TI Audio For Portable Application

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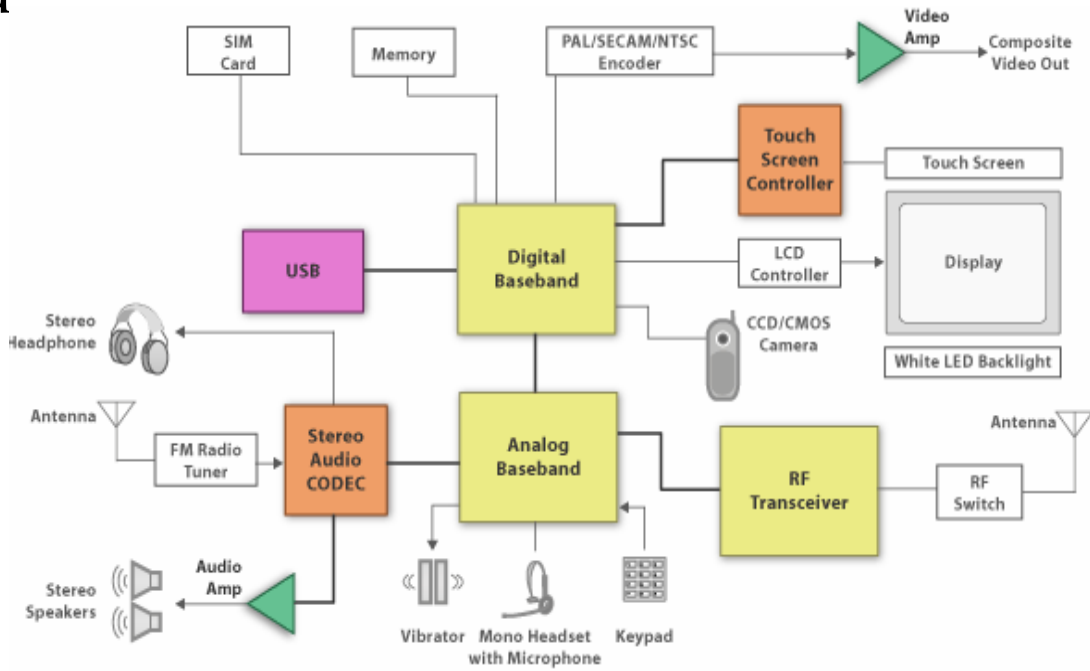
Agenda

- Audio basic background
- Class D vs. Class AB
- How to layout PCB
- Digital audio interface
- Product information



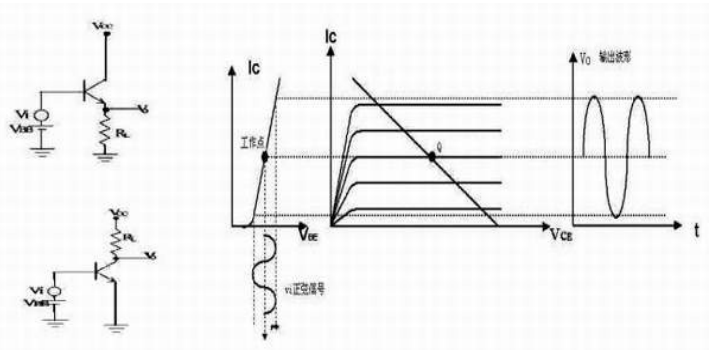
Audio basic background

Class A,B,AB

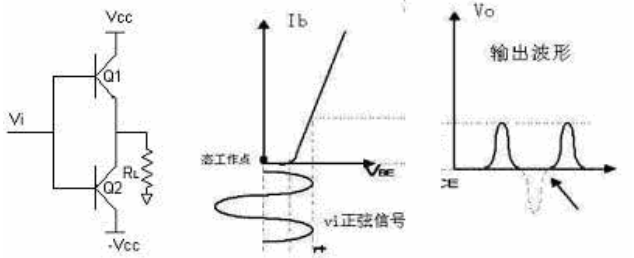
- **A类放大器:**放大器的工作点Q设定在负载线的中点附近,晶体管在输入信号的整个周期内均导通。放大器可单管工作，也可以推挽工作。由于放大器工作在特性曲线的线性范围内，所以瞬态失真和交替失真较小。电路简单，调试方便。但效率较低，晶体管功耗大，功率的理论最大值仅有25%。 由于效率比较低 现在设计基本上不在再使用。

- **B类放大器:** 放大器的静态点在(VCC，0)处，当没有信号输入时，输出端几乎不消耗功率。在Vi的正半周期内，Q1导通Q2截止，输出端正半周正弦波；同理，当Vi为负半波正弦波，所以必须用两管推挽工作。其特点是效率较高(78%)，但是因放大器有一段工作在非线性区域内，故其缺点是"交越失真"较大。即当信号在-0.6V~ 0.6V之间时， Q1 Q2都无法导通而引起的.

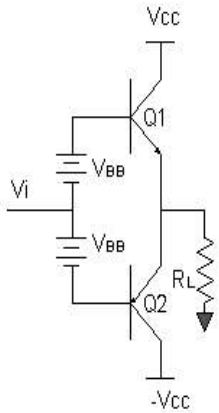
- **AB类放大器:**晶体管的导通时间稍大于半周期，必须用两管推挽工作。可以避免交越失真。交替失真较大，可以抵消偶次谐波失真。有效率较高，晶体管功耗较小的特点。

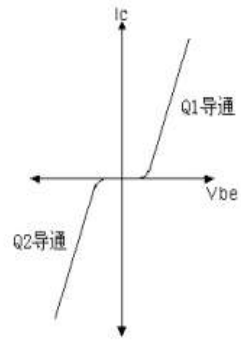


A类放大器



B类放大器





B类放大器的交越失真

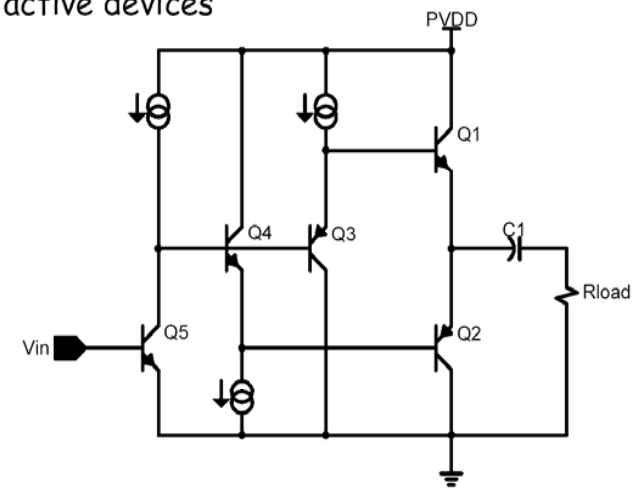
AB类放大器消除交越失真的情形

Amplifier Technology
Class-AB vs. Class-D

Class-AB amplifiers use the same push-pull architecture as class-B, but active devices are biased on with a small quiescent current when Vin = 0.

Advantages:
- Great feature set
- Very common, well understood technology

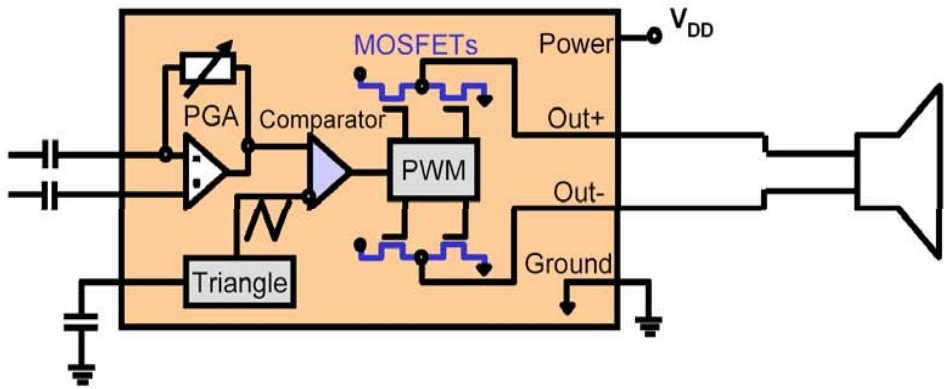
Disadvantages:
- High heat dissipation
- Only 20% to 30% efficient at normal listening levels



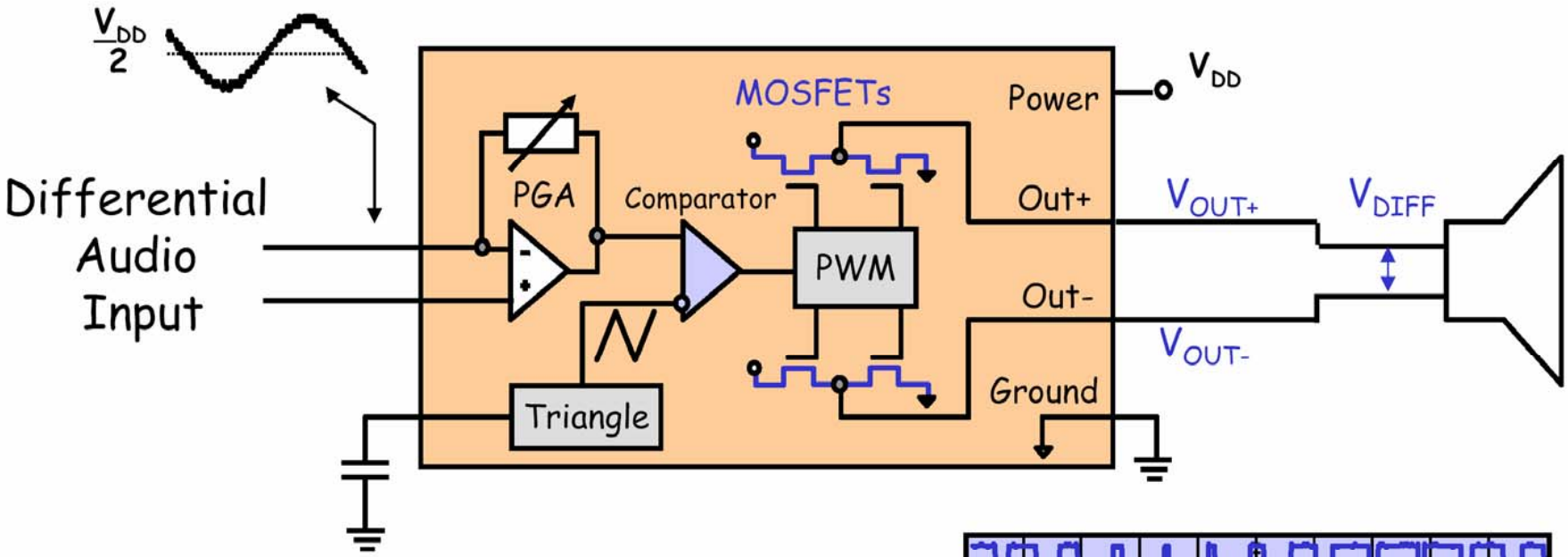
Class-D amplifiers modulates the audio signal in to a high frequency PWM signal that drives the speaker(s).

Advantages:
- High efficiency
  - Maximizes battery life
  - Minimizes heat

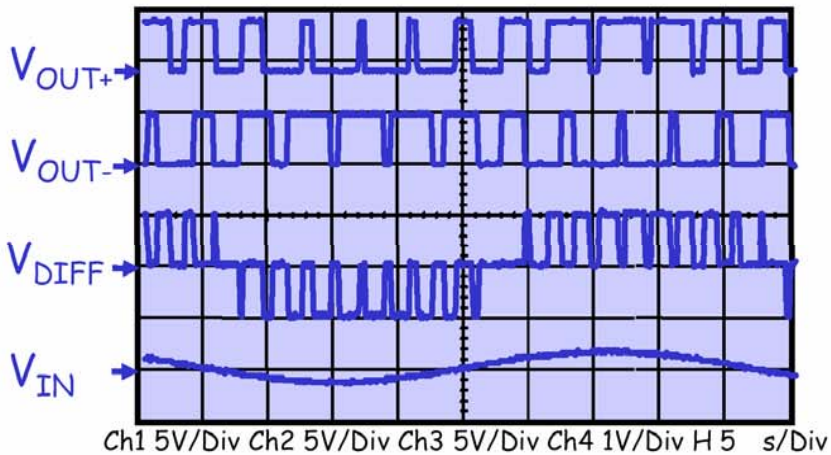
Disadvantages:
- New technology—market needs help understanding
- A few more layout considerations



Amplifier Technology
Filter-Free Class-D

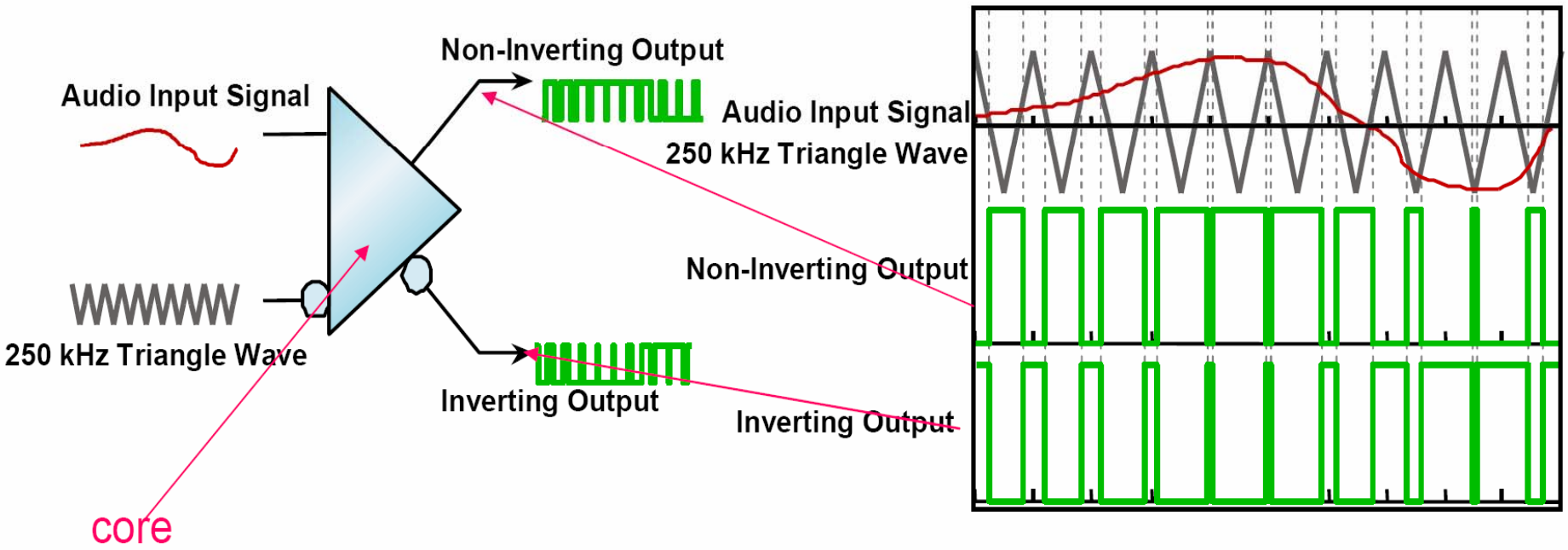


Modulation scheme optimized to operate without a filter!



Audio power amplifier Basic Configuration

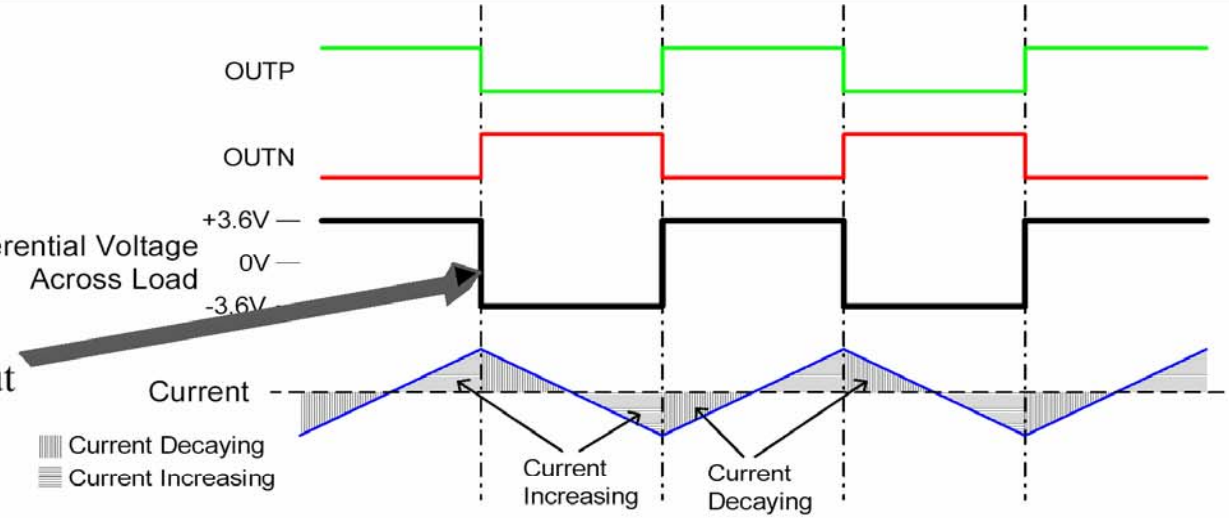
Class-D amplifier is a switching amplifier which creates a PWM signal whose duty cycle is proportional to the audio signal. The core of the amplifier is a comparator.



Modulation Scheme

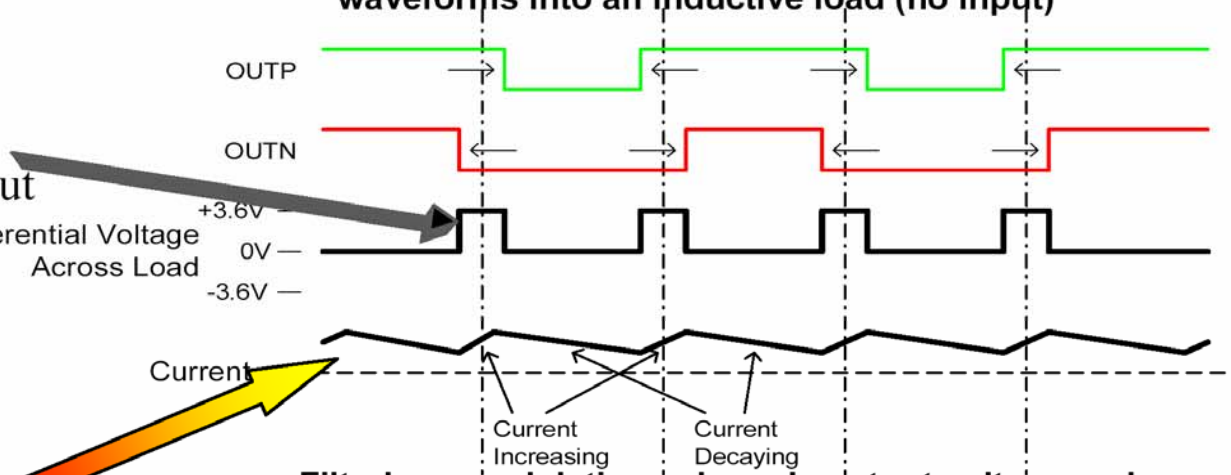
Traditional vs Texas Instruments Class-D

7.2 Volts Peak-to-Peak
Duty Cycle = 50% at 0-V out



Traditional modulation scheme's output voltage and current waveforms into an inductive load (no input)

3.6 Volts Peak-to-Peak
Duty Cycle = 0 % at 0-V out



Small peak-to-average current

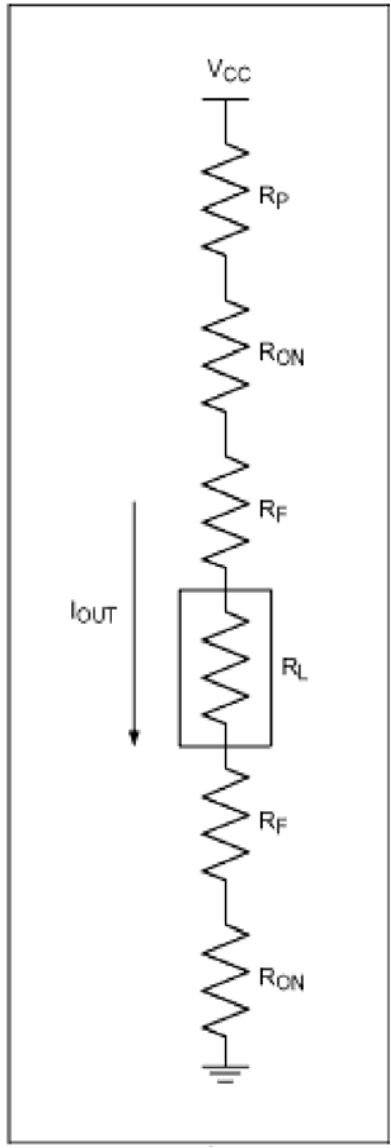
Filterless modulation scheme's output voltage and current waveforms, example signal

Class-D Efficiency

RON is the MOSFET on-resistance,
RP is parasitic resistance for the combined metal interconnects, bond wires, lead frame, and PCB traces
RF is the parasitic resistance of the filter components, and
RL is the load.

$$\eta = \frac{P_{OUT}}{P_{SUPPLY} + P_{SWITCH}} = \frac{I_{OUT}^2 R_L}{I_{OUT}^2(2R_{ON} + 2R_F + R_P + R_L) + \frac{1}{2} f_{OSC} I_{OUT}^2 (t_{ON} + t_{OFF}) 2R_{ON}}$$

RL = 4 , f_{OSC} = 250kHz, t_{ON} = tOFF = 25ns, R_{ON} = 250m , RF = 25m , and RP =80m , equals 86.33%.
Increasing RL to 8 boosts the efficiency to a surprising 92.66%.



音频放大器的主要参数

- 电源纹波抑制比(PSRR) PSRR用来衡量电源中的交流纹波或噪声向输出的耦合。电源电压的变化会造成音频信号的恶化，因为通过电源调制效应造成了RON的变化.(采用19kHz 1VP-P正弦波叠加在5V直流电源上.) 87dB　500mV----22uV

- 总谐波失真加噪声(ＴＨＤ＋Ｎ) (total harmonic distortion)是指一个模拟电路处理信号后，在一个特定频率范围内所引入的总失真量。噪声(noise)是指通常不需要的信号。有时是由于由于热或者其它物理条件产生的。从ＴＨＤ＋Ｎ的定义中不难看出总谐波失真和噪声越小越好。

- 信噪比(SNR) 通常指一个模拟信号中有用信号和噪声之间的比值。

- 增益(AO) 对音频功率放大器来说增益通常指放大器输出功率和输入功率之间的比值。增益越大说明放大器的效率越高。

- 最大输出功率(POCM)输出功率反映了一个音频功率放大器的负载能力，通常音频放大器厂家会提供产品的在工作电压一定条件和额定负载下的的最大输出功率

- 关断电流(Shutdown current)和输出偏移电压(Output Offset Voltage)：关断电流越小，说明在待机条件下的放大器功耗小。输出偏移电压小有利于电池寿命的延长。

Wireless Application
Noise Sources

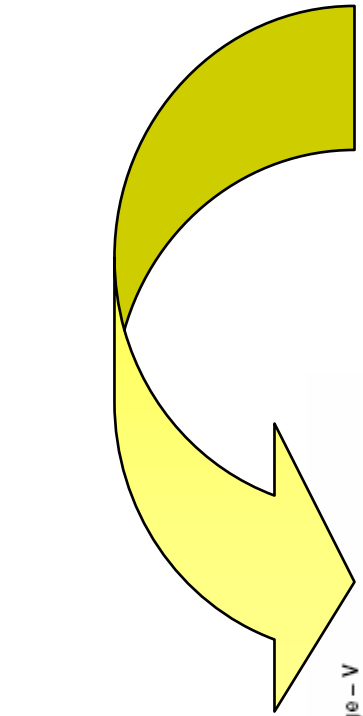
- Noise on power supply
  - GSM phone RF stages switch ON&OFF at 217Hz to save power and this cause large dips in the power supply
  - Without good PSRR, this noise will appear on the amplifier outputs as audible 217Hz sound
- Noise on the inputs
  - Any noise coupled onto the amplifier inputs, will be amplified by the closed-loop gain and will be heard on the speaker
  - Without good CMRR, this noise will appear on the amplifier outputs as noise
  - Fully-Differential Audio Amplifier architecture provides good CMRR
- Noise on the outputs
  - Any RF signals coupled onto the outputs, will be heard as audible 217Hz sound
  - Fully-Differential Audio Amplifier architecture will remove this effect

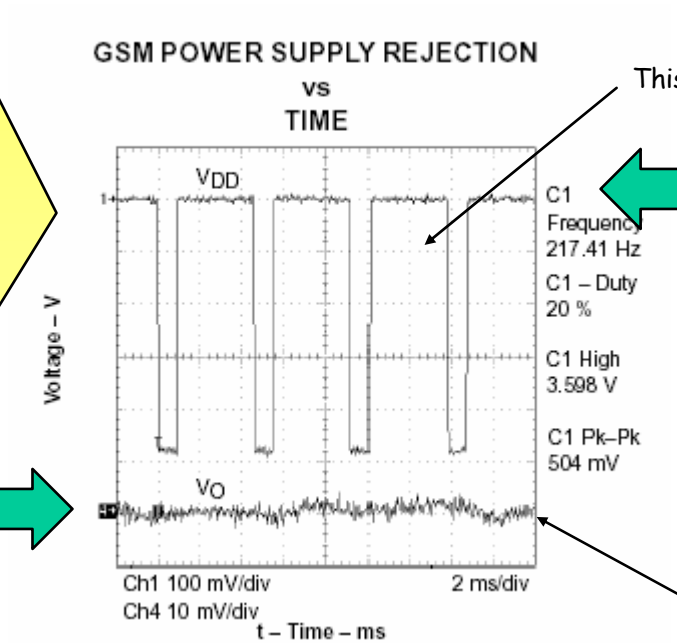
Power Supply Noise

How good is your PSRR?

Power Supply Rejection Ratio

GSM cellphone switch the RF stage ON & OFF at 217Hz. This can cause ripple on the supply rail





This ripple can be up to 500mV

Power Supply

Output Signal

An Audio Amplifier with good PSRR is virtually immune to this power supply noise.

放大器的应用设计技巧

1:采用了全差分输入及输出的音频功率放大器，提高电源抑制比。
2:尽量采用效率高，功耗低，内部升温小的设计，这样可以延长电池和芯片的使用寿命。
3:音频放大器在使用时一定要注意供电电源电压不能超过其极限值，以免造成芯片损坏。

无滤波器D类放大器的设计

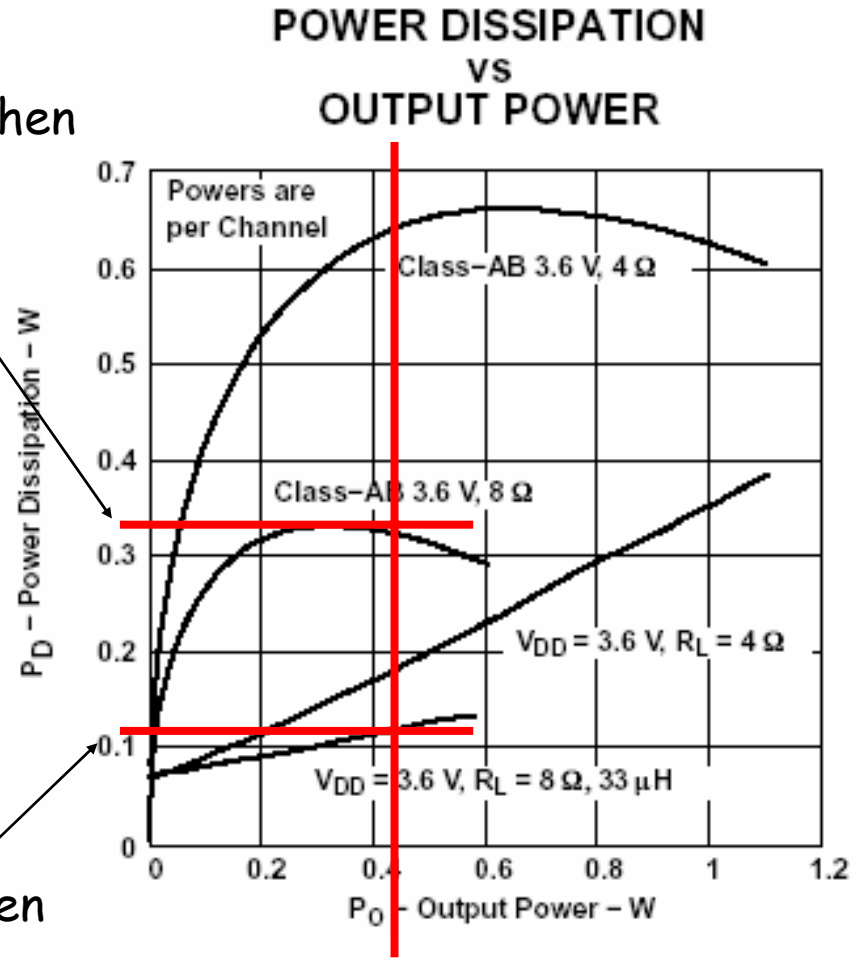
1:功率放大器输出中存在的杂波形可能会对系统中的其它器件带来幅射或影响，从而产生干扰。有必要保持输出连线较短,如果有可能的话，还要对其进行很好地屏蔽。

手机PCB设计上的挑战在于：一是板面积小，二是有RF的电路。板面积有限，而又有数个不同特性的电路区域，如RF电路、电源电路、话音模拟电路、一般的数字电路等，它们都各有不同的设计需求。在这种情况下，好的布局必须防止射频能量与电话中的基频部分或音频电路的音频与功率连线产生串扰。从布局方面考虑，我们不可以将功率放大器放在天线附近，因为在有电话拨入或拨出时天线的辐射会与高功率输出产生串扰。此外，所有的信号路径必须通过接地层进行屏蔽/隔离。使用接地层、磁珠和微带设计技巧对于防止发生多余的干扰而言都非常有好处。

2: 而随着输出功率提高，放大器、负载和电源之间的互连阻抗(PCB连线和连线)会产生电压降。放大器与负载之间的连线上的电压损耗会使输出功率降低，效率下降。而电源与功率放大器之间过高的连线阻抗也会导致同样的结果，如电源供应不稳定、电源线纹波增加，以及峰值输出功率下降。此外，由于输出功率提高，输出电流也随之提高，残余连线阻抗也会升高。为了维持最高的输出电压摆幅和相应的峰输出功率，连接输出引脚到负载引脚的PCB连线应该足够宽，从而将连线阻抗最小化。

Power Dissipation
Class-AB vs. Class-D

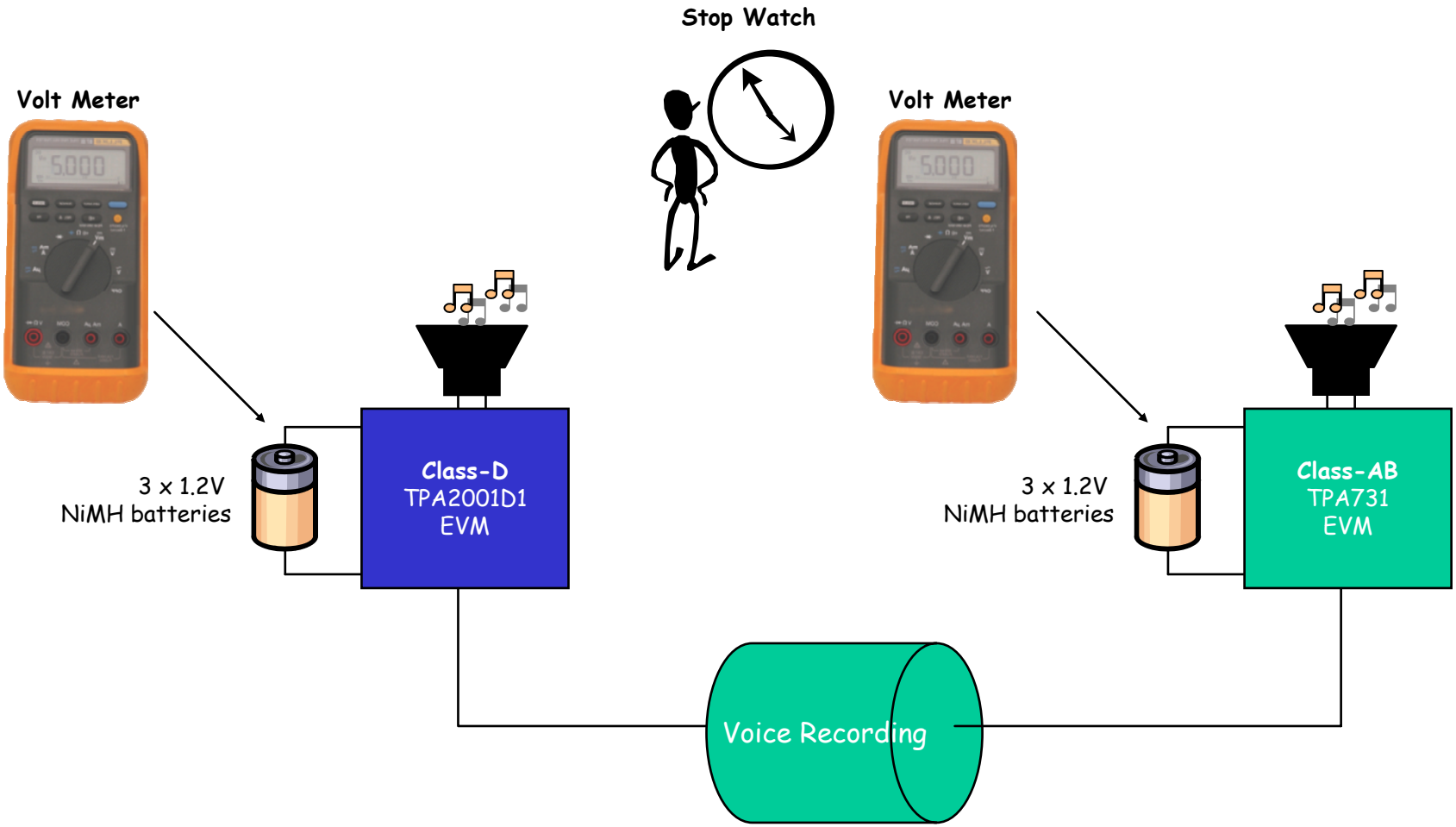
Class-AB dissipates about **320mW** when providing 400mW to the load



Class-D dissipates about **120mW** when providing 400mW to the load

Output Power = 400mW

Battery Life - Class-D vs. Class-AB
Test Setup

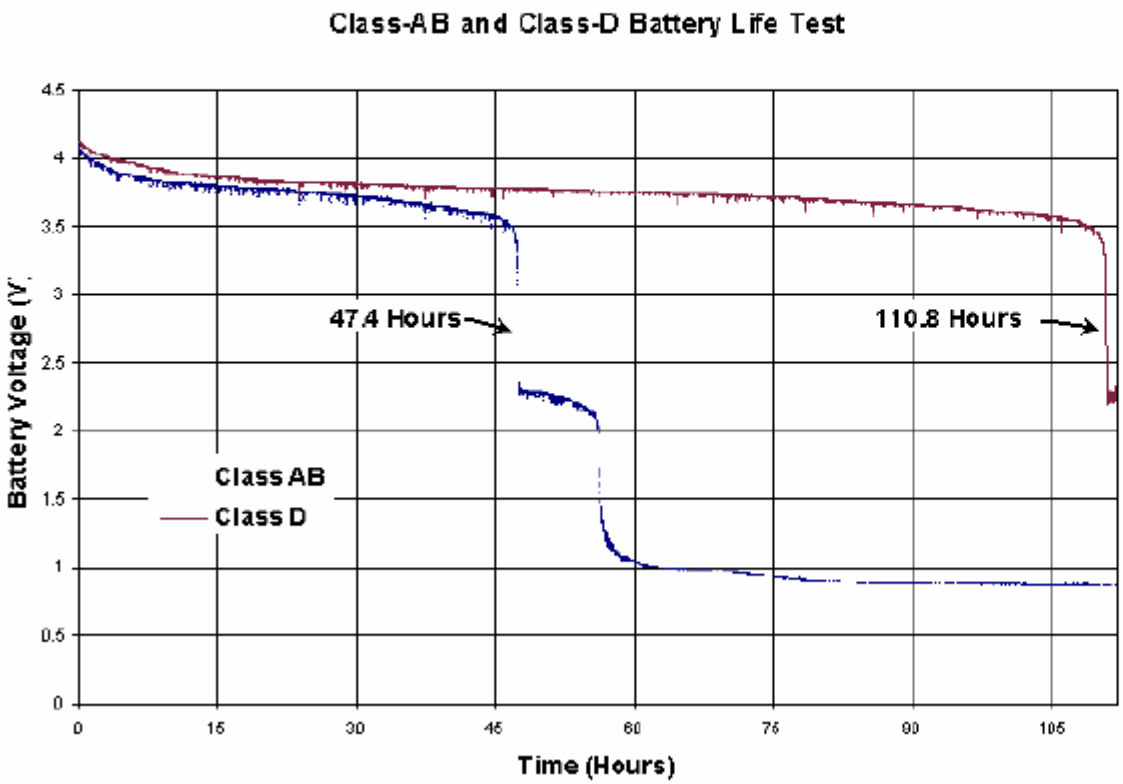


A voice recording was repeatedly played through both a Class-AB and Class-D Audio Power Amplifier.
The battery voltage and the time were was both measured

Power Efficiency
Class-AB vs. Class-D

Class-AB - 47.4 hours

Class-D - 110.8 hours or 2.3 times longer



A head to head test of TI's class-AB and class-D ~1W mono solutions:

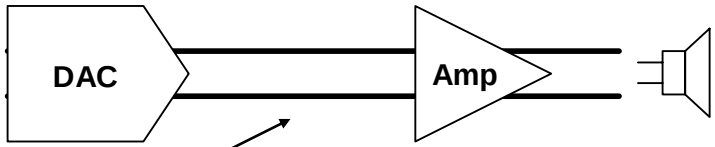
Class-AB - TPA731
Class-D - TPA2001D1

Both powered by 3x1.2V NiMH batteries driving 8-Ω speaker.

Less Thermal Dissipation

Different input Implementations

Fully Differential DAC and Amplifier

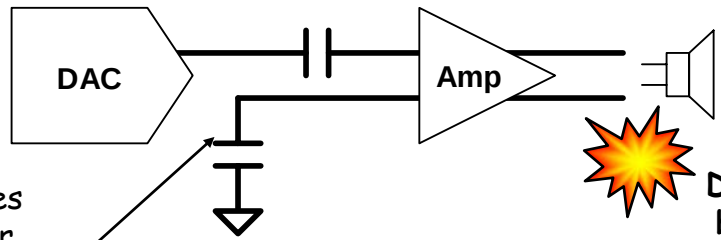


Benefits:

1：相对于单端输入，其效率提高四倍。
2：无须输入耦合电容，提高CMRR
3：无须中间电源旁路电容。
4：提高了RF抗干扰。

Differential signal lines should be as close to each other as possible to maximized common-mode noise coupling

Single-Ended DAC and Fully Differential Amplifier

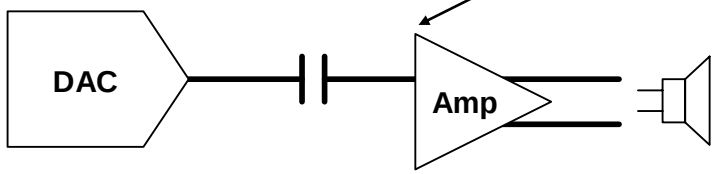


Signal lines should be as close to each other as possible to maximized common-mode noise coupling with one input AC coupled to the DAC and the other AC coupled to ground

Differential amplifiers can be used with single-ended output signals from DAC

Signal line should be AC coupled to the DAC to remove bias voltage

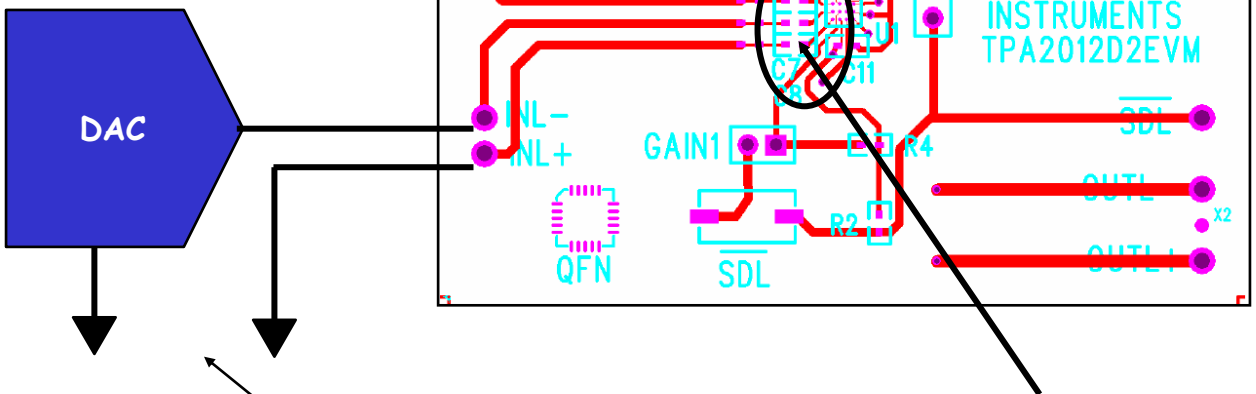
Single-Ended DAC and Amplifier

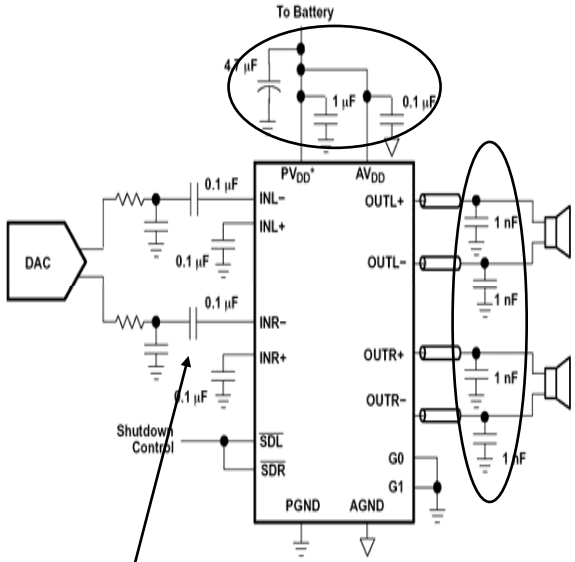


Recommendation for layout Using TPA2012D2EVM

Single-ended output from DAC

(Top of EVM)





Use the same ground as the DAC

Input AC Coupling capacitors already on the EVM

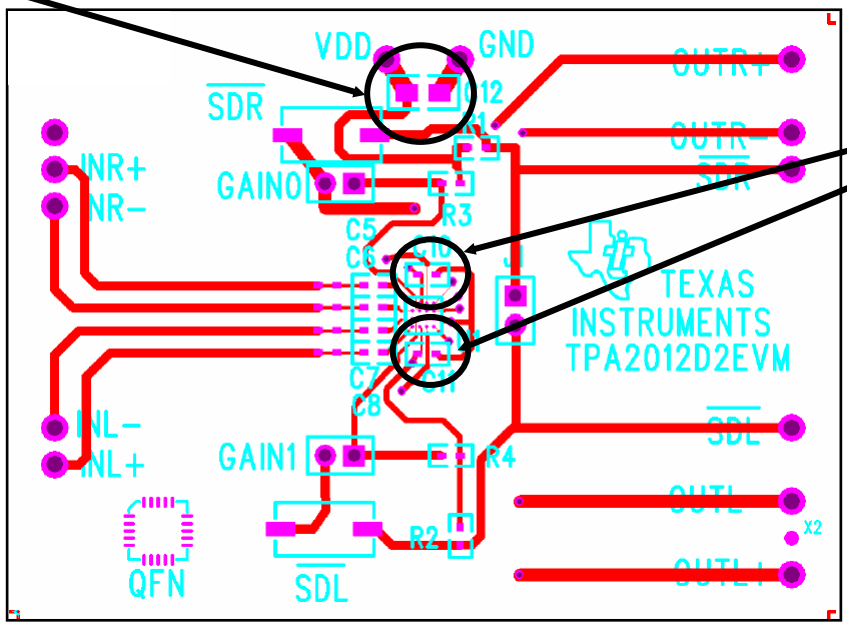
In a real application, these capacitors would need to be added to be PCB board for correct AC coupling and placed near to the DAC.

Recommendation for layout Using TPA2012D2EVM

The Bulk capacitor should be placed close to the VDD and GND and is needed when amplifier delivers audio power to the load
Typical values 10uF

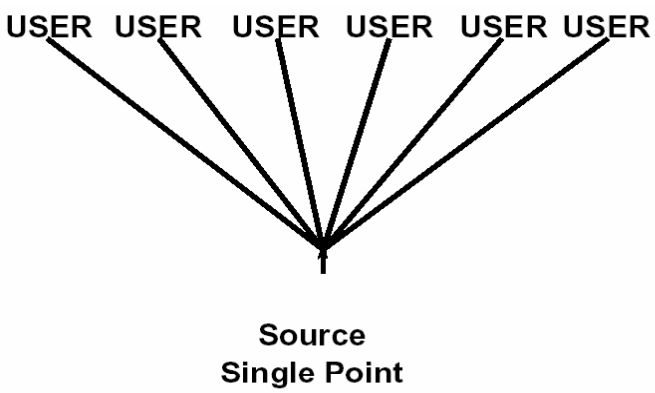
Power Supply decoupling

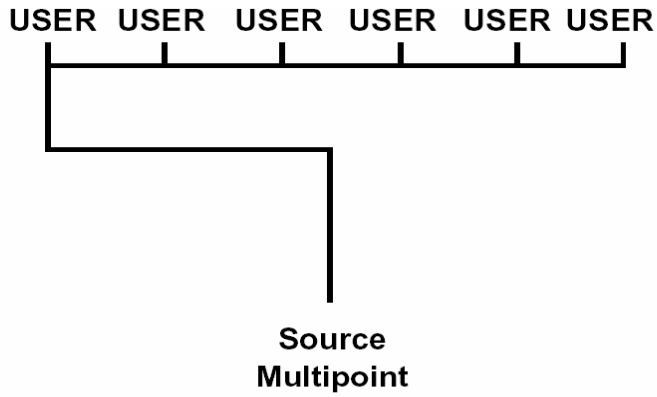
(Top of EVM)

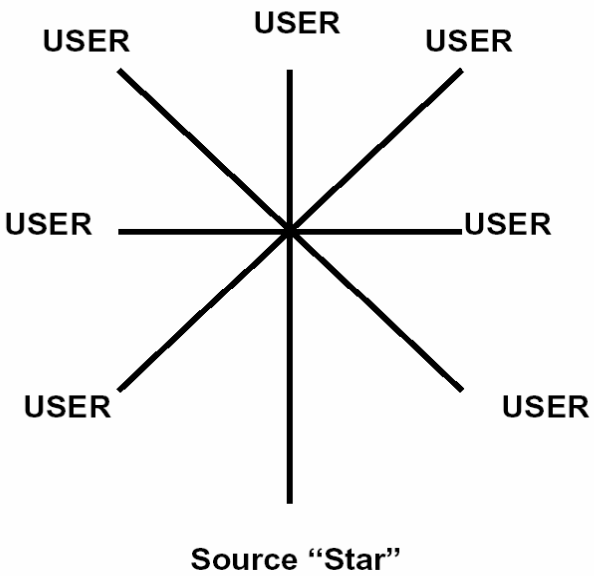


Local decoupling capacitors should be placed as close as possible to the supply pin of device and are needed for the high-frequency switching currents of the device
Typical values 1uF and 0.1uF

如何Layout PCB 减少EMI---GND





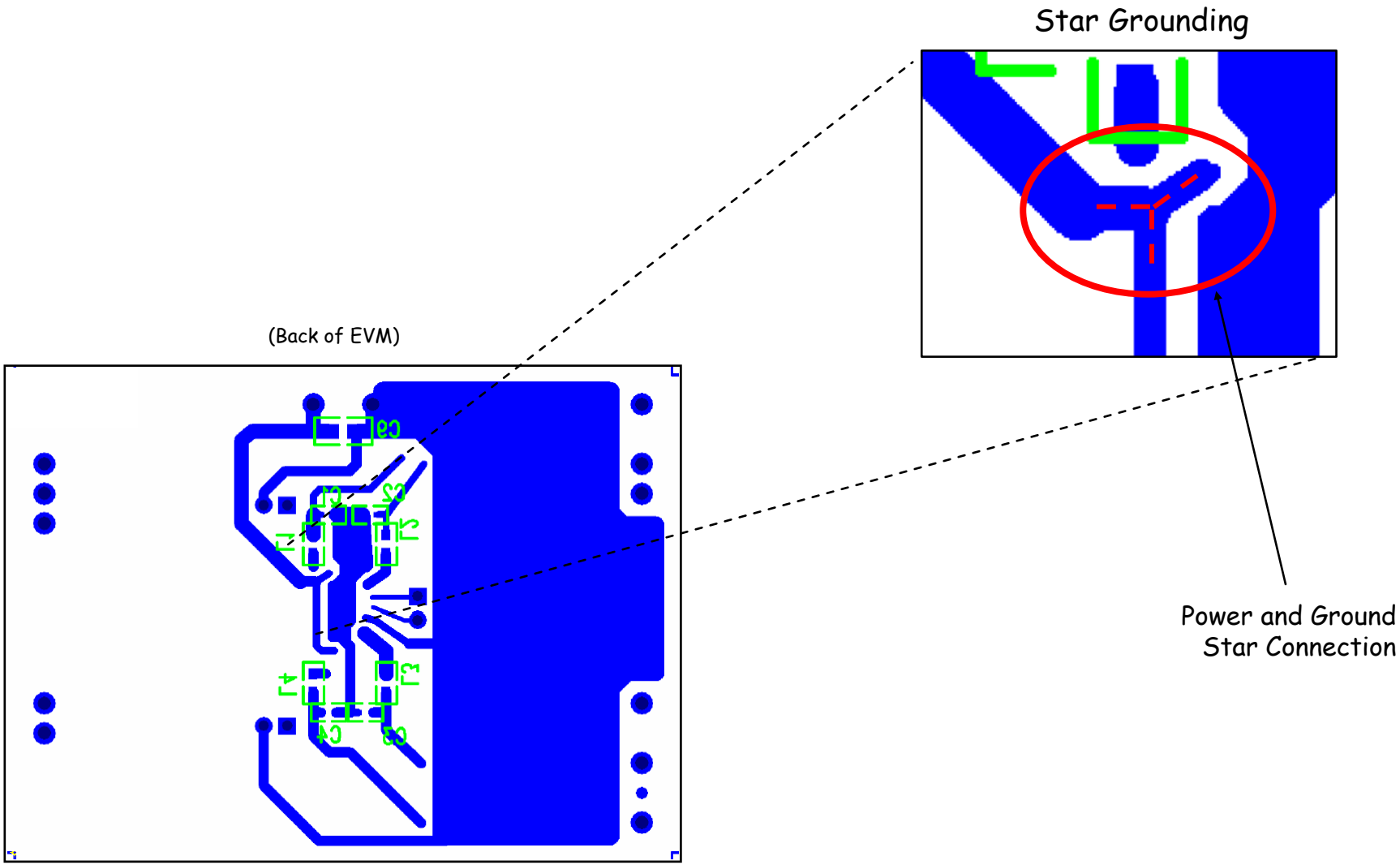


	Trace Type	
	Power	Signal
Single Point	Best	O.K.
Star	O.K.	Best
Multipoint	Worst	Worst

Figure 6. Power Distribution

Recommendation for layout

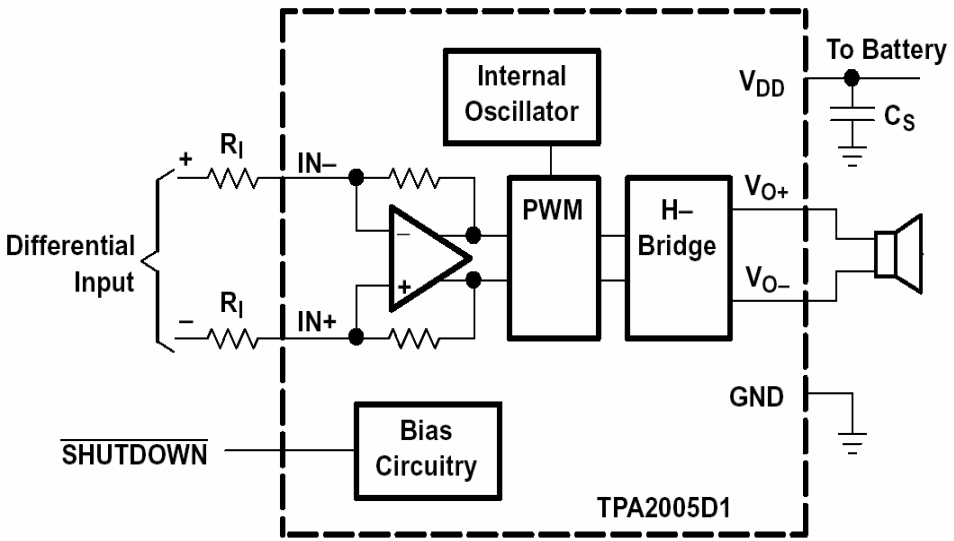
Using TPA2012D2EVM



How to layout Class-D PCB----TPA2005

- Place all the external components very close to the TPA2005D1. The input resistors need to be very close to the TPA2005D1 input pins so noise does not couple on the high impedance nodes. Placing the decoupling capacitor, CS, close to the TPA2005D1 is important for the efficiency of the class-D amplifier. Any resistance or inductance in the trace between the device and the capacitor can cause a loss in efficiency.

- Make the high current traces going to pins VDD, GND, VO+ and VO- of the TPA2005D1 have a minimum width of 0,7 mm. If these traces are too thin, the TPA2005D1's performance and output power will decrease. The input traces do not need to be wide, but do need to run side-by-side to enable common-mode noise cancellation.



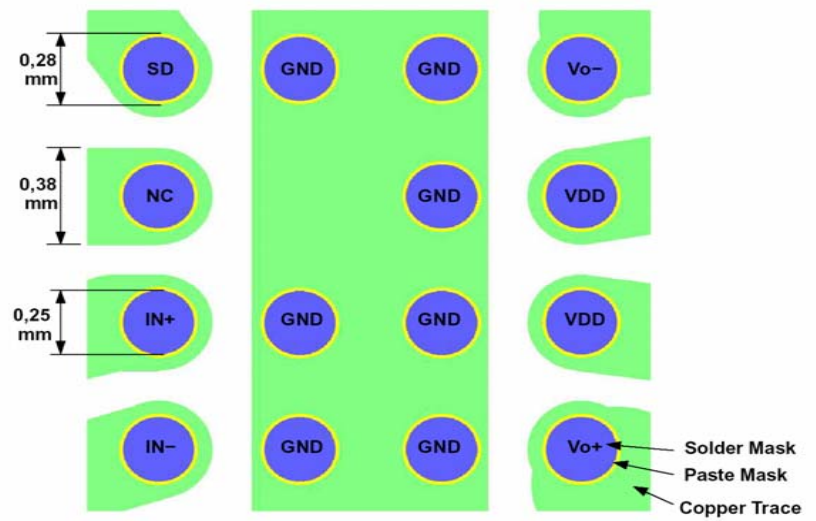
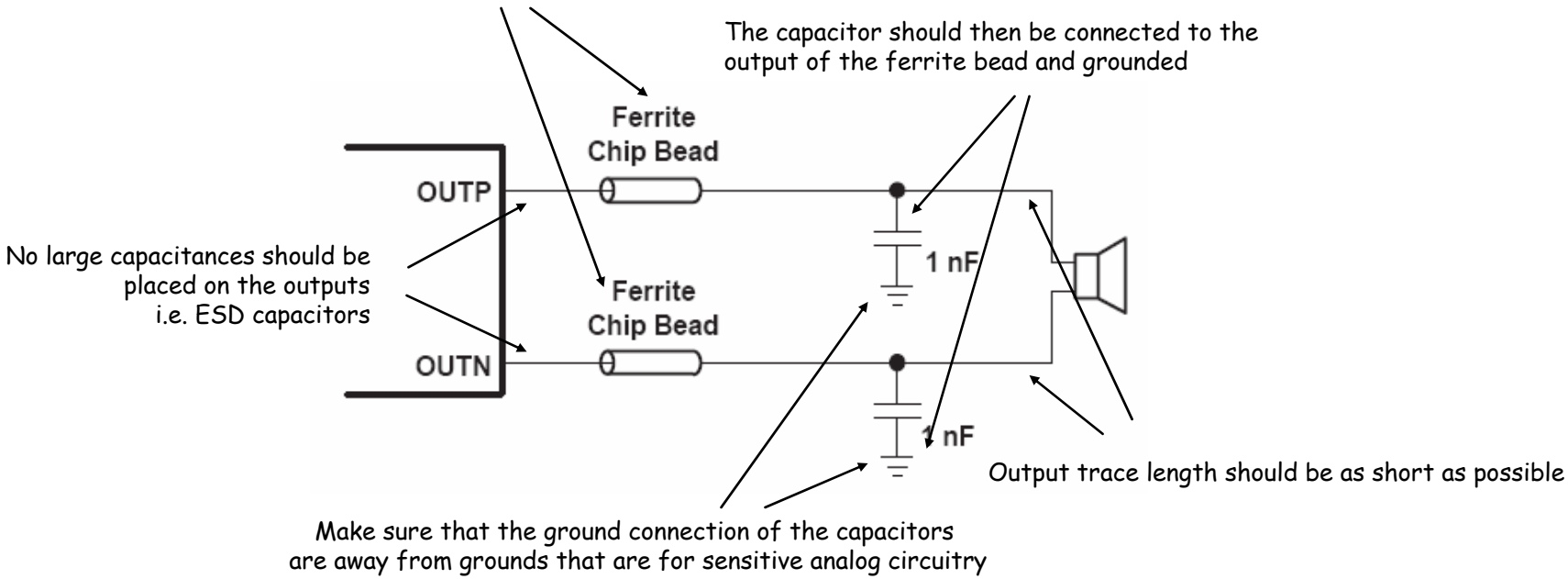


Figure 32. TPA2005D1 MicroStar Junior BGA Board Layout (Top View)

Typical Ferrite Bead Filter（铁氧体磁珠）

The ferrite bead should be placed as close to the output pin of the IC as possible.



Proper routing, using a ferrite bead filter and minimizing the trace length are all steps that will improve the design

加磁珠降低EMI

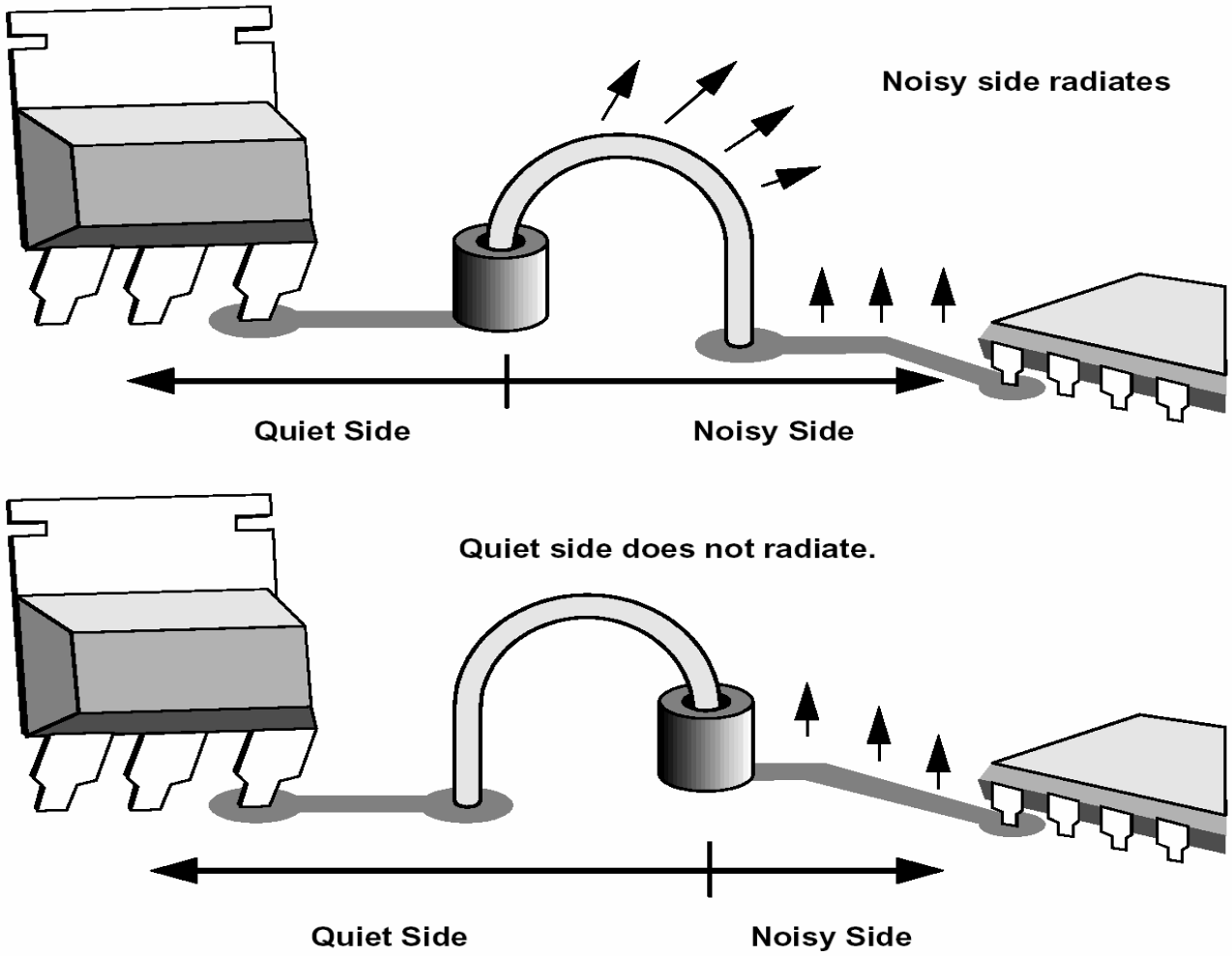
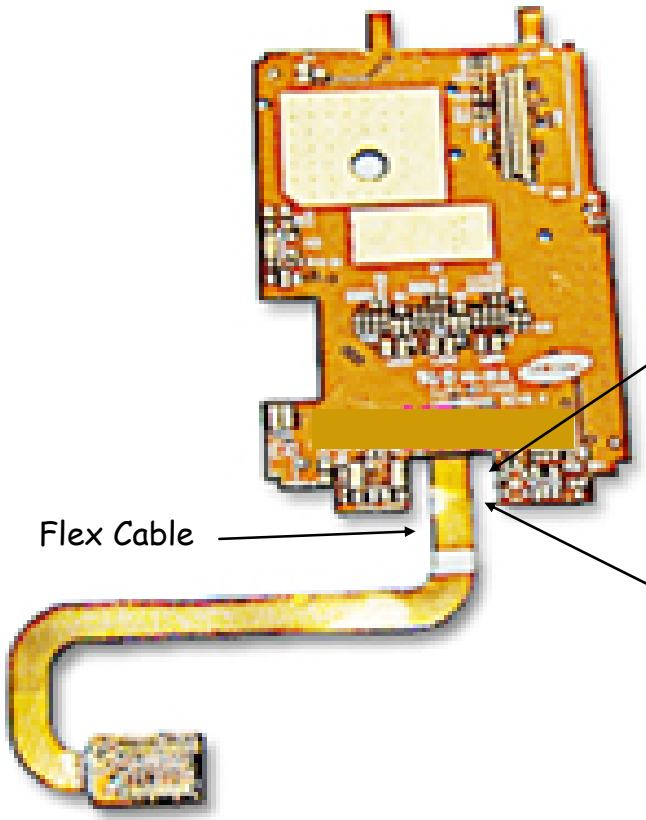
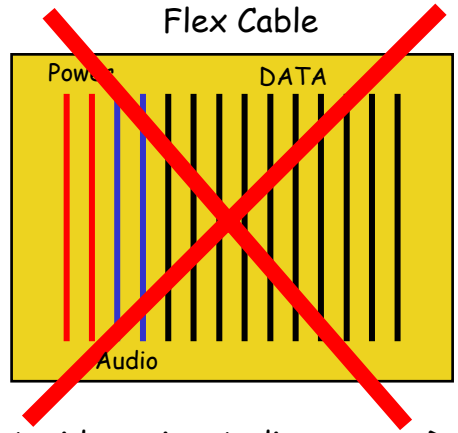


Figure 9. Ferrite-Bead Placement Closest to the Noise Source

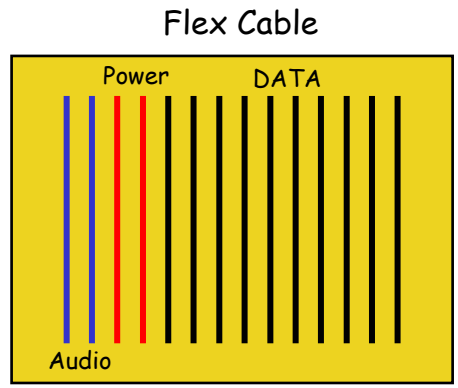
Recommendation for layout Using Flex Cable

Cellphone with Flex Cable





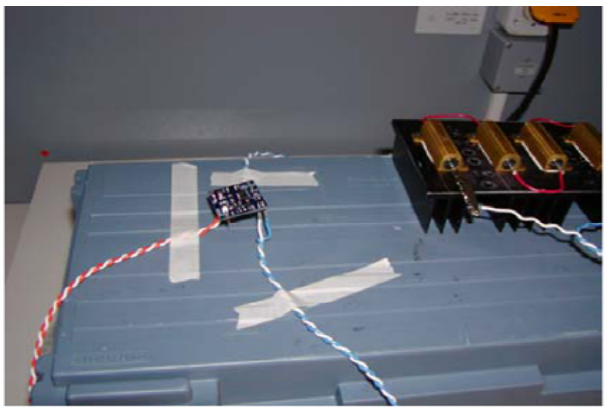
Avoid routing Audio next to Data



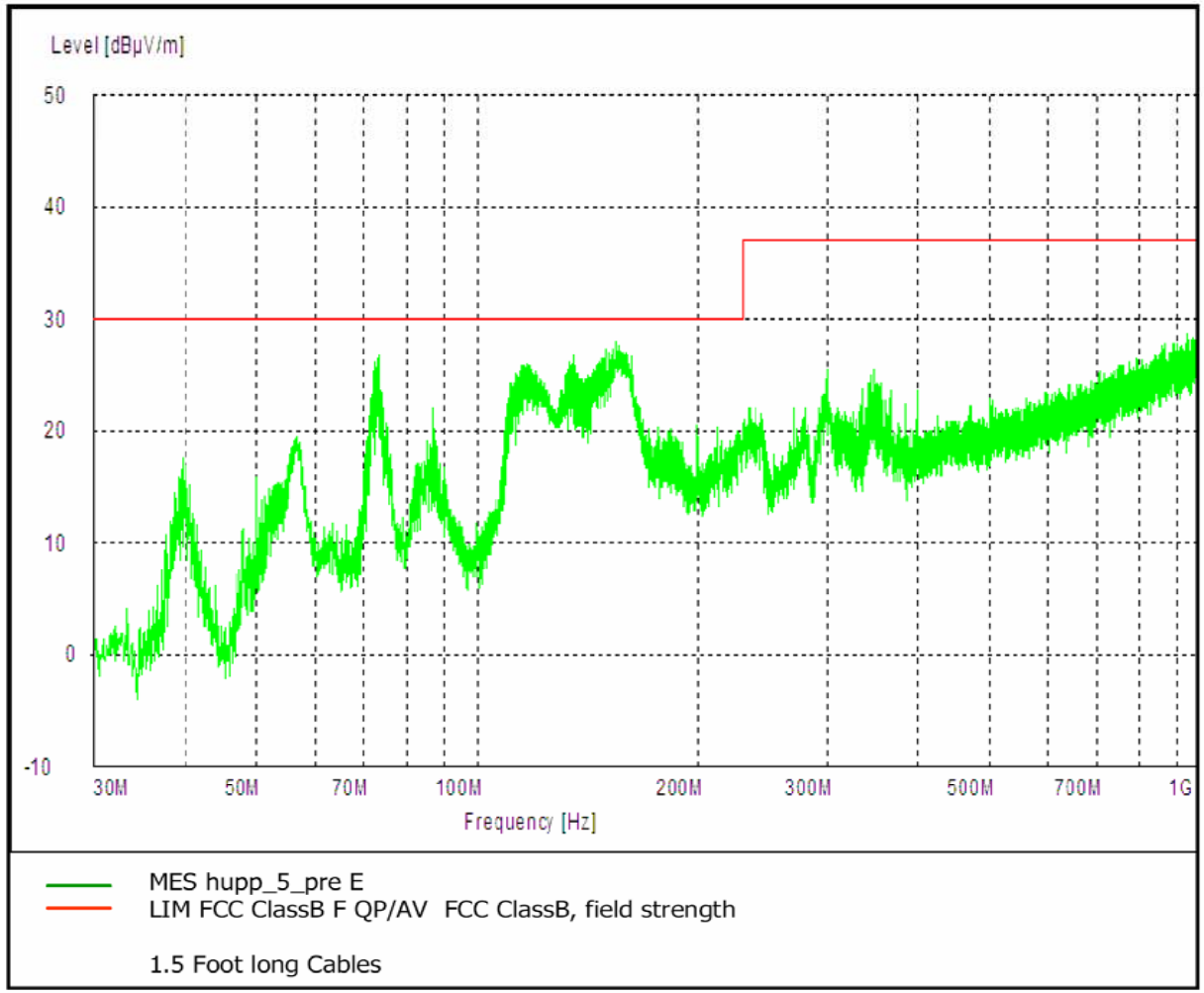
Ideally, power separates Audio and Data

TPA3007D1EVM EMI Results

Test Setup in EMI Chamber



Test Results:



RC Filter and RC Filter Box

The cut-off frequency for a first order RC filter is:

$$f_o = \frac{1}{2\pi RC}$$

The filter cut-off frequency should be around 30 kHz

Setting R = 100 Ω and C = 0.047 μF

The resulting f_O was 33.86 kHz

RC Filter Implementation