开关电源EMI技术交流

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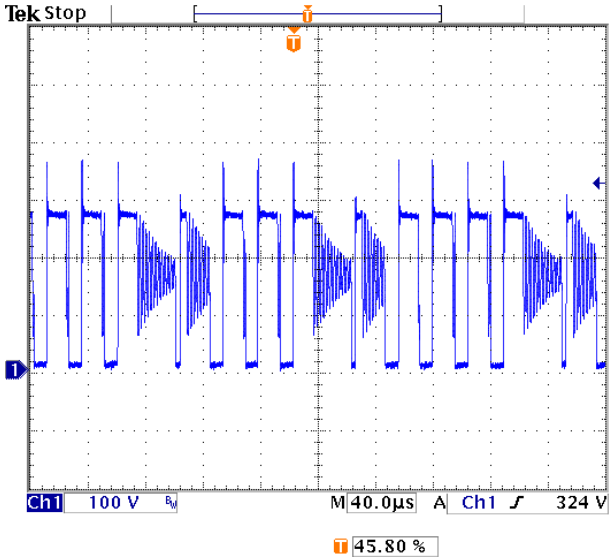
主要内容

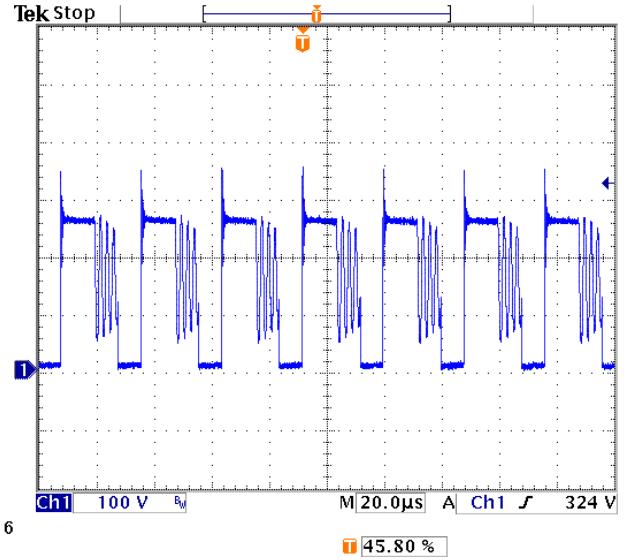
- 电磁干扰(EMI)分析及处理方案
  - Reducing The Noise Source
  - Improving the Noise Path
- MPS产品介绍

EMI 危害

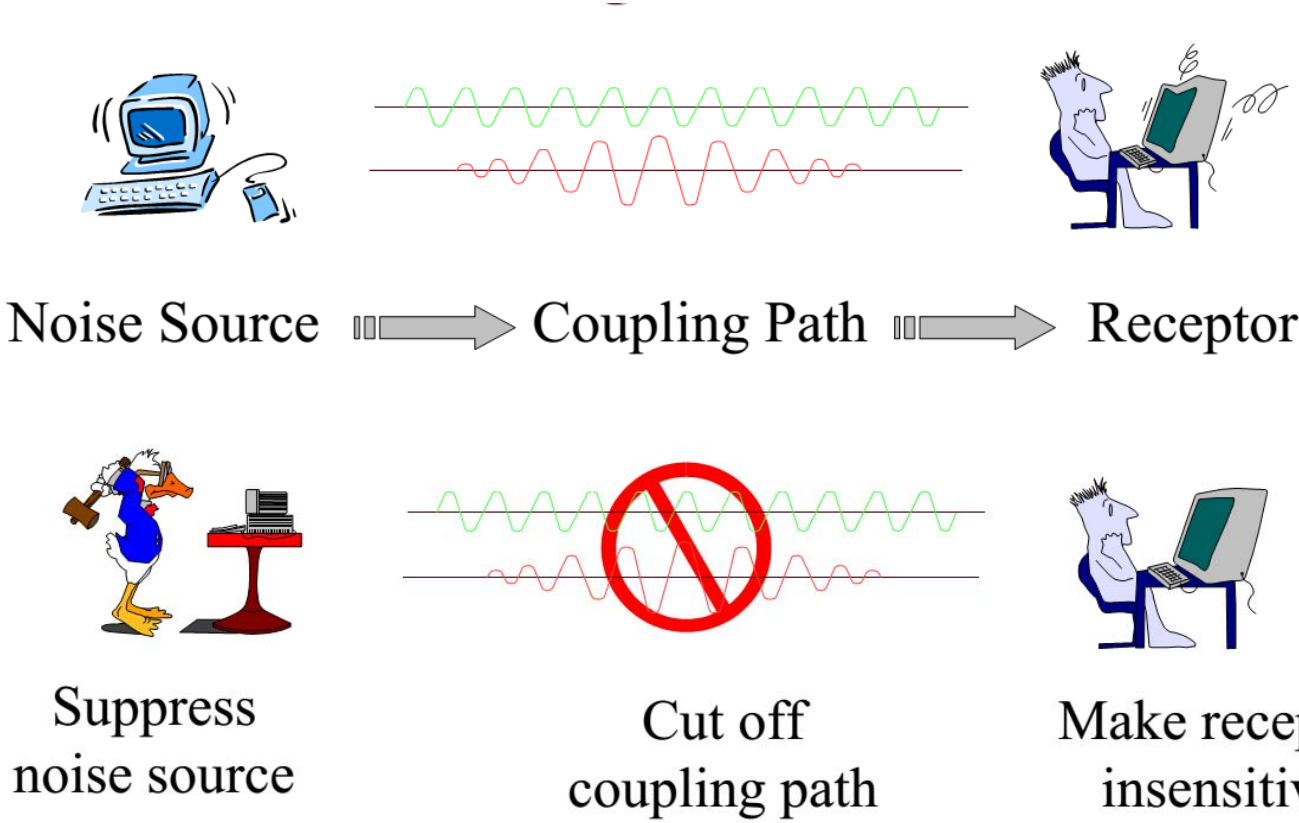
大的共模噪声导致芯片工作不正常



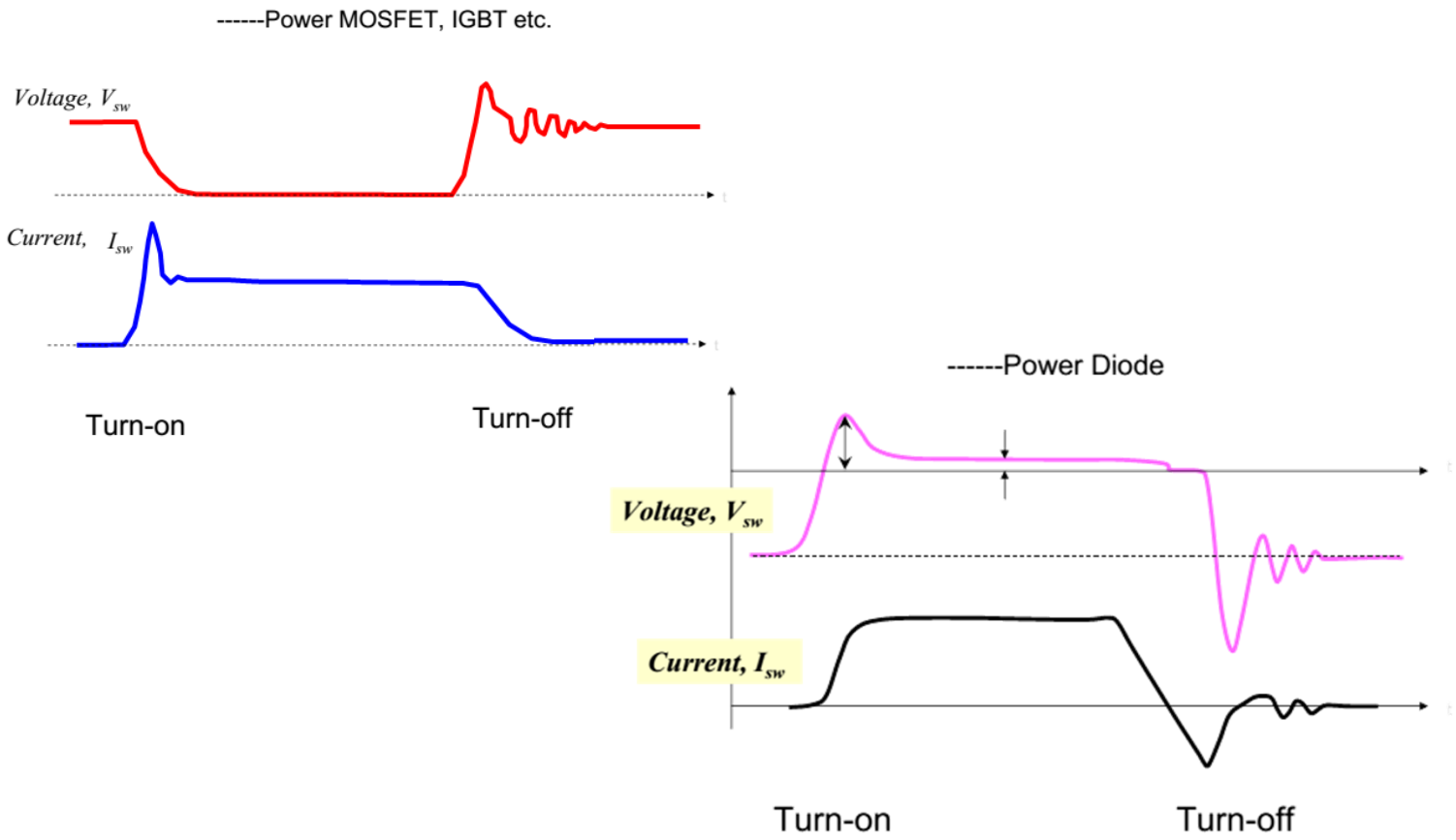
优化后的工作波形



基本概念

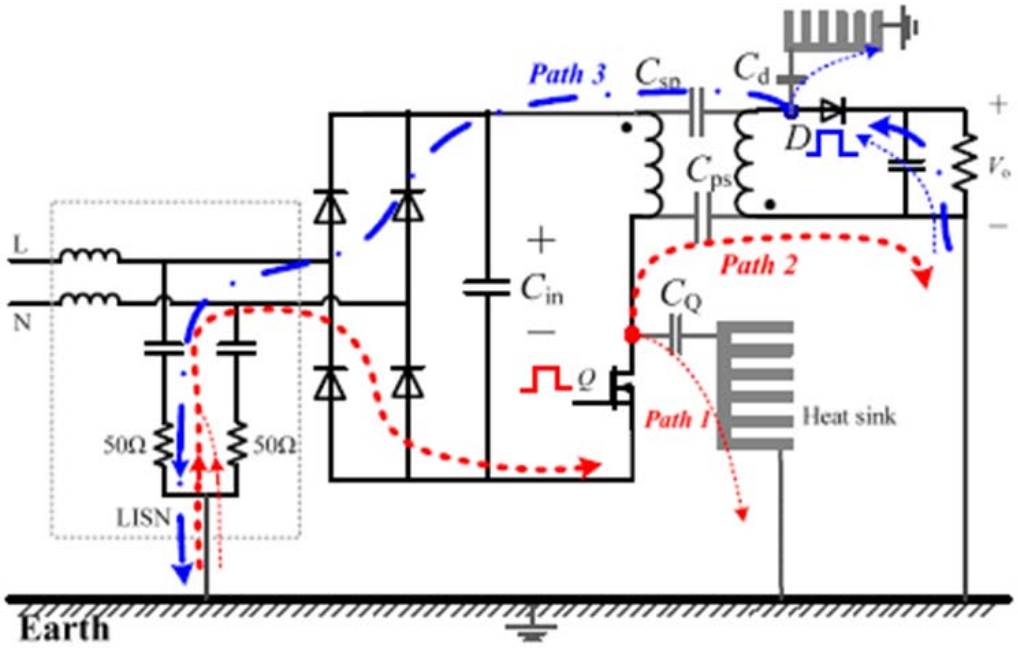

Noise Source
Coupling Path
Receptor
Suppress
noise source
Cut off
coupling path
Make receptor
insensitive

开关电源中的主要噪声源



传导（conducted EMI）

The main noise sources and coupling paths in flyback converter



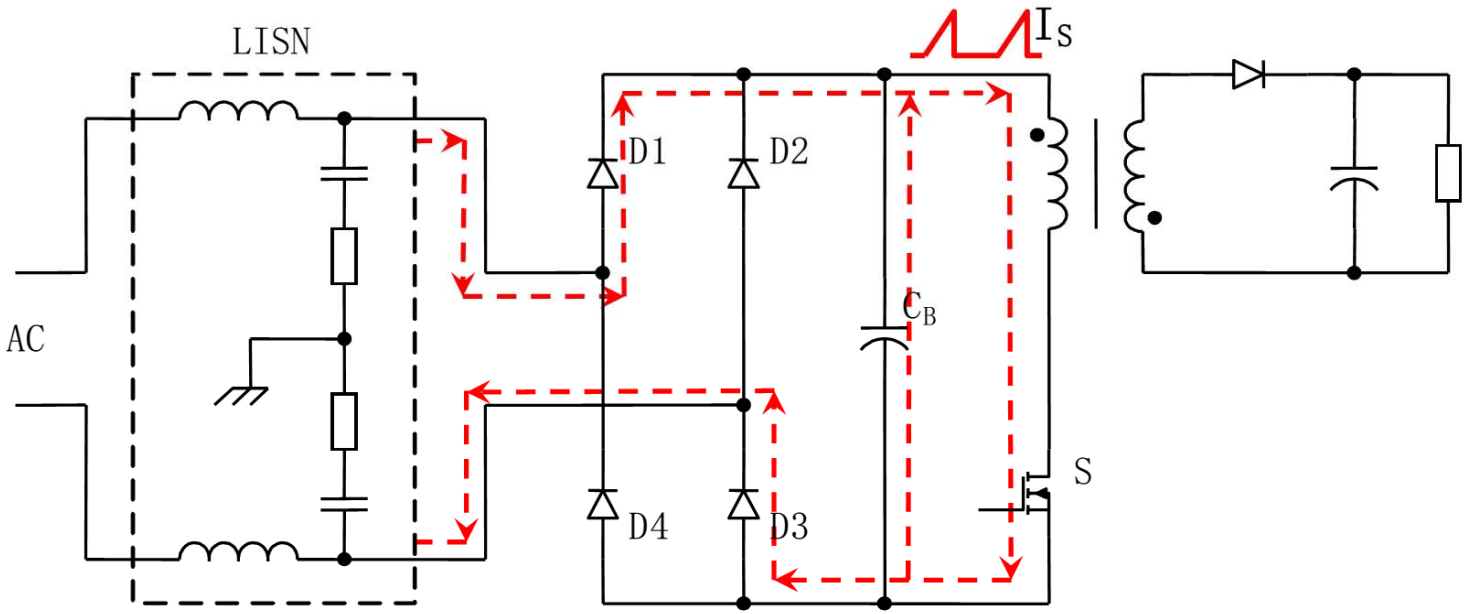
Noise Source: MOSFET, Diode

Coupling path: parasitic capacitance, PCB routing

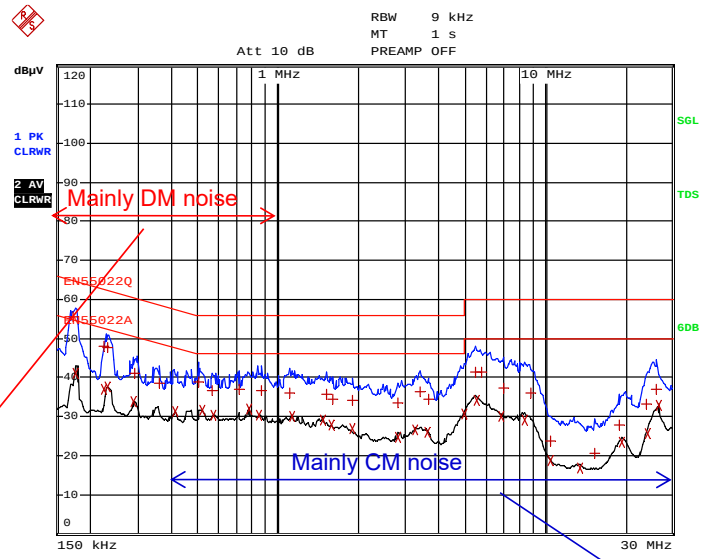
Load: 25Ω resistor

传导（Conducted EMI）

差模噪声耦合路径



传导（Conducted EMI）



Differential mode noise is mainly current phenomenon and is driven by rapidly changing current signals.

- **DM = f (di/dt)**
- **DM is associated with voltage across bulk cap created due to switching currents**

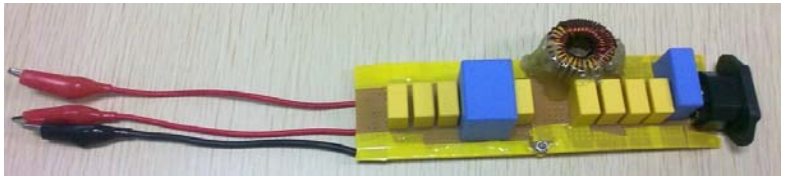
Common mode noise is mainly voltage phenomenon and is driven by rapidly changing voltage signals

- **CM = f(dV/dt)**
- **CM can be associated with capacitive coupling and displacement currents external to the power supply**

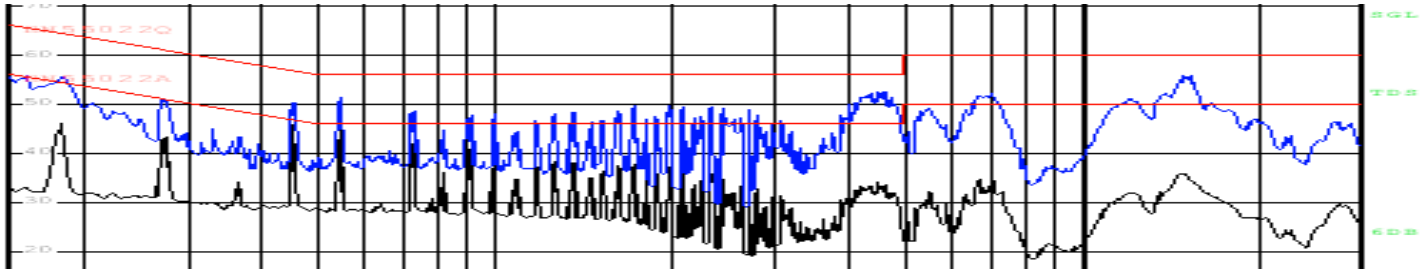
传导（Conducted EMI）

传导电磁干扰改善步骤

❖ 用滤波器来区分共模与差模干扰;



❖ 根据频率分布来确定主导的电磁干扰;



- 主要差模
- 低次谐波
- 交流整流相关
- 近场干扰
- …

- 差模与共模
- 高次谐波
- 低频震荡
- 近场干扰
- …

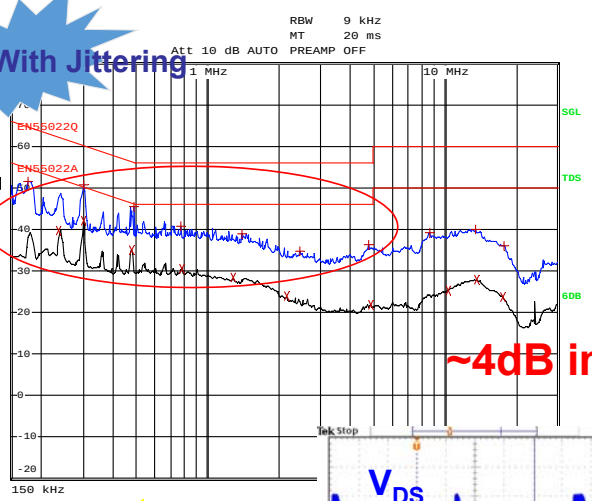
- 共模
- 近场干扰
- 高频振荡
- 开关上升下降沿
- 二极管反向恢复
- Layout
- …

传导（Conducted EMI）

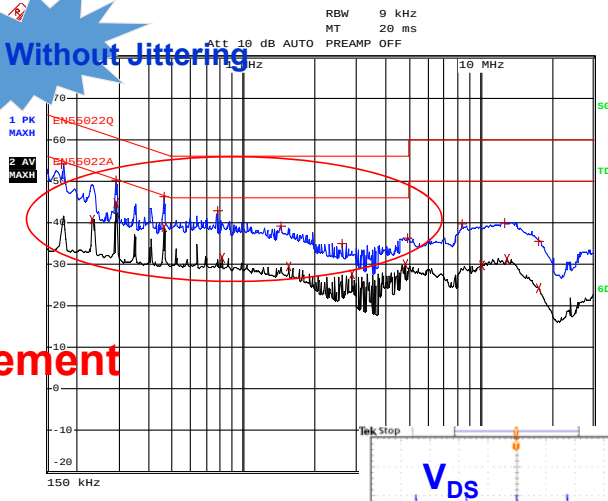
Frequency Jittering

Test condition: V_{IN}=220VAC/50Hz, V_O=12V, I_O=3A

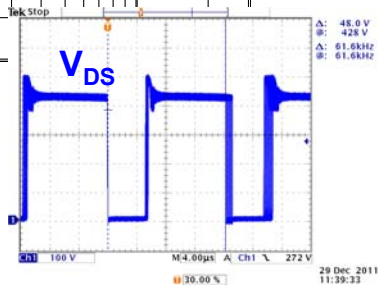
With Jittering

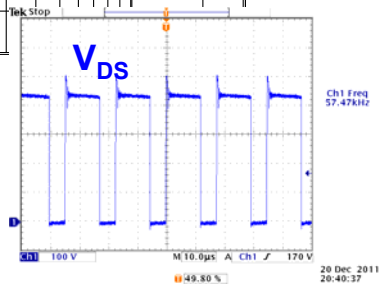


Without Jittering



~4dB improvement





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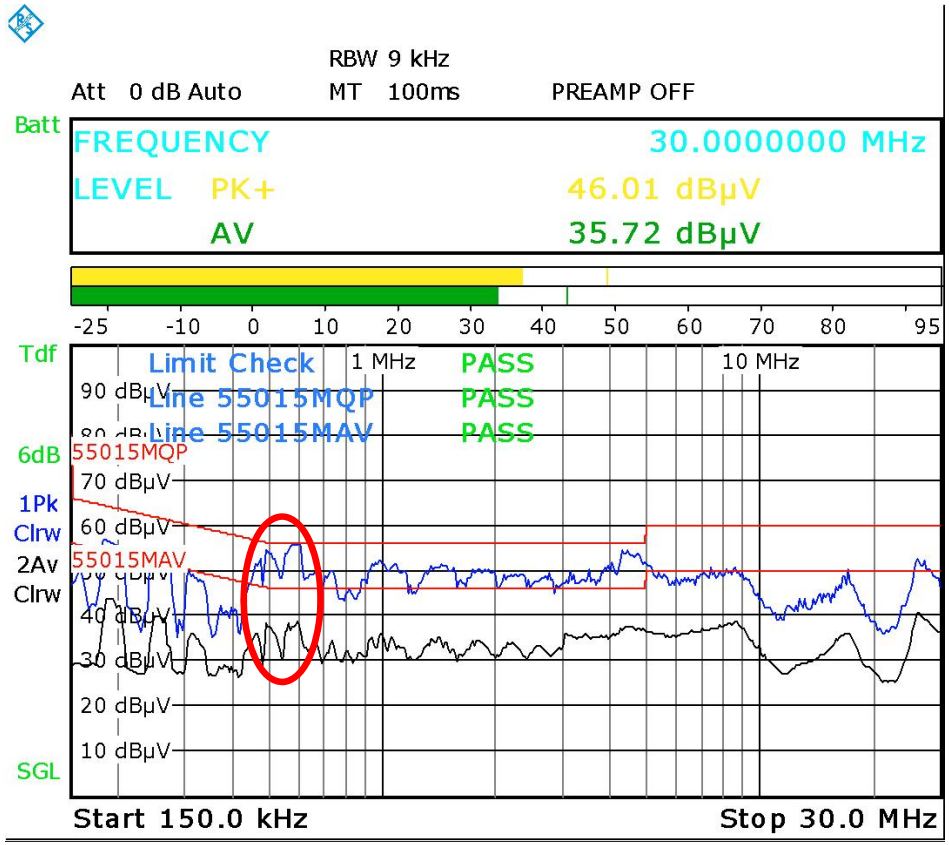
Better EMI Performance

65kHz±6.5%

Frequency jittering which leads to better EMI performance.

传导（Conducted EMI）



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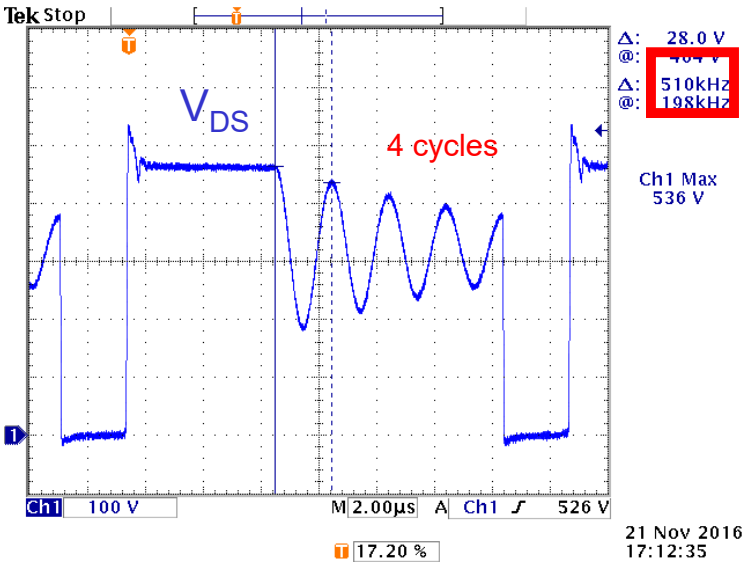
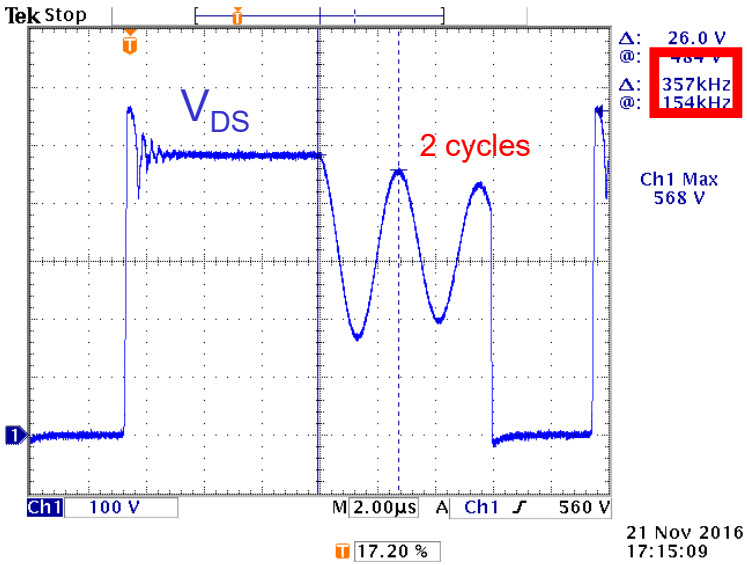
传导（Conducted EMI）

Test Condition: Vin=230VAC, Output=20V/2.25A

L=365uH, N=7, K@90VAC=I_{ripple}/I_{peak}=1.



L=740uH, N=8, K@90VAC=I_{ripple}/I_{peak}=0.7.

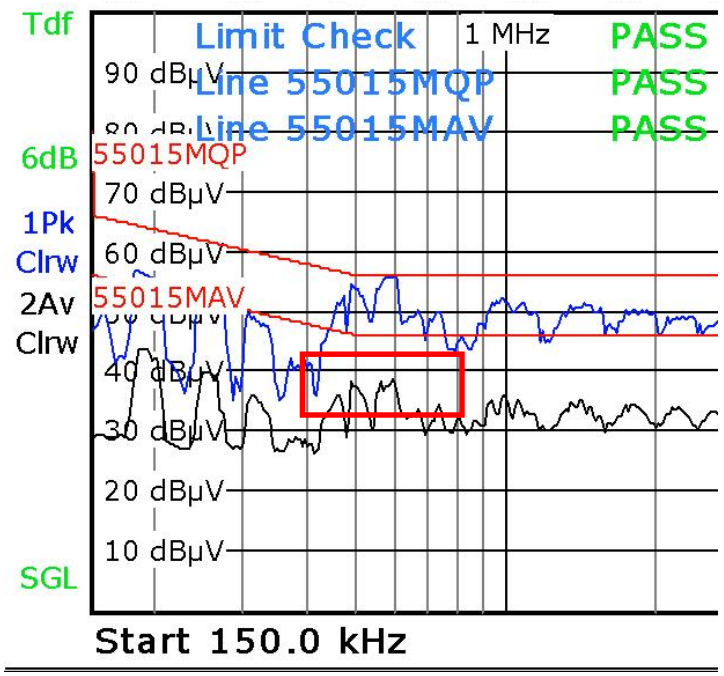


When the system enter DCM, the oscillation is determined by primary inductance L and parasitic capacitor (MOS and transformer).
The oscillation frequency is hundreds kHz, it's hard to get enough EMI margin.

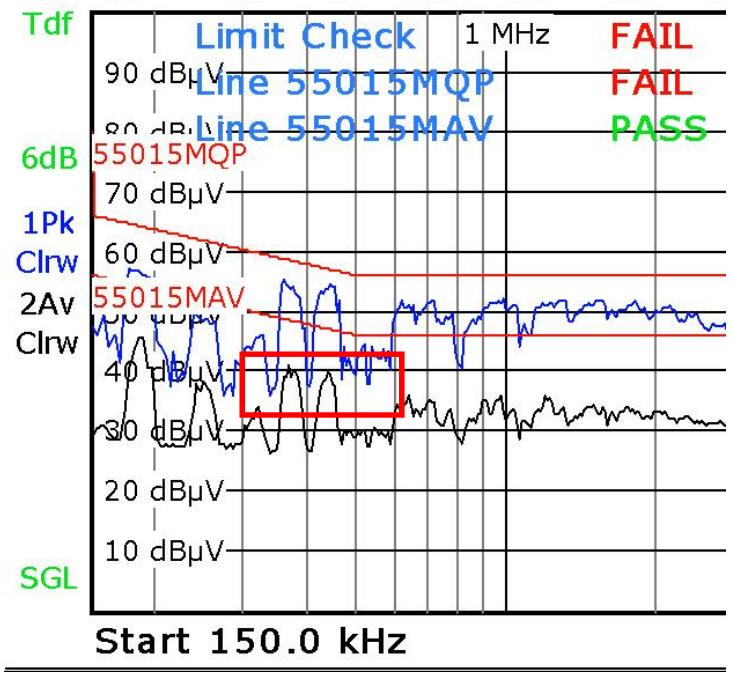
传导（Conducted EMI）

Test Condition: Vin=230VAC, Output=20V/2.25A

L=365uH, N=7, K@90VAC=I_{ripple}/I_{peak}=1.



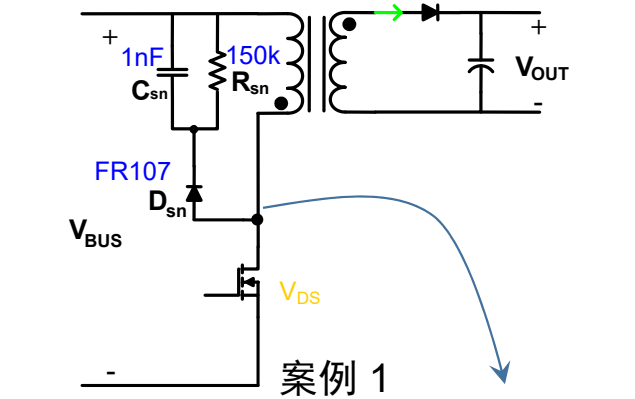
L=740uH, N=8, K@90VAC=I_{ripple}/I_{peak}=0.7.

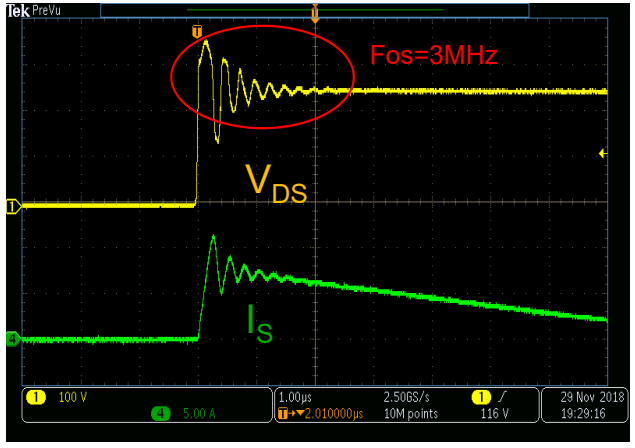


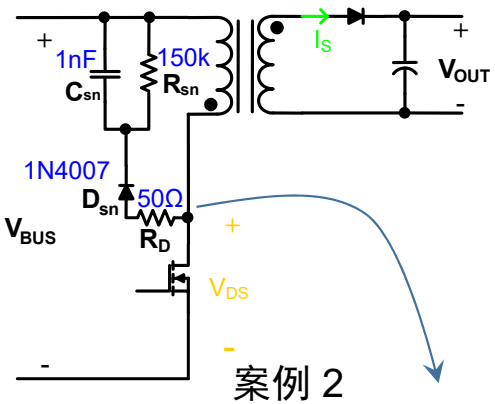
Increasing inductor can reduce frequency, and chooses smaller K can reduce the cycles.

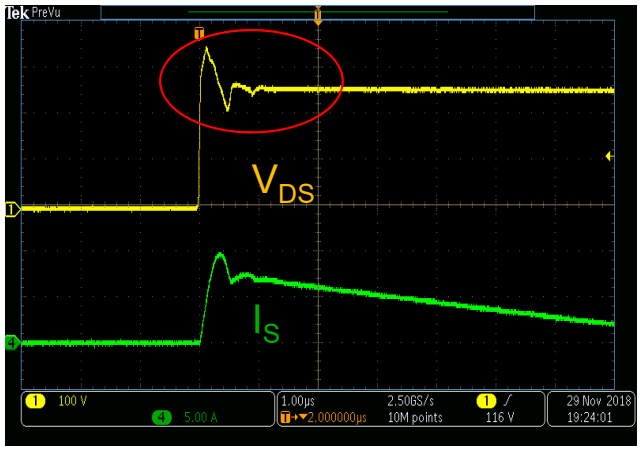
传导（Conducted EMI）

❖ 改善效果快速判定方法







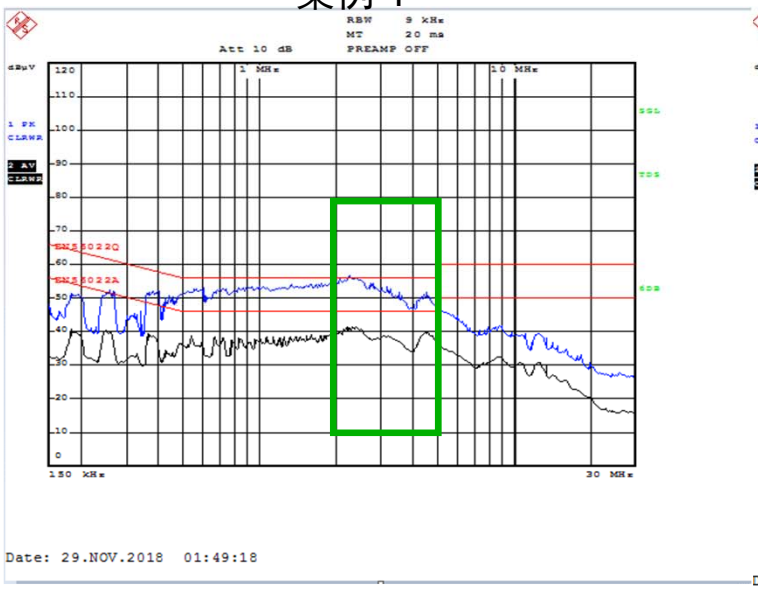


通过改变原边Mosfet关断时VDS的震荡来改善EMI

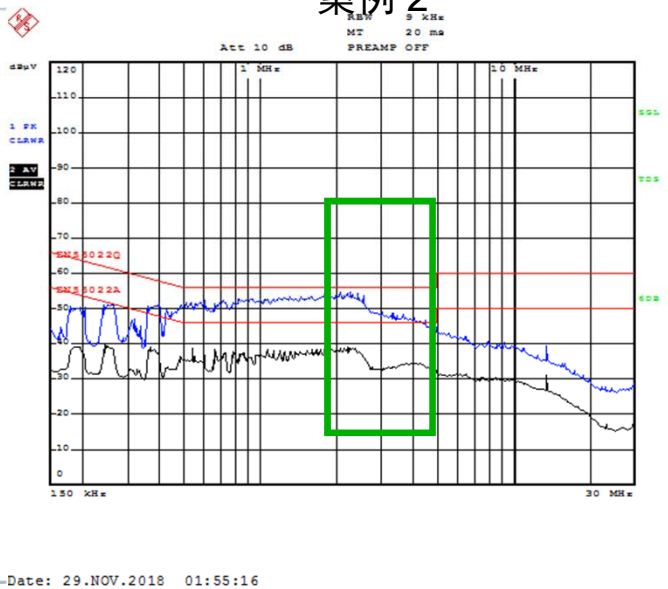
传导（Conducted EMI）

- 改善效果快速判定方法

案例 1



案例 2

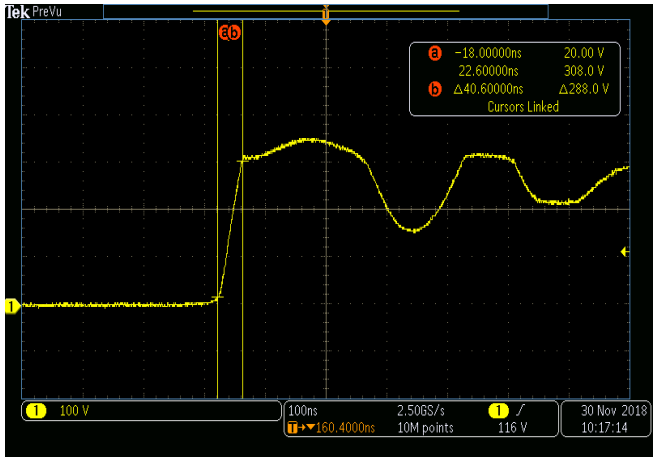


传导EMI在3MHz段有~5dB改善

传导（Conducted EMI）

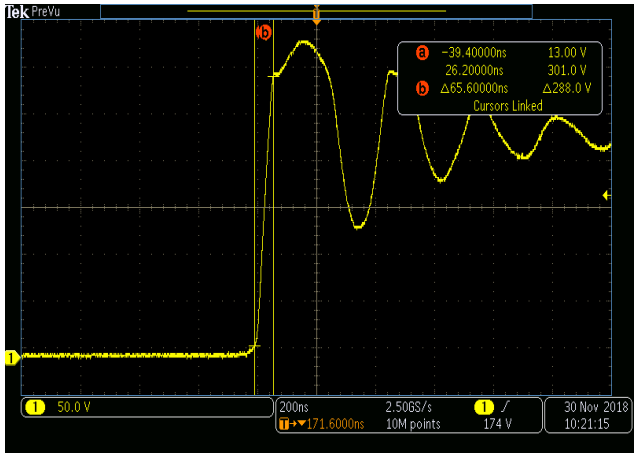
- 改善效果快速判定方法

案例 1



$1/(\pi * \mathrm{tr1}) = 7.8\mathrm{MHz}$

案例 2



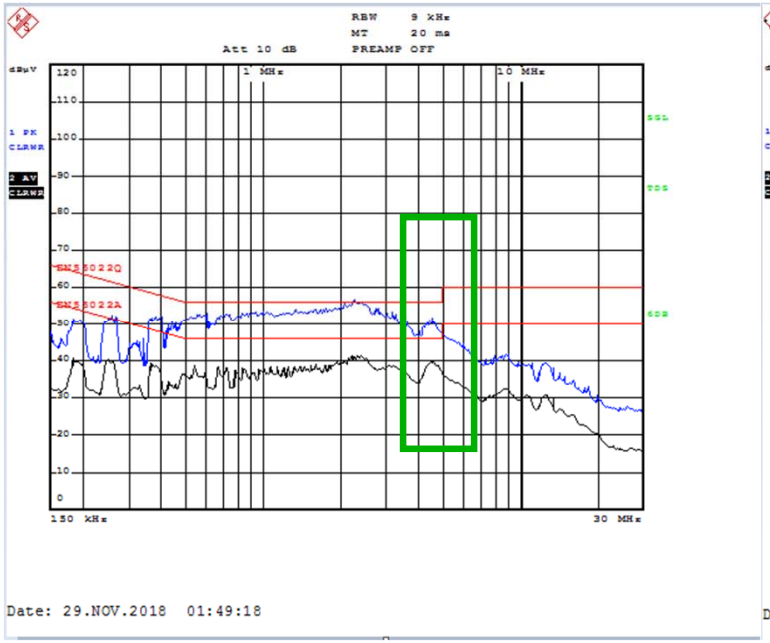
$1/(\pi * \mathrm{tr2}) = 4.9\mathrm{MHz}$

改变VDS的上升/下降斜率来改善EMI

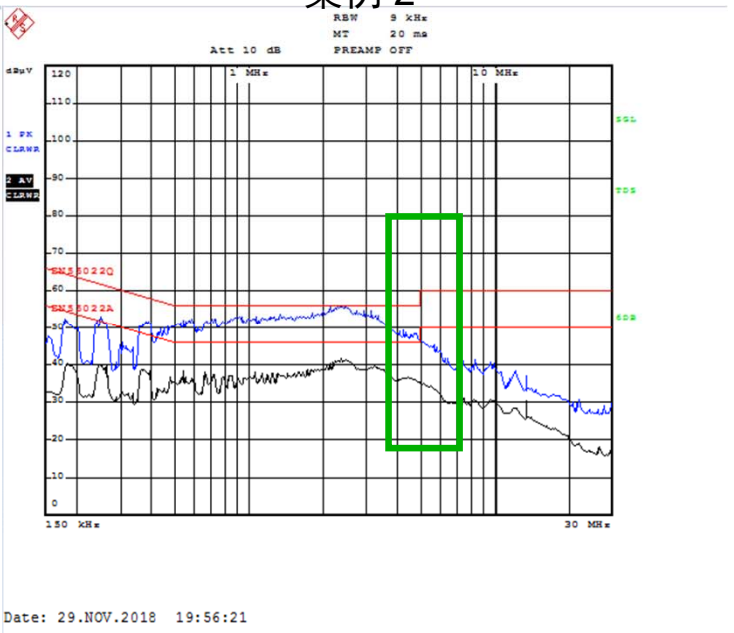
传导（Conducted EMI）

- 改善效果快速判定方法

案例 1



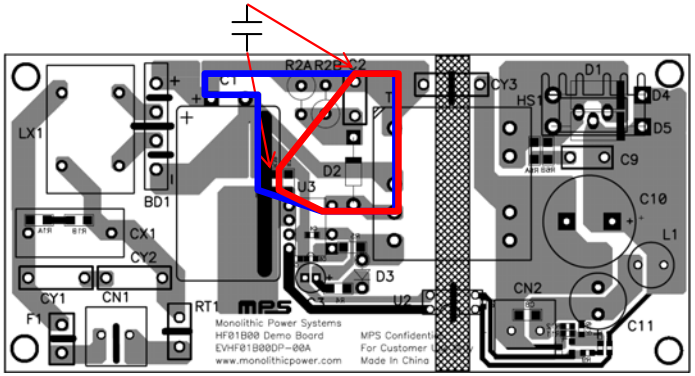
案例 2

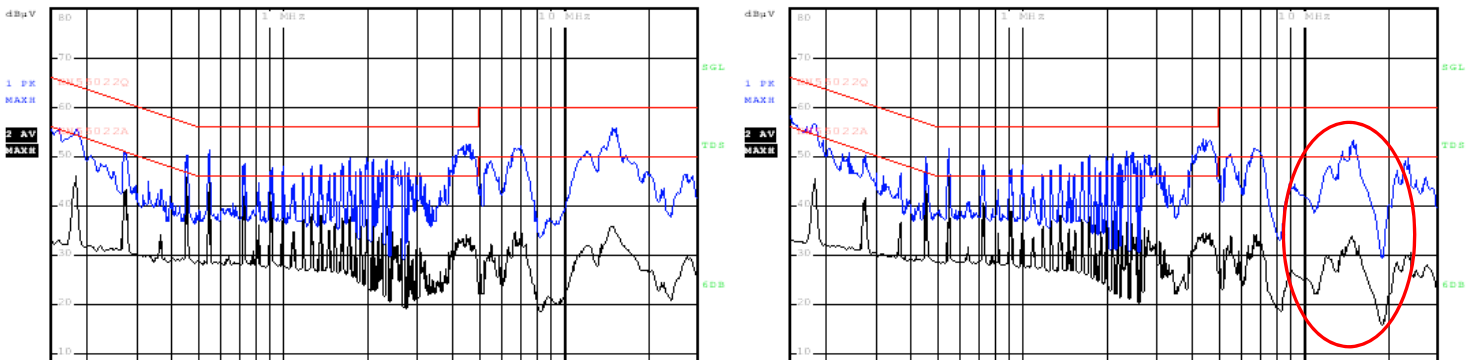


传导EMI在5MHz段有~3dB改善

传导（Conducted EMI）

- 减小传导电磁干扰途径一 – 改善电路板的布线





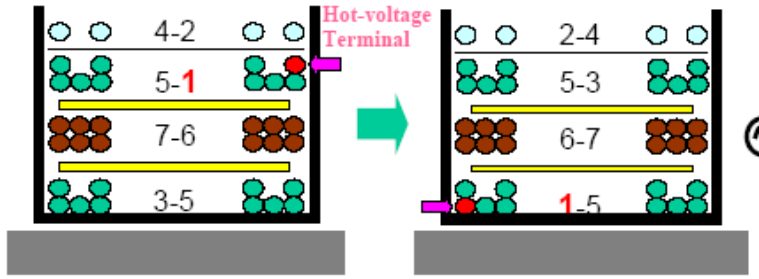
传导EMI在10MHz+段有~3dB改善

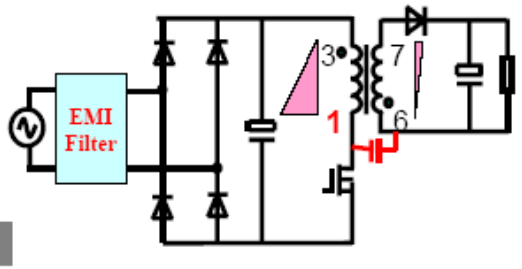
传导（Conducted EMI）

- Y capacitors
- Common mode filters (Common Choke)
- Better transformer construction techniques aimed at reducing CM noise at its source thus reducing the need for heavy filtering using CM line filters and Y capacitors
  - Basic transformer construction recommendations
  - Use of Shield windings
- Near field coupling

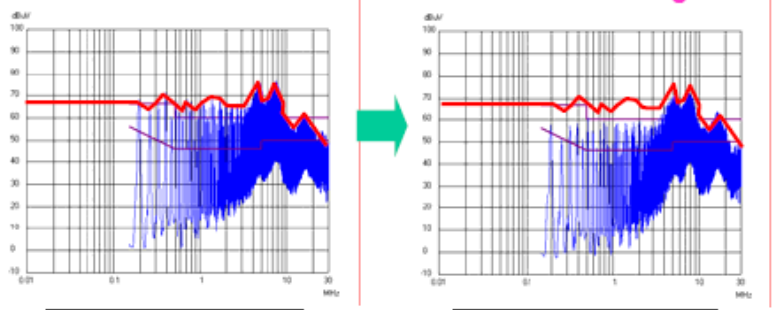
传导（Conducted EMI）

Effects of terminal position on conducted EMI noise





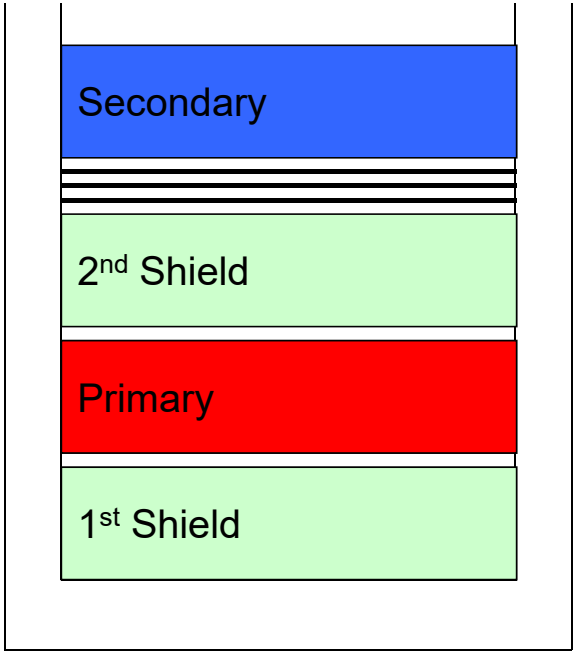
Point 1: Hot-voltage terminal



CL Filter:
Y cap: 1000pf
L: 5.26mH

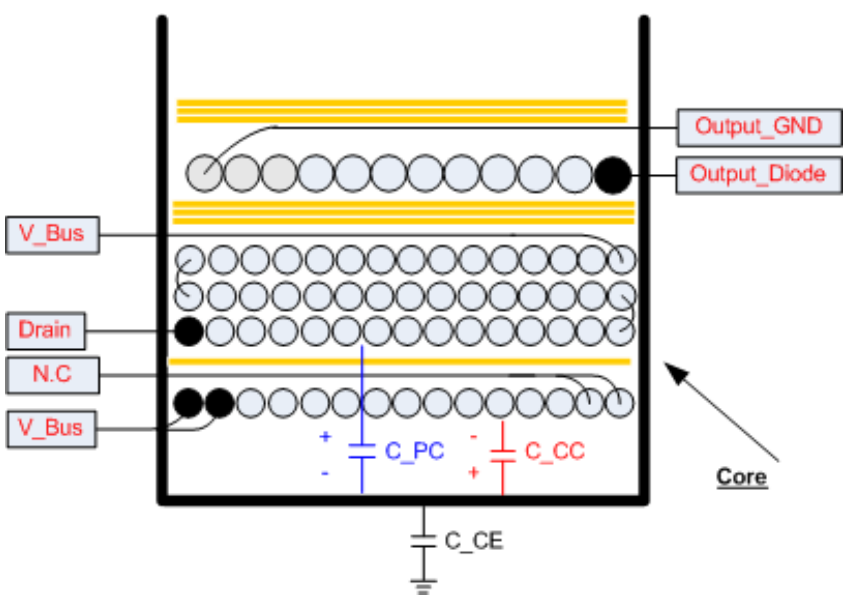
CL Filter:
Y cap: 1000pf
L: 1.23mH

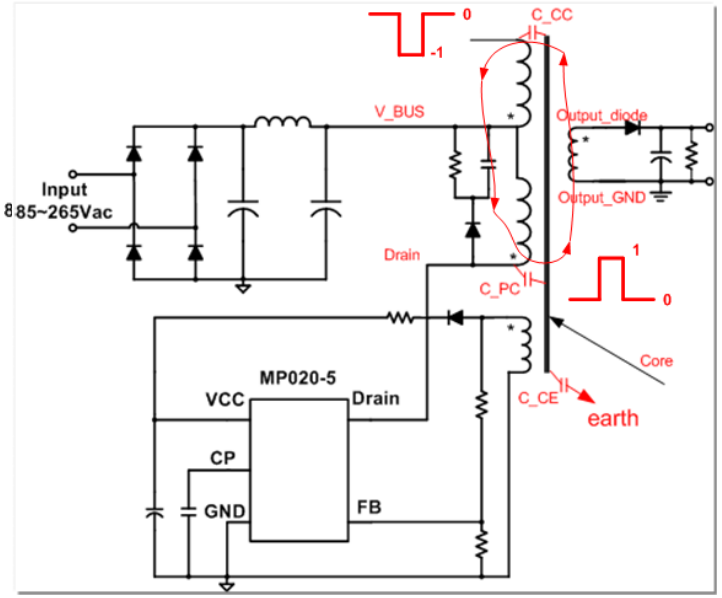
传导（Conducted EMI）



- Generally 2 separate shield windings are recommended
- 1st shield is the “Cancellation Shield winding” and is normally placed between core and primary winding
- 2nd shield is the “Balanced Shield winding” placed between the Primary and the Secondary windings

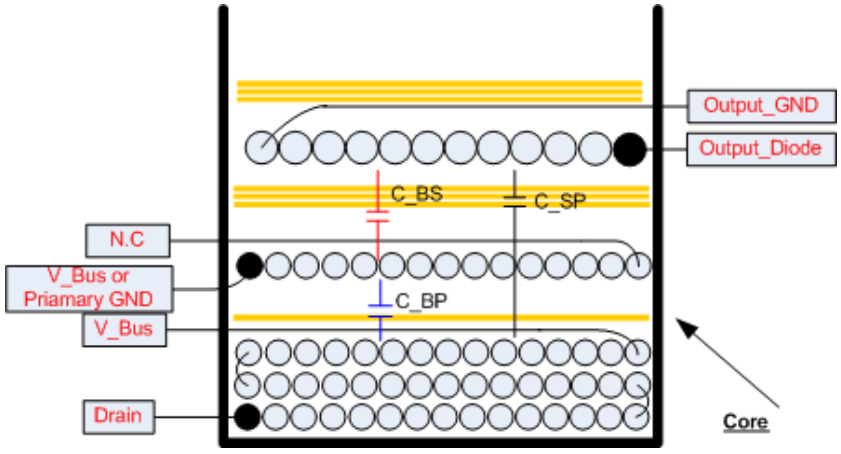
传导（Conducted EMI）

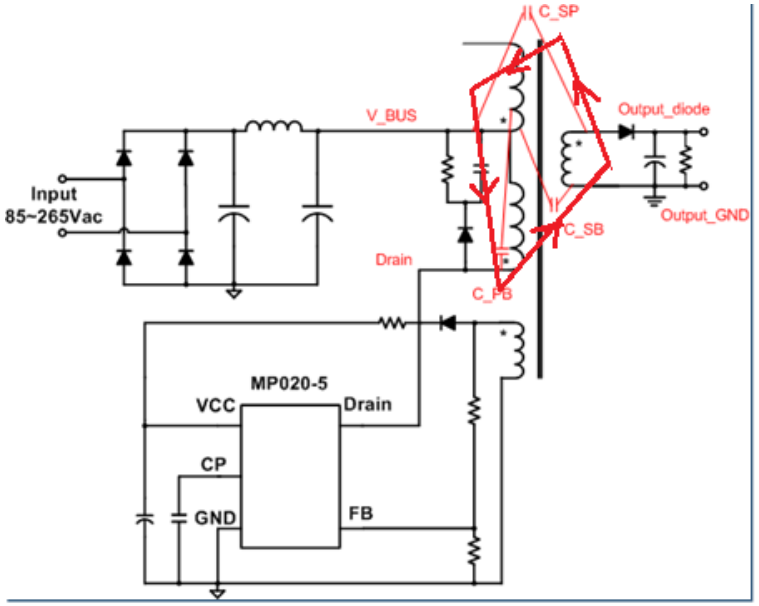




- Cancels out the P-E noise mechanism
- Generally uses around ½ the number of turns in the first layer of primary winding (should be tuned by the evaluation)
- Both the primary and cancellation windings induce displacement currents in opposite directions, leading to “cancellation” of displacement currents within the LISN

传导（Conducted EMI）

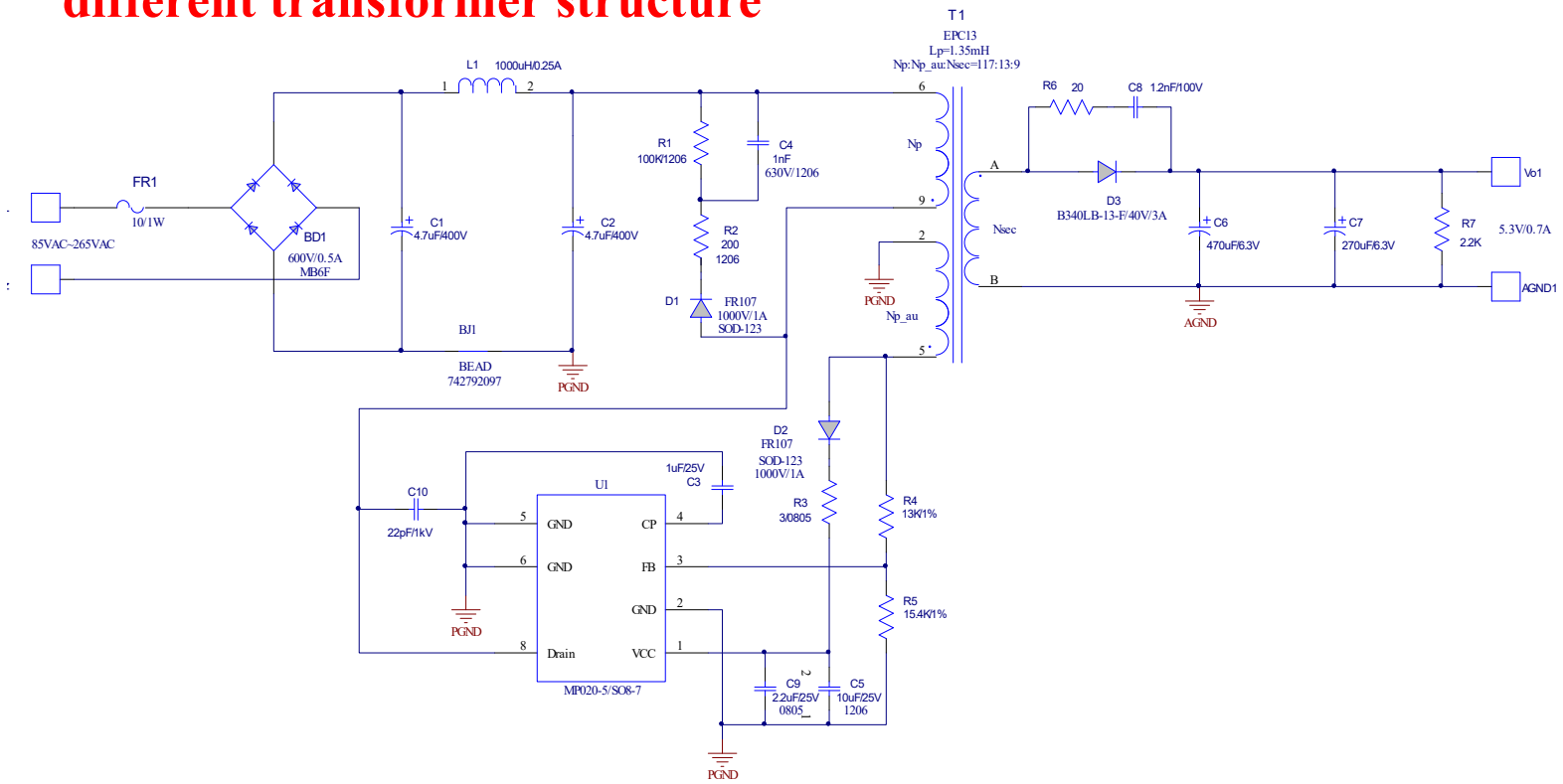




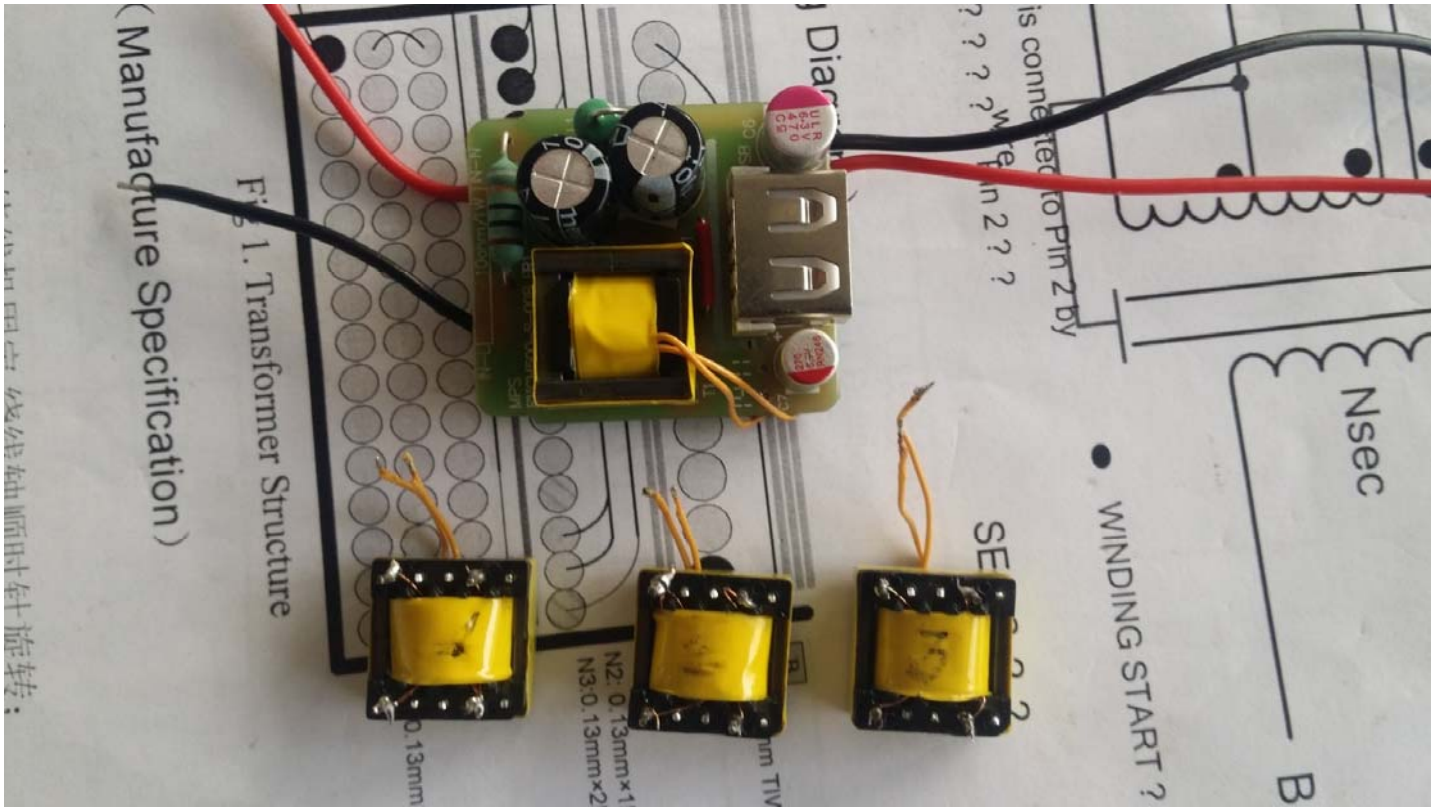
- Used to reduce P-S coupling mechanism
- Generally uses 1-2 turns less than the secondary winding
- Principle is to “balance” the potential at the primary & secondary side thereby reducing noise coupling

传导（Conducted EMI）

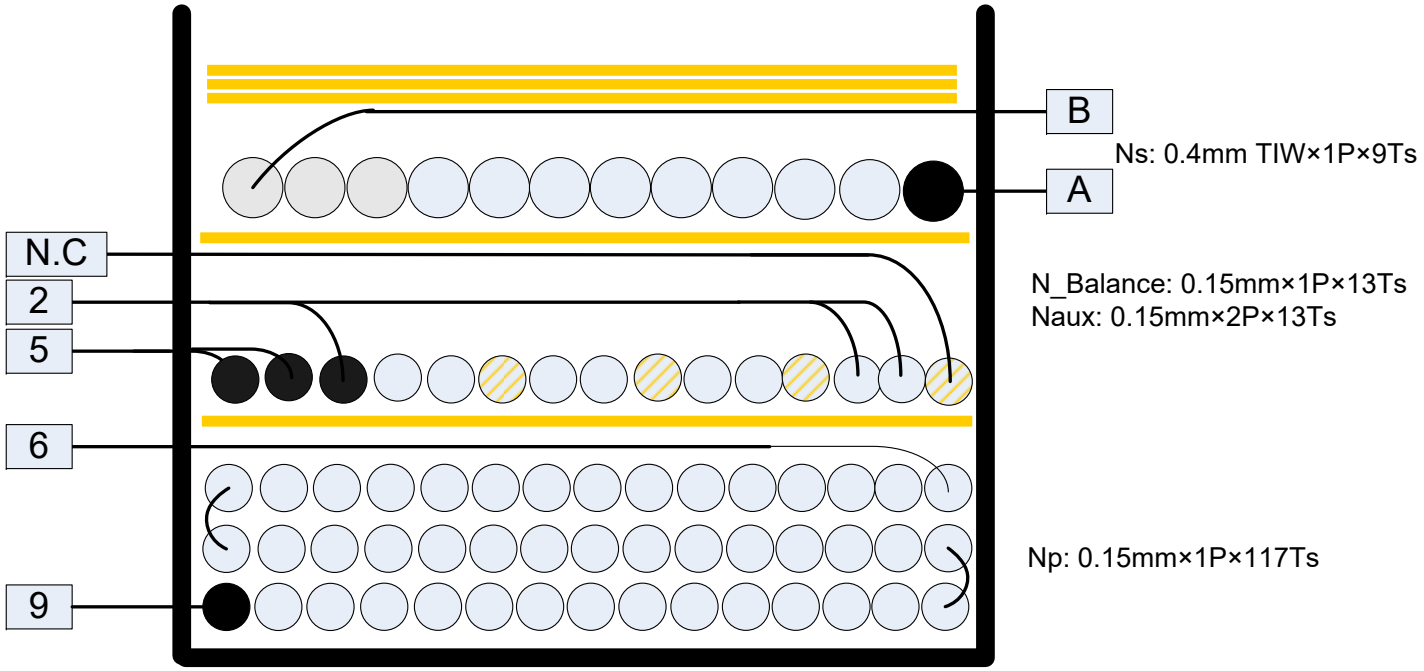
The following test results is based on the same SCH except the different transformer structure



传导（Conducted EMI）

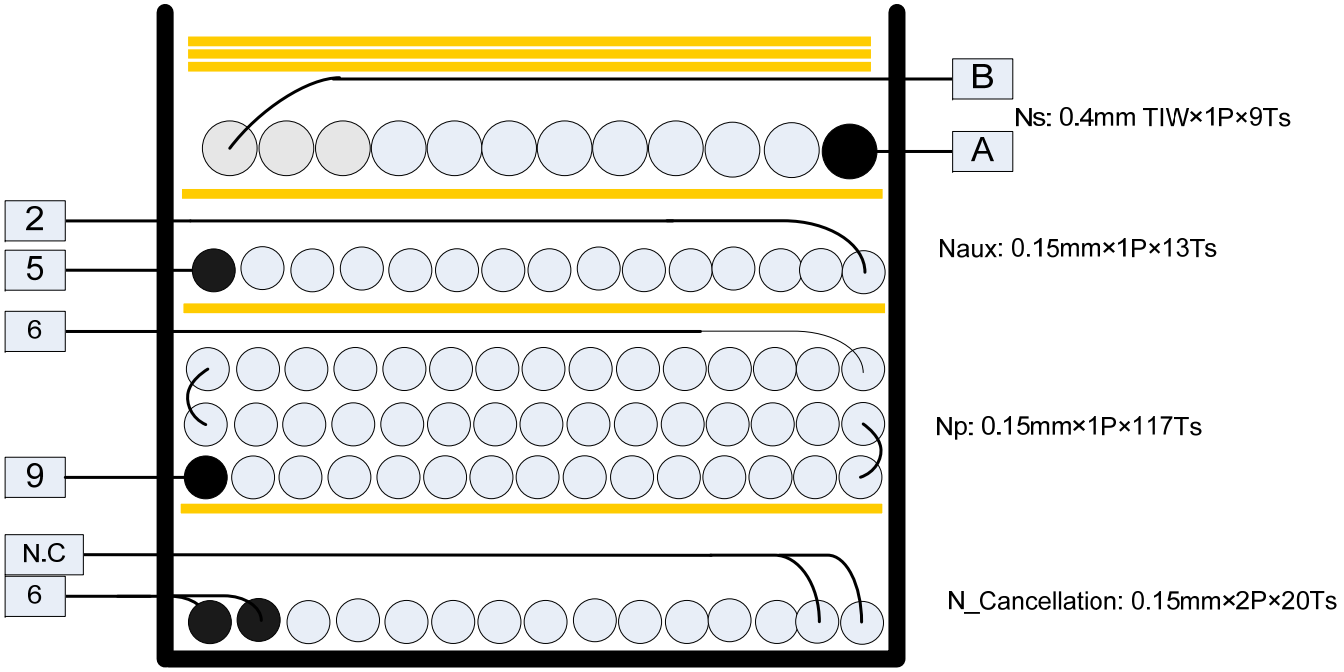


传导（Conducted EMI）



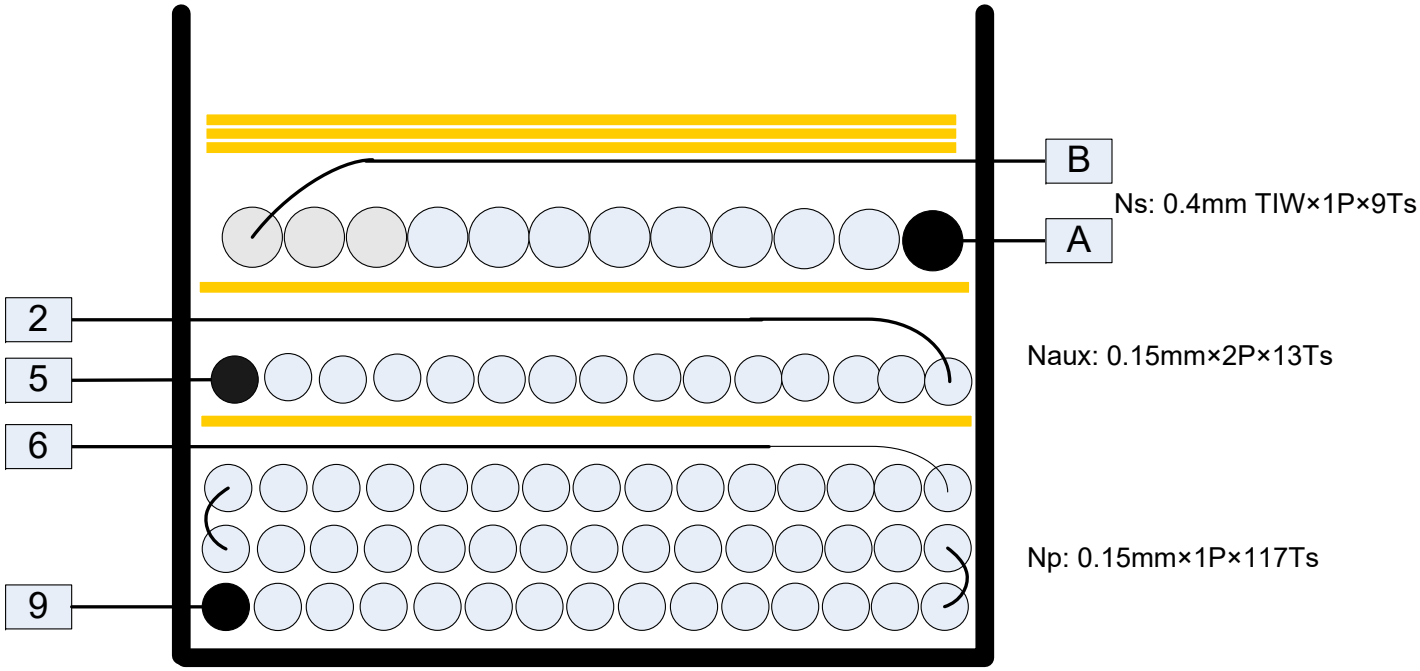
Xformer #1 W/I balance winding, which wound with the auxiliary winding

传导（Conducted EMI）



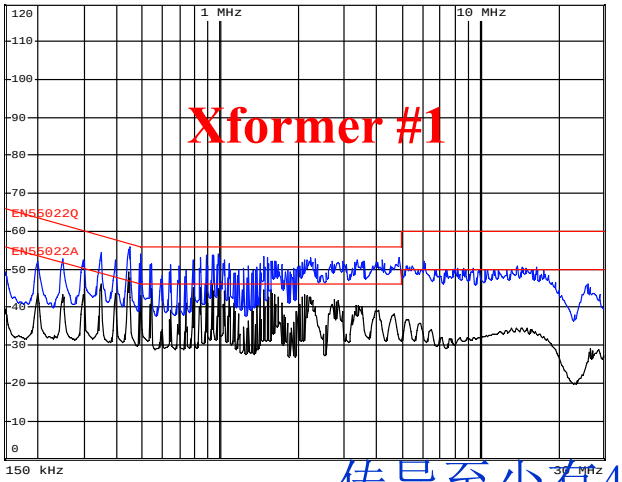
Xformer #2 W/I cancellation winding

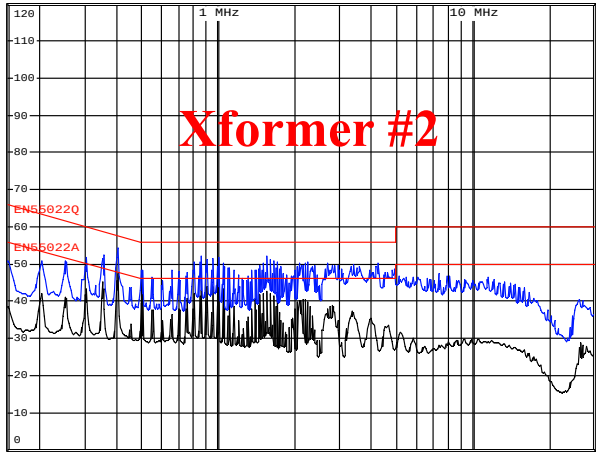
传导（Conducted EMI）



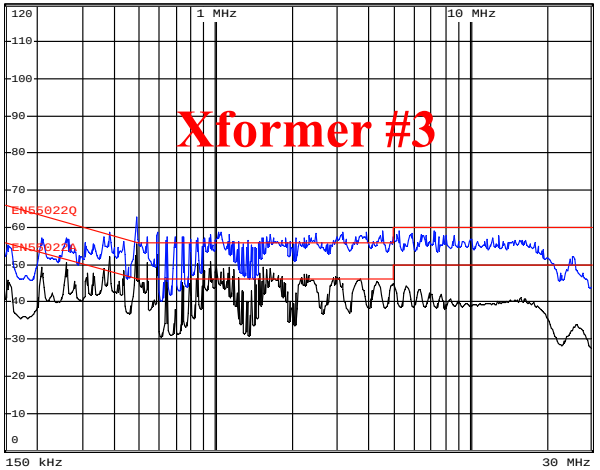
Xformer #3 W/O any cancellation or balance winding

传导（Conducted EMI）





传导至少有4~5dB改善#1，#2 Vs #3



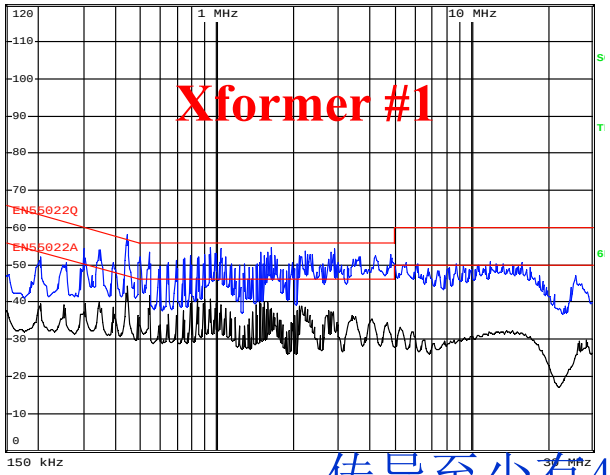
Test conditions:

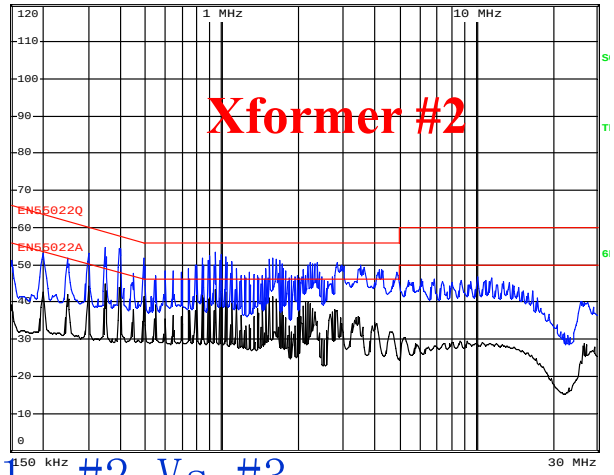
220Vac input

5.3V/0.7A output

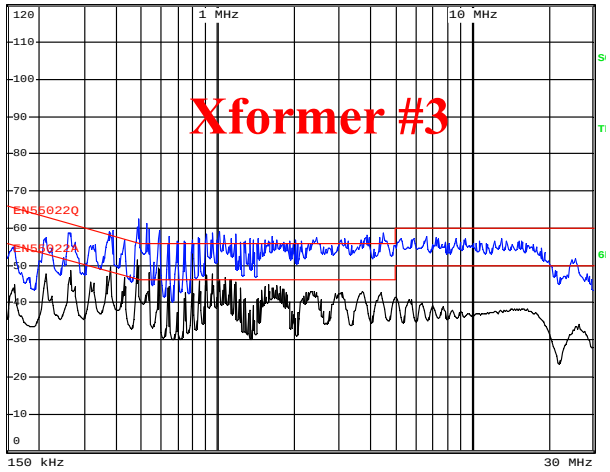
L line

传导（Conducted EMI）





传导至少有4~5dB改善#1，#2 Vs #3



Test conditions:

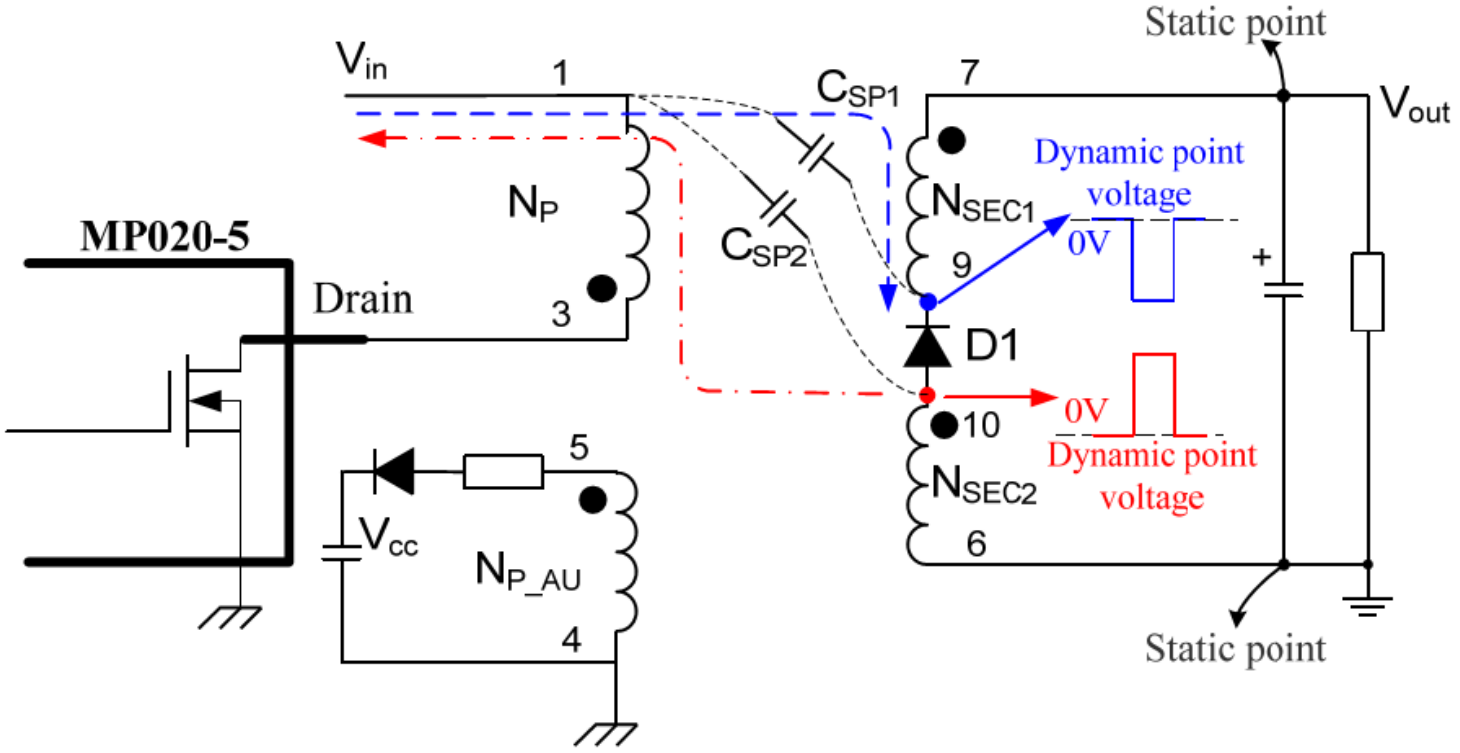
220Vac input

5.3V/0.7A output

N line

传导（Conducted EMI）

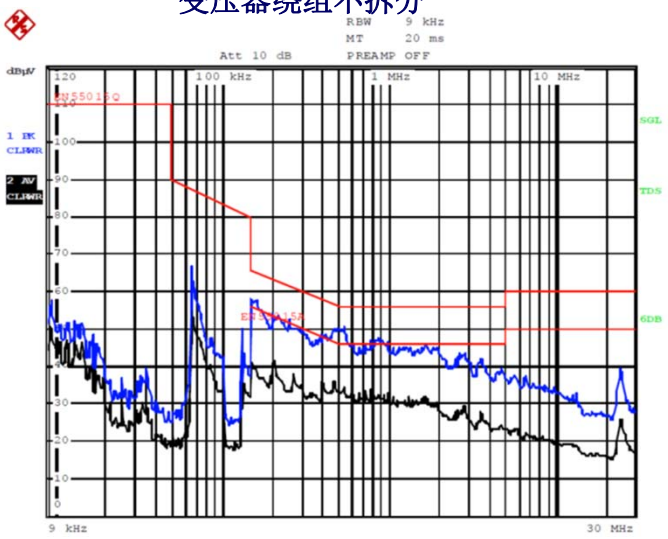
- 减小传导电磁干扰途径 – 改变变压器结构



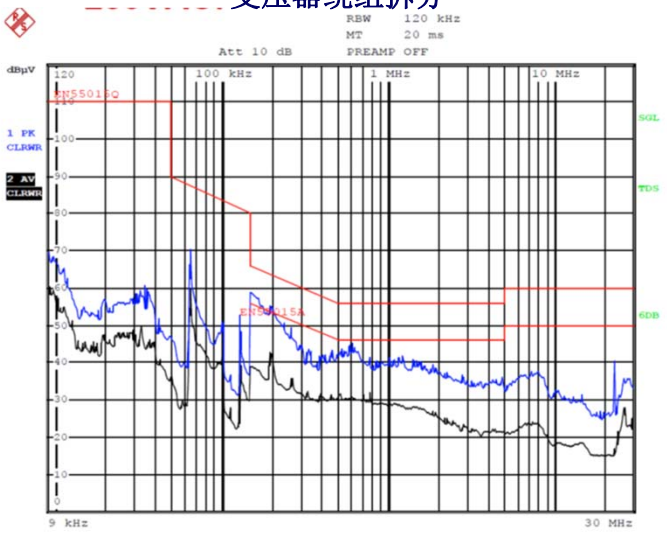
传导（Conducted EMI）

- 减小传导电磁干扰途径四 – 改变变压器结构

变压器绕组不拆分



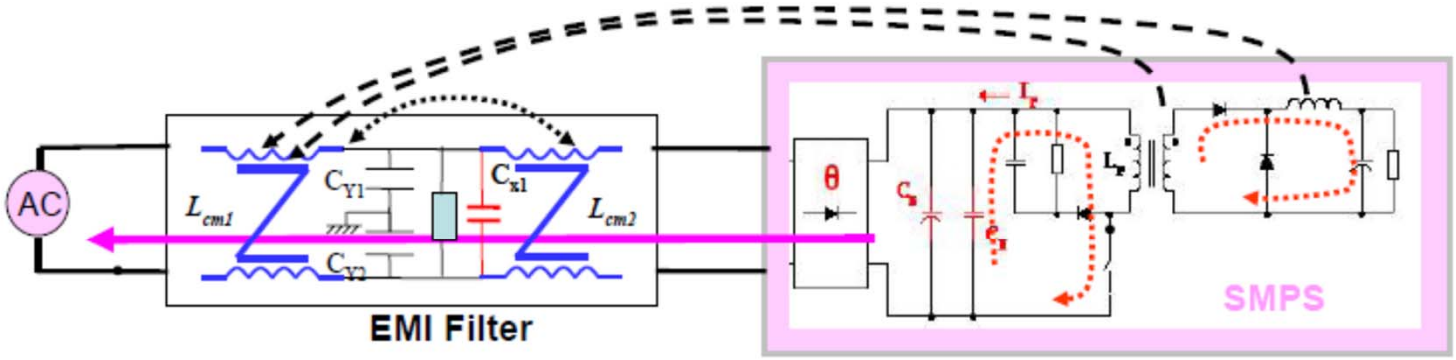
变压器绕组拆分



在通过将变压器的一个绕组拆分为两部分，200kHz 至 5MHz 有大约 6dB 的改善.

传导（Conducted EMI）

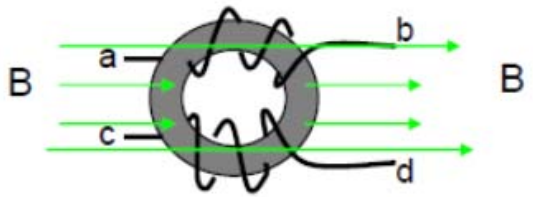
- 近场耦合效应

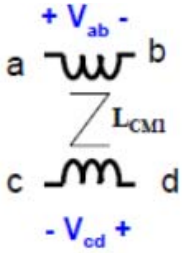


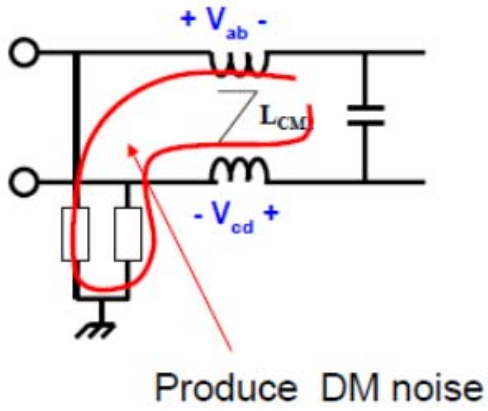
- Coupling inside EMI filter: CMC to CMC, CMC to Cap, Cap to Cap.
- Coupling between EMI filter and transformer/inductor.

传导（Conducted EMI）

- 近场耦合效应



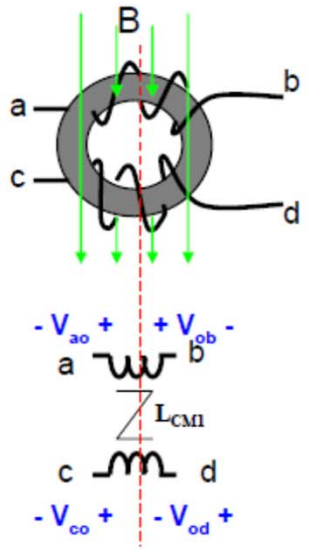




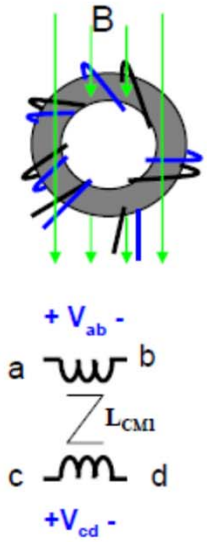
传导（Conducted EMI）

- 近场耦合效应

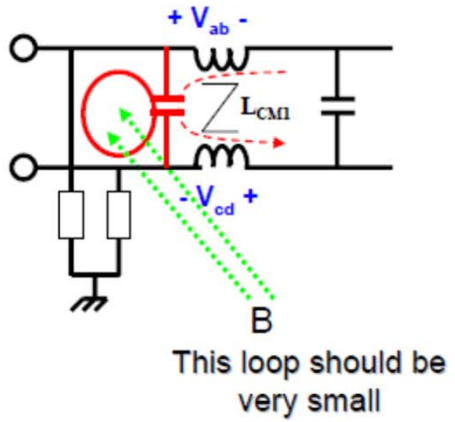
方案1
改变共模电感方向



方案2
共模电感双线并绕

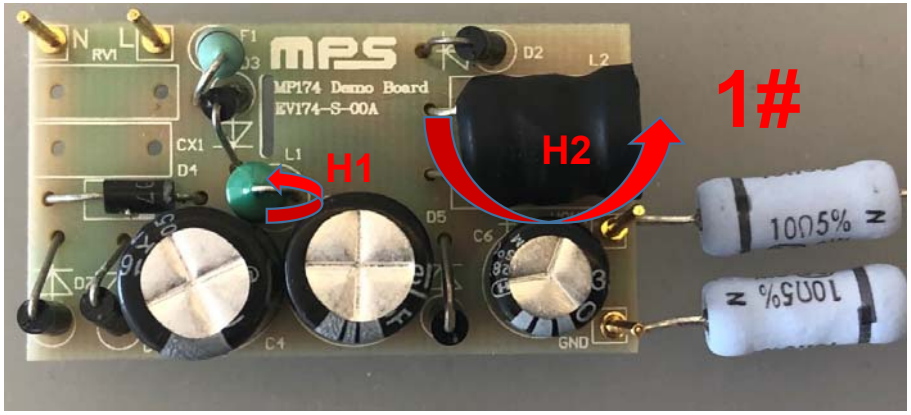


方案3
共模电感前加电容

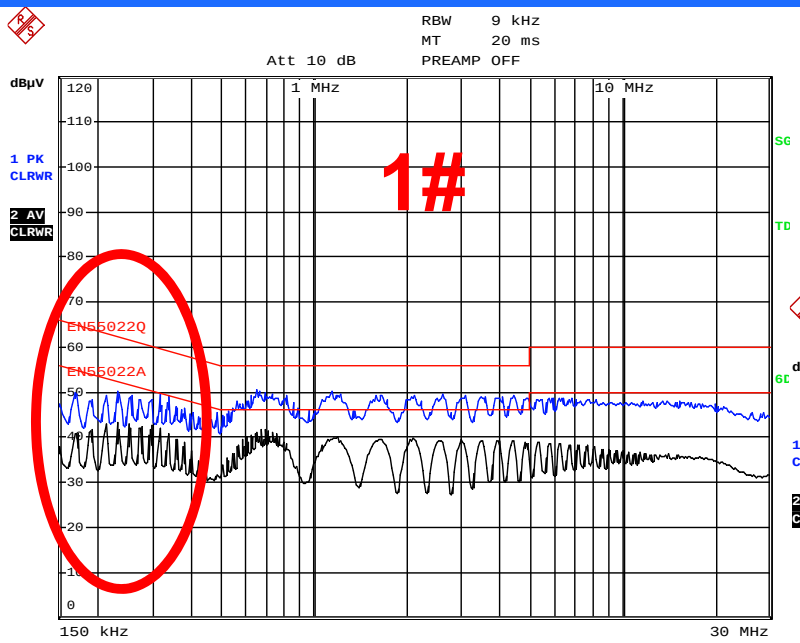


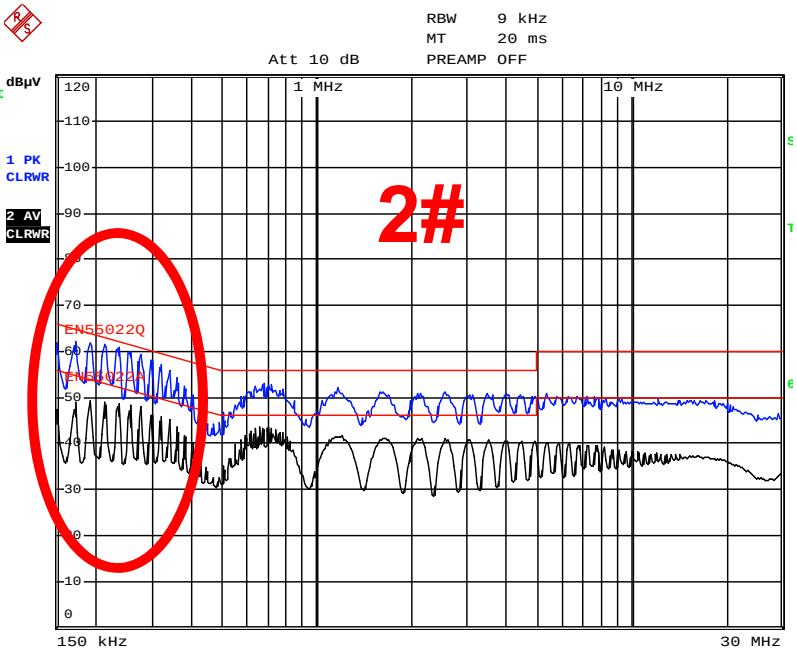
传导（Conducted EMI）

- 近场耦合效应



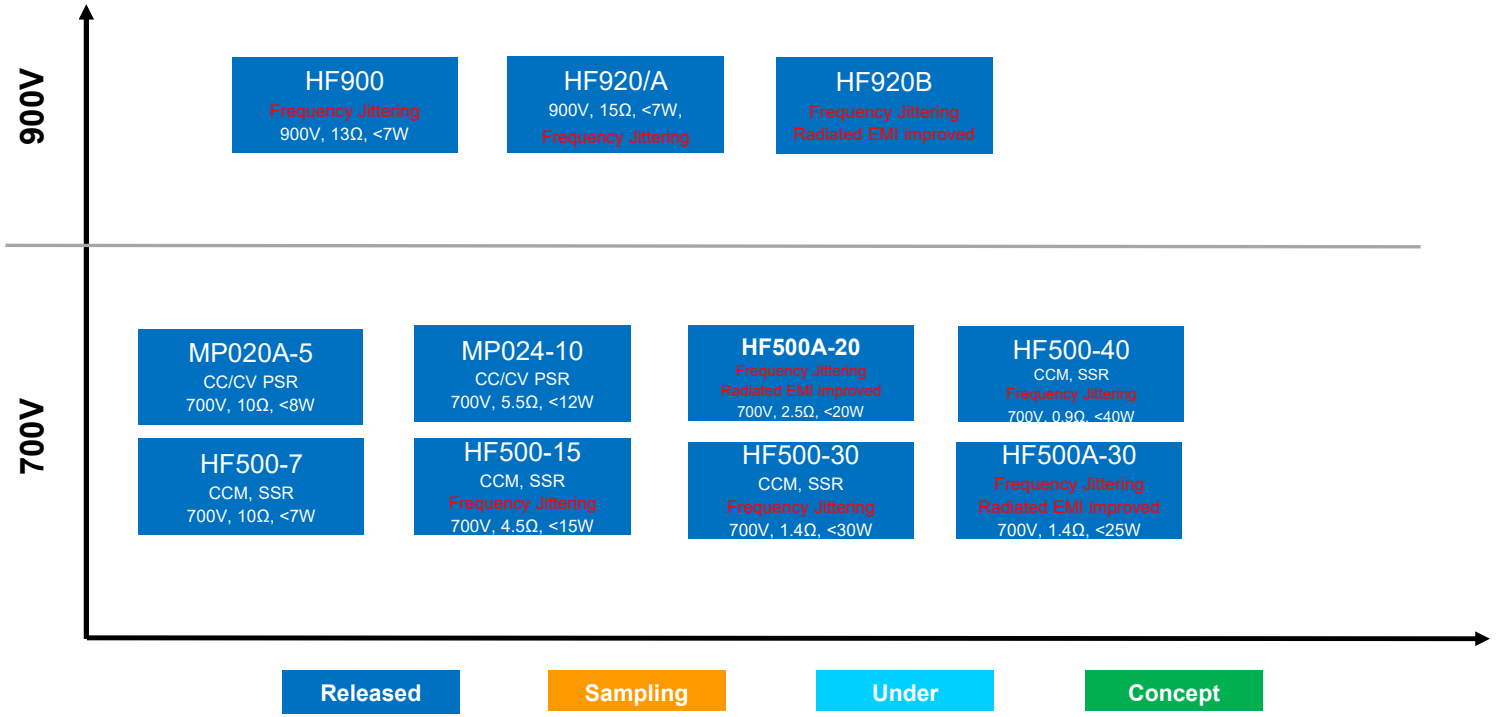
传导（Conducted EMI）



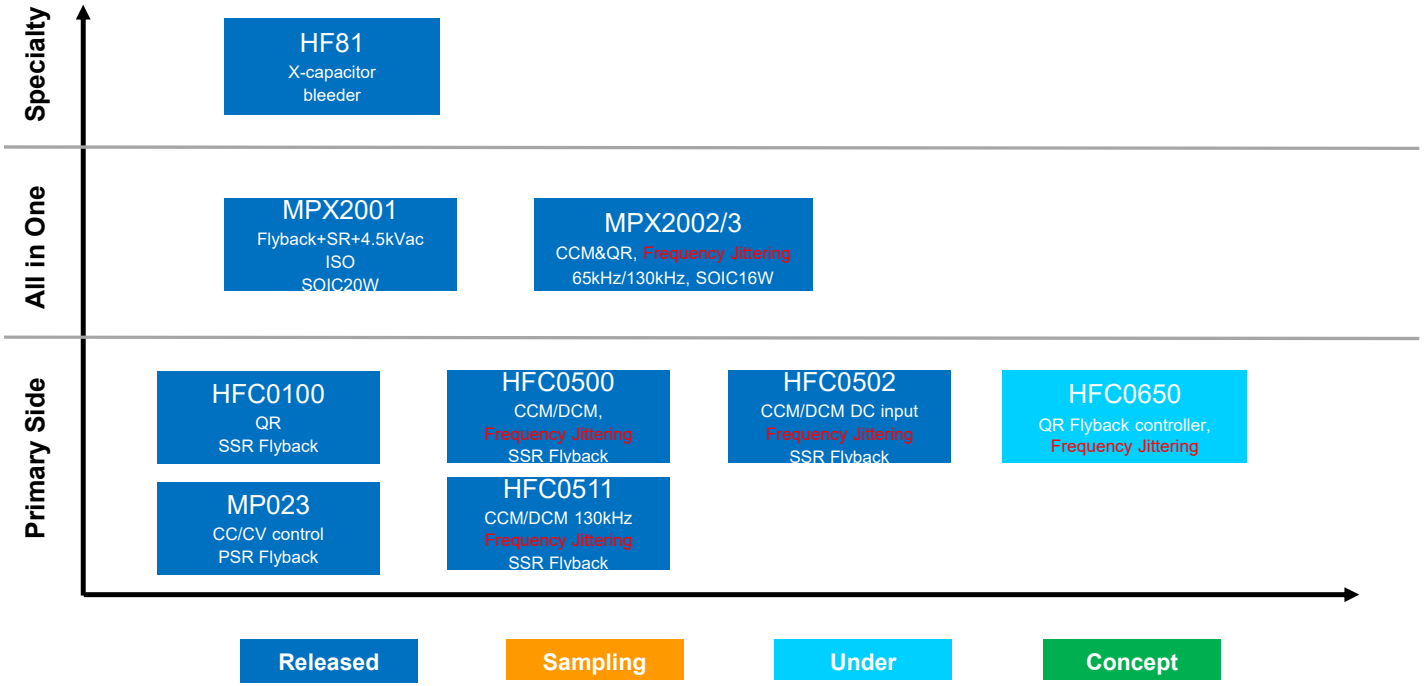


+10dB improvement

AC/DC Flyback regulator with integrated MOSFET, up to 40W



AC/DC Flyback Controller, up to 140W



Q&A