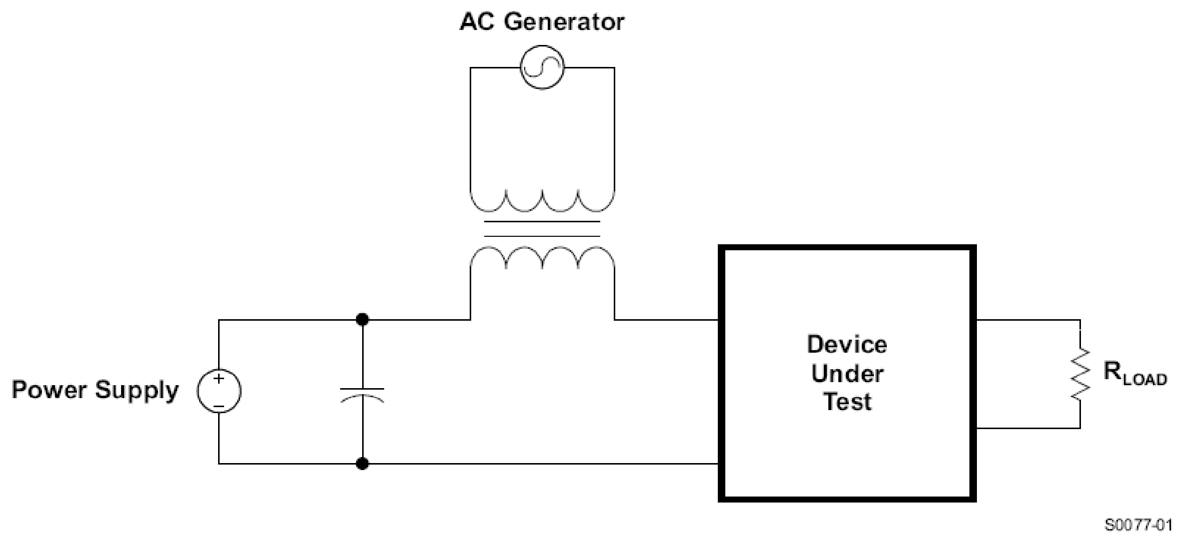
# Power Supply Rejection Ratio

- A switch mode power supply will not have ripple within the audio band.



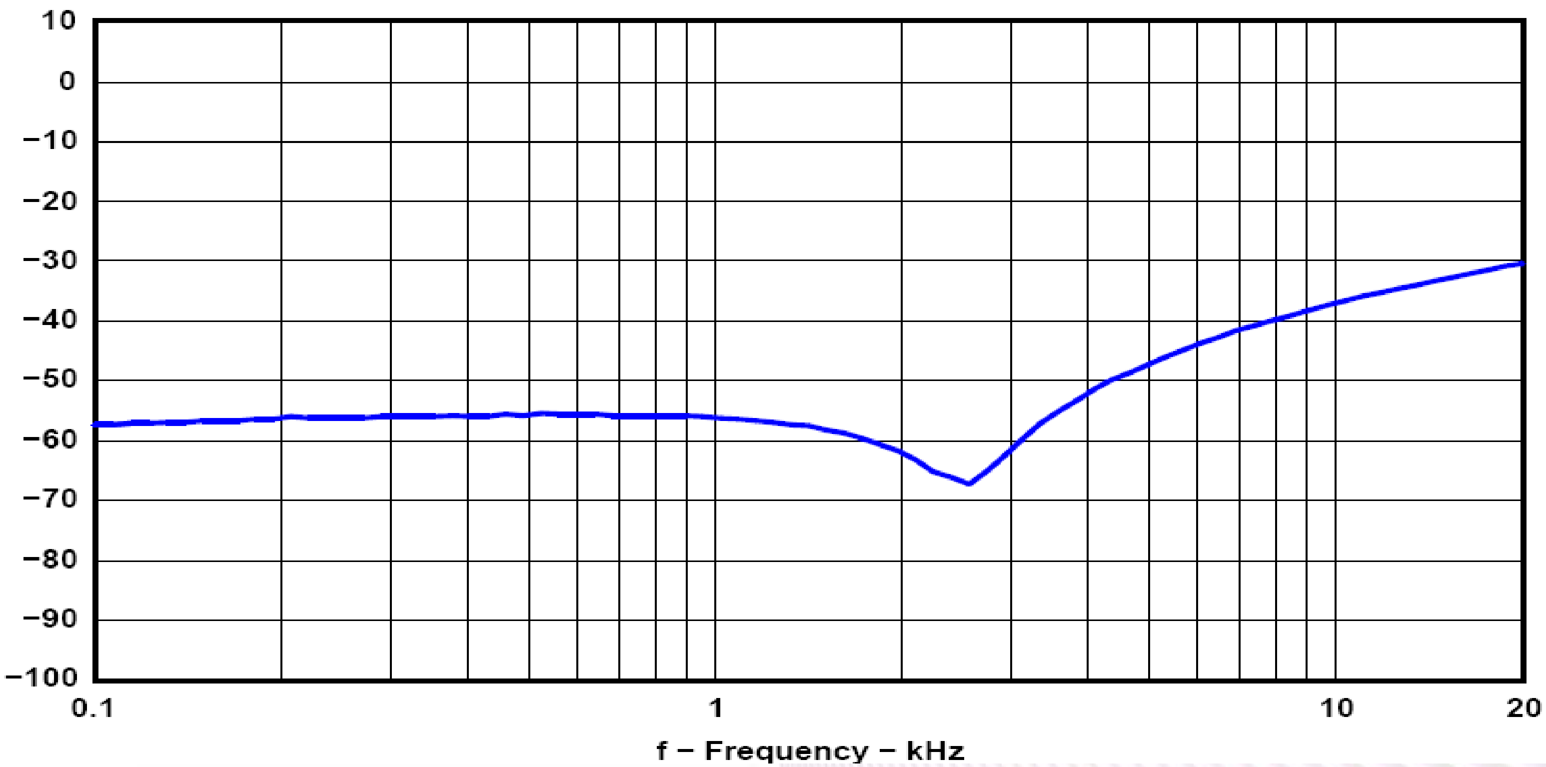
# Power Supply Rejection Ratio

- How to measure PSRR




$$PSRR(f) = 20 \cdot \log \frac{V_{OUT}(f)}{V_{INJECT}(f)}$$

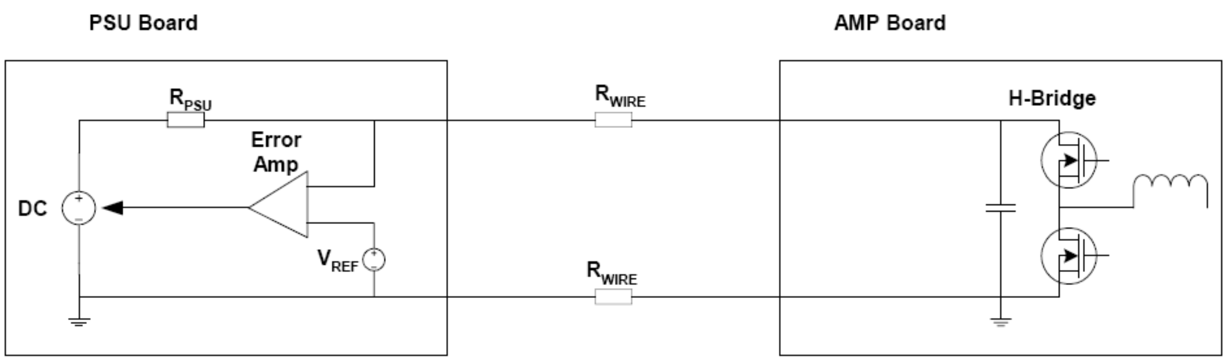
# Power Supply Rejection Ratio



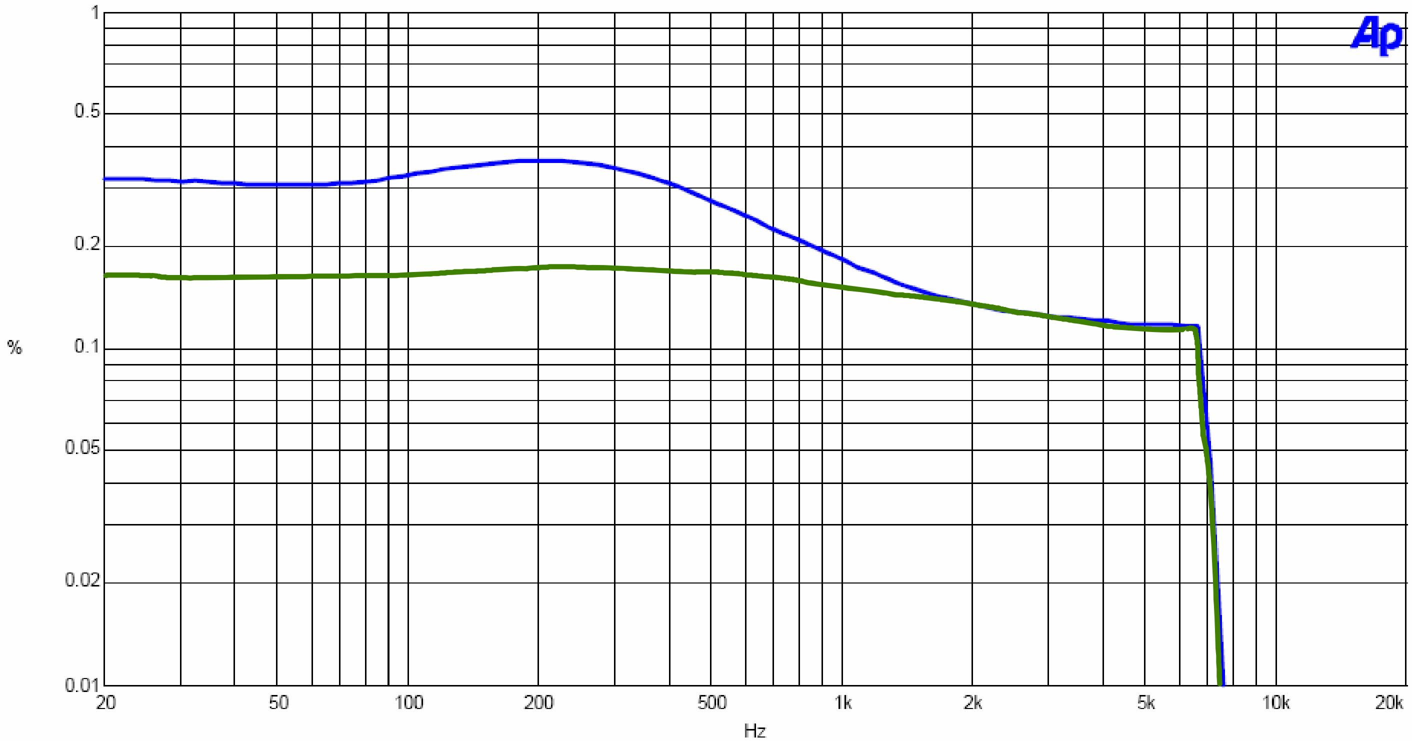

PSRR measurement for TAS5086-5142V6EVM

# Power Supply Output Impedance

- The Power supply output impedance and the wire resistance to and from the amplifier will affect THD performance of the amplifier.
- If designed poorly, THD will increase at low frequencies up to around 1kHz, depending on application.
- This is due to the fact that the current to the amplifier is twice the frequency of the audio current.



# Power Supply Output Impedance




Blue Line – High power supply Output Impedance
Green Line – Correct power supply Ouput Impedance

# More Info

- Power Supply Recommendations for DVD Receivers, TI Literature No. SLEA027
- Power Supply Recommendations for A/V Receivers, TI Literature SLEA028
- PSRR for PurePath Digital Audio Amplifiers, TI Literature SLEA049

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# Thermal Overview

# Device Thermal Parameters

- The thermal parameters for each device are available in its datasheet.
- As in the case of the power supply, the size of the heatsink is dependant on the system thermal requirement and its power specification.
- The thermal solution is generally not designed to accommodate all channels (if there are >2) at full power, simultaneously.

| Specification | Preconditioning (Warm-Op) | Time at Continuous Rated Power |
|---|---|---|
| DIN EN 61305-3 | None | 600 seconds |
| EIA/CEA-490-A | 1/8 power for ½ hour | 5 minutes[1] |
| FTC 16 CFR Part 432 | 1/8 power for 1 hour | 5 minutes[2] |

(1) Each channel is tested individually with the other channels at 1/8 power.
(2) Channels in same frequency range test at full power. The subwoofer test is separately.

# Heatsink Size

- In many cases a heatsink of 2.5°/W to 4.5°C is appropriate.
  - There are many variables such as airflow and test temperature to be considered.
- TI EVMs are delivered with a good thermal solution.
  - It may be necessary to change the size or geometry to meet space constraints or other system factors.

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# PCB Layout

## - Do's and Don'ts

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# PCB Layout and EMI

- PCB layout, Audio Performance and EMI are linked closely together.
- Generally EMI is concerned with reducing EMI sources and removing antennas.
- Circuit contains high currents at high frequencies.
- Care must be taken to prevent unwanted ringing and spikes.
- Current loops with high currents and high frequencies act as EMI sources and must be kept as small as possible.
- Small signal level CMOS inputs can pick up noise and must therefore be kept away from EMI sources.

# Ground Plane

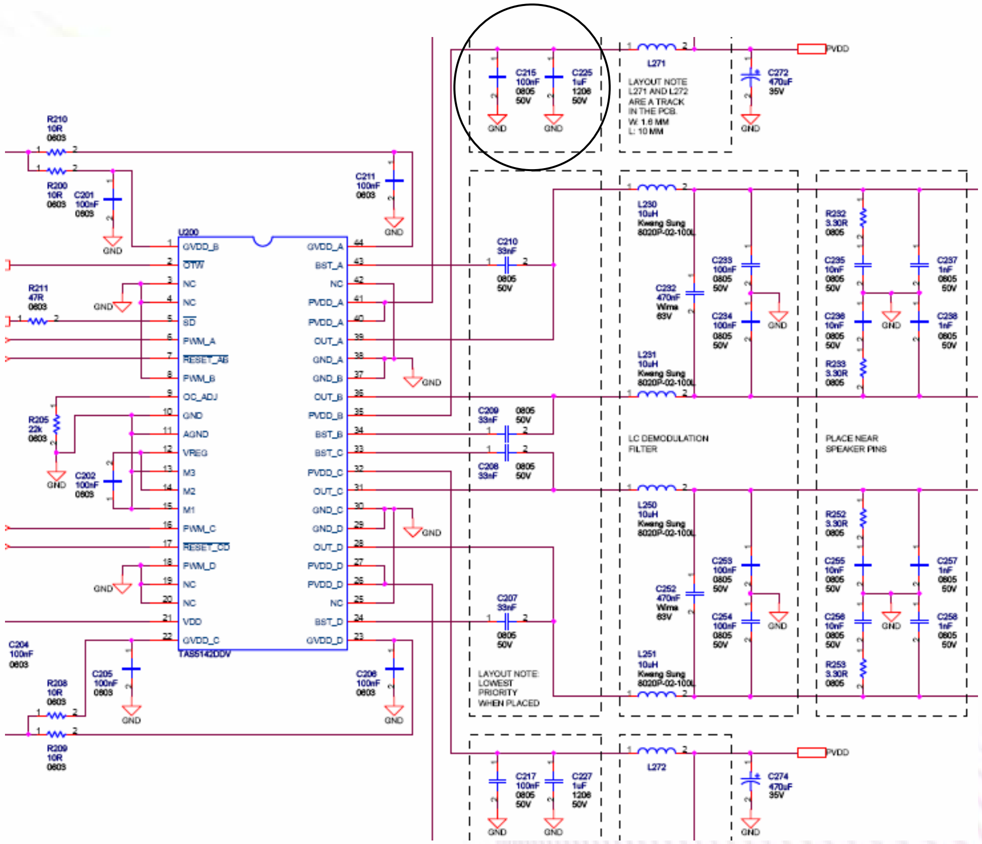
## Ground Plane → The forgotten return path

- Every signal has a return current.
- Routing of the return path is just as important as signal current.
- The best/only solution is the use of a ground plane.
- Ground plane is an unbroken Cu-PCB layer only used for ground signal.
- Optimum path for return currents then becomes embedded in the design.
- Note that optimum return path is not necessarily the shortest path for high frequency currents.

# Routing of Sensitive Tracks

- Decoupling capacitors must be placed close to the device. Goal - .050” of PCB track length in decoupling path.
- All Power tracks must be designed with care to get good audio and EMI performance.
- PWM tracks must go as directly as possible from TAS5086/TAS5508 to TAS5142 and other power stages. The tracks must not interleave the PCB.
- MCLK track must be as short as possible and must always be accompanied by ground.

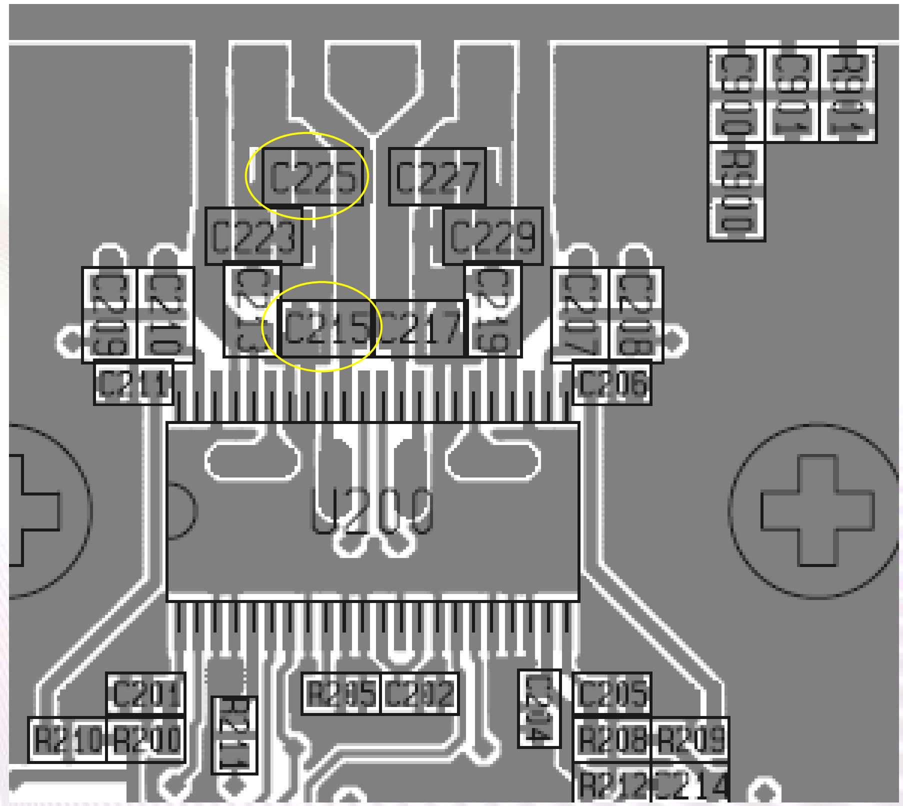
# Implementation of TAS5142




- **PWM output voltage goes from 0V to 32V within 5ns.**
- **Ripple current in inductors is 2A at 384kHz in idle.**

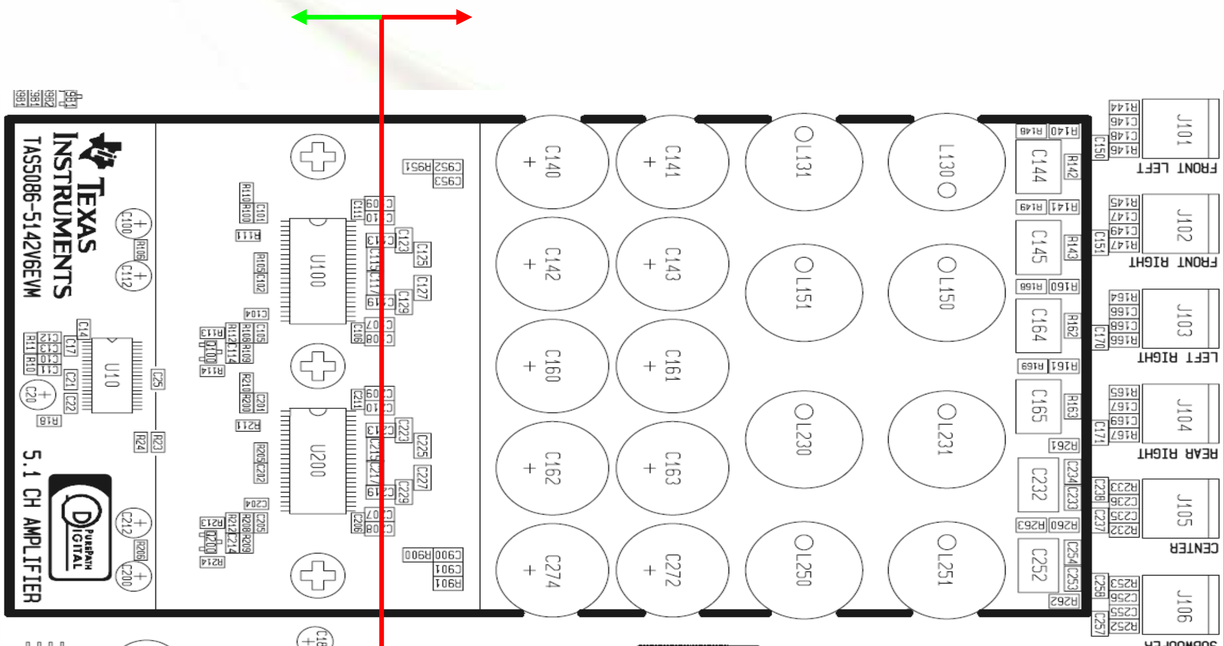
# Implementation of TAS5142

- Decoupling capacitors must be placed close to the device.
  - Return path should be on the top PCB layer (with the device)
- High power and high frequency paths must be routed with as few vias as possible.
- A via has 5nH to 7nH of inductance.



# PCB Ground Domains

- PCB must be divided into a high power zone and a low power zone.



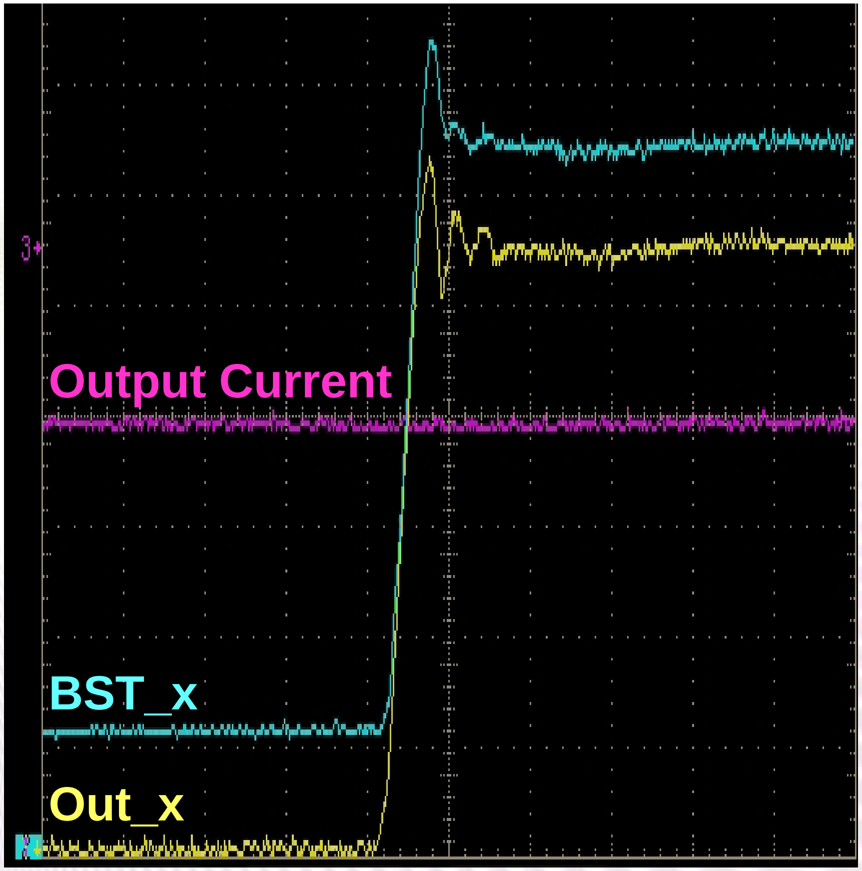
Low power and sensitive electronics

High power electronics

***This does not mean split the plane! (or you may develop a "Contentious Plane")***

# Spike Voltage

- Spike voltage is the voltage overshoot on the output pins.
- Its amplitude is a function of current and is maximum during an error event (short circuit).
- The Absolute Maximum Voltage specified for the device <u>includes</u> the spike voltage.



# Voltage Spike Reduction

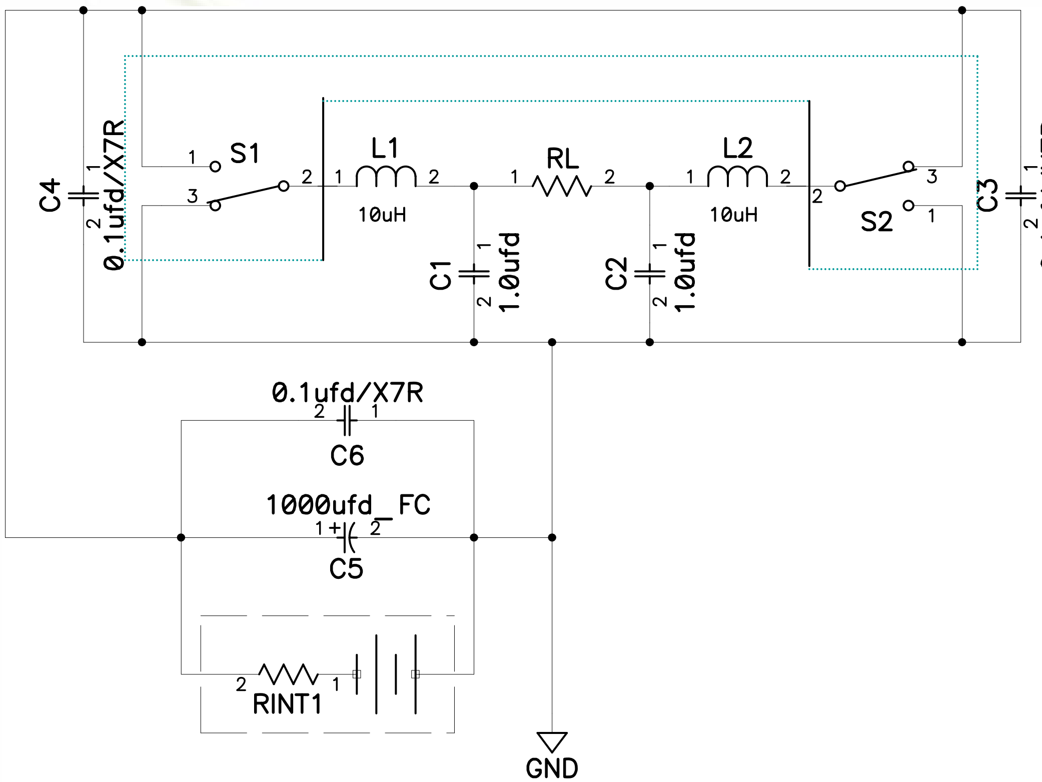
- Good PCB layout
  - Careful placement of close decoupling caps
  - PVDD bulk cap close to power stage
  - Good ground plane
- Use Transient Voltage Suppressors (TVS)
  - Bi-Directional TVS should be used
  - 1SMAxxx series for all designs except TAS5261 and the TAS5162
  - 1SMBxxx for the TAS5261and the TAS5162
  - TVS's will also decrease system issues with ESD
- Spike Voltage will adversely impact device reliability and cause EMI problems.

# Key Components –

## and their Critical Parameters

# Simplified Amplifier Diagram

**Power Stage is S1 and S2**

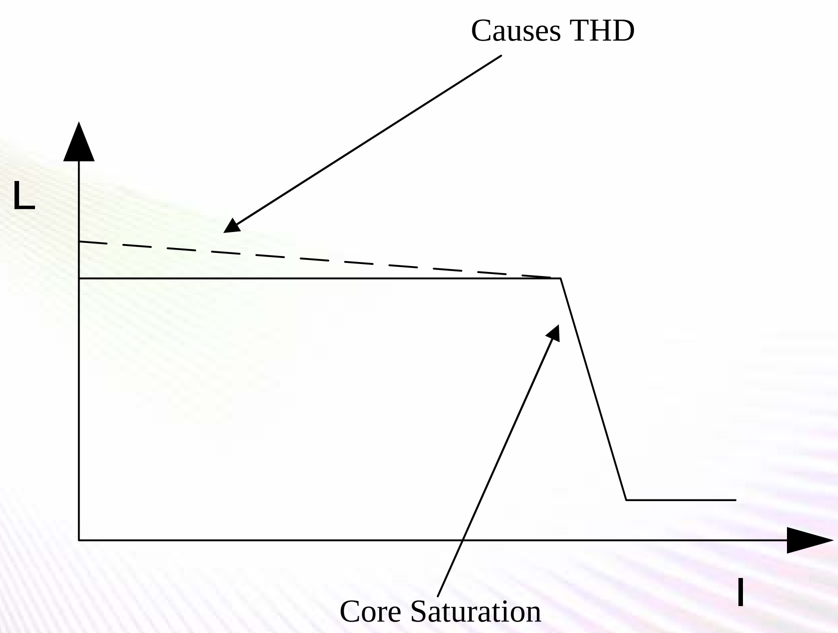


# Amplifier Component Considerations

- Choice of components sets the audio performance.
- MOSFET Switches (taken care of by the power stage)
- PWM Filter Capacitor (use a film capacitor)
  - Stability with voltage
  - Ripple Current
- Inductor (use TI recommended)
  - Series resistance (dc), skin effect (ac)
  - Parallel resistance (hysteresis loss)
  - Parallel capacitance
  - Saturation in core material
- Decoupling capacitor (use X7R)
  - Series resistance
  - Series inductance
- Bulk Capacitor (Use low ESR)
  - ESR
  - ESL
  - Ripple Current
- PSU
  - Output impedance
  - Current limitation
  - Current Slew-rate
  - Surge Capability

# Inductors: Inductance vs Current

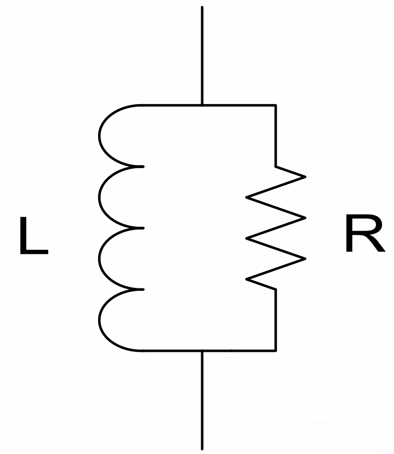
- Inductance versus current diagrams are typically shown in the datasheet for an inductor.
- In order to have a proper working current limitation there must be > 5µH inductance at 2x the programmed current limit. Worst case test condition is short at the output.
- Note that the saturation current decreases with temperature.
- Any variation in inductance within the operating area will result in increased THD. This is normally seen above 1kHz.



# Inductor Losses

Parallel Impedance Model

- When measuring an inductor a Parallel Impedance model can be used.
- The model assumes an ideal inductor in parallel with an ideal resistor.
- Applying this model when measuring at 100kHz gives an indication of idle power losses.




| 100kHz Measurements | Measured Inductance | Measured Parallel Resistance |
|---|---|---|
| **Bad Inductor** | 9.8µH | 53.4Ω |
| **Medium Inductor** | 11.5µH | 125Ω |
| **Good Inductor** | 10.2µH | 220Ω |

# More Info

- Magnetics Design Handbook, MAG100A, (Texas Instruments)
  - Available from TI Website

# PWM Filter Capacitor Considerations

- Capacitor Types
  - Metal Film Capacitors, linear over applied voltage
  - Ceramic X7R, change value over applied voltage resulting in increase THD
- SMD – Leaded
  - SMD capacitors, especially ceramic capacitors, change physical size over applied voltage.
  - This will result in audible noise and mechanical stress of the part and its soldering.

# Putting It All Together

# Components

- Choice of components sets the audio performance
- MOSFET Switches S1 & S2 (Power Stage)
  - TAS5132, 0W to 25W, 2 Channels
  - TAS5142, 0W to 100W, 2 Channels
  - TAS5152, 0W to 125W, 2 Channels
  - TAS5162, 0W to 210W, 2 Channels
  - TAS5261, 0W to 315W, 1 Channel
  - TAS5186, 210W Total Power, 6 Channel
- Modulators
  - TAS5086, Low cost, 6 Channel
  - TAS5508B, 8 Channel, Feature Rich
  - TAS5518A, 8channel, Feature Rich, High Performance
- PWM Filter Capacitor (Use a film capacitor)
  - Generally .47µ for AD Mode Filter
- PWM Filter Inductor (Use TI recommended)
  - Generally 10µH
- Decoupling capacitors (Use X7R)
  - 0.1µF is a good rule of thumb
  - Select voltage for PVDD + Overshoot + Temperature Derating
- Bulk Capacitors (Use low ESR)
  - 1000µF Good rule of thumb
  - Select voltage for PVDD + Overshoot + Temperature Derating
- PSU
  - Output impedance
  - Current limited
  - Current Slew-rate
  - Surge Capability

# Getting Started

- TI has a complete library of EVMs and reference designs @ www.ti.com -- follow the design carefully .
- Contact your local TI FSE for assistance.