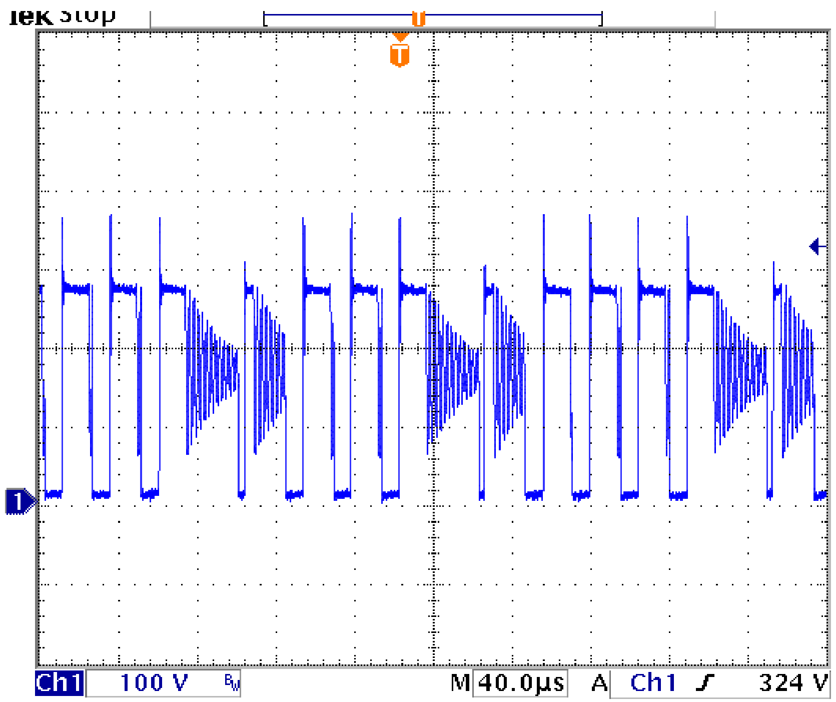
AC/DC开关电源EMI优化设计

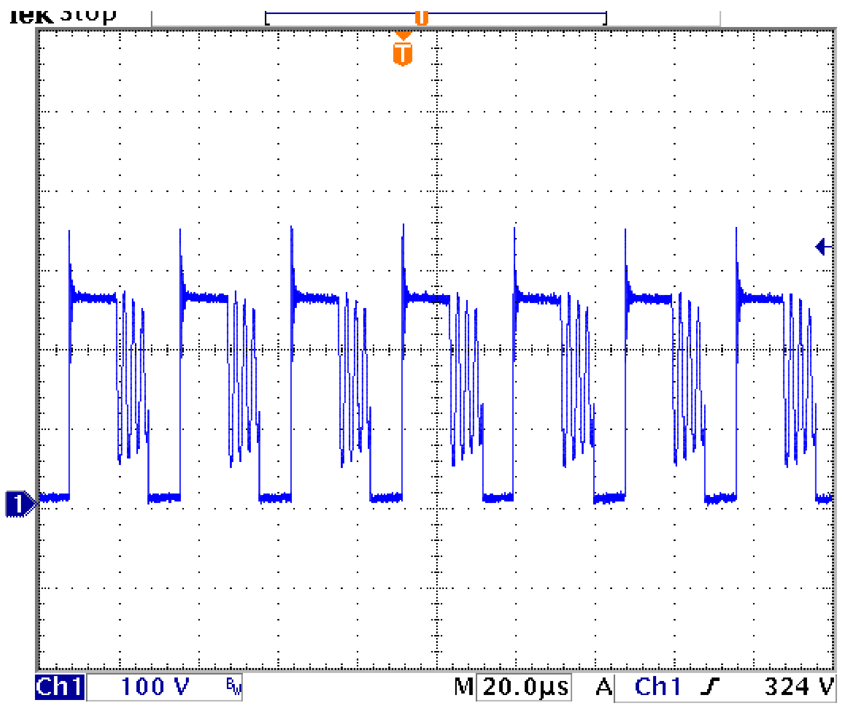
Aug. 2023

EMI 危害

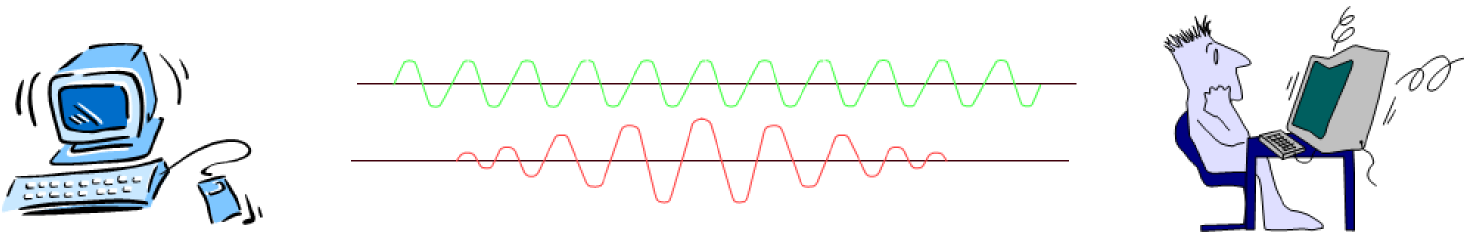
大的共模噪声导致芯片工作不正常



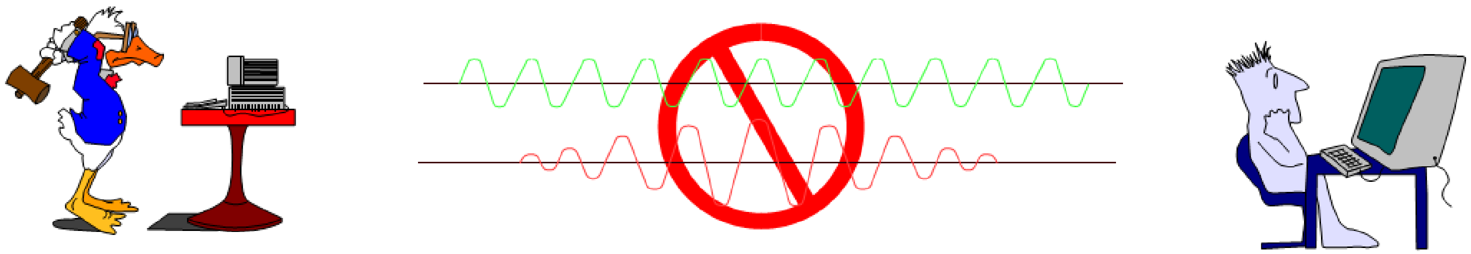
优化后的工作波形



基本概念

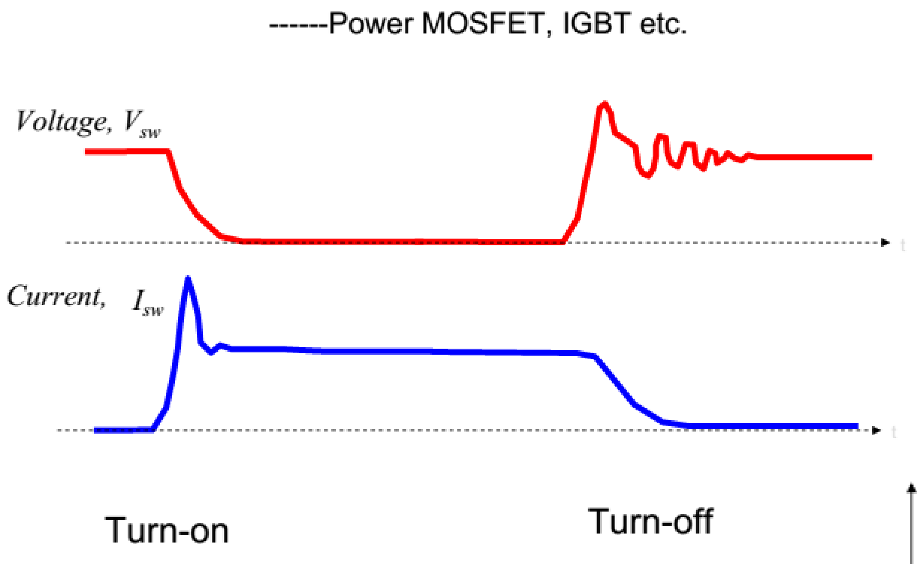


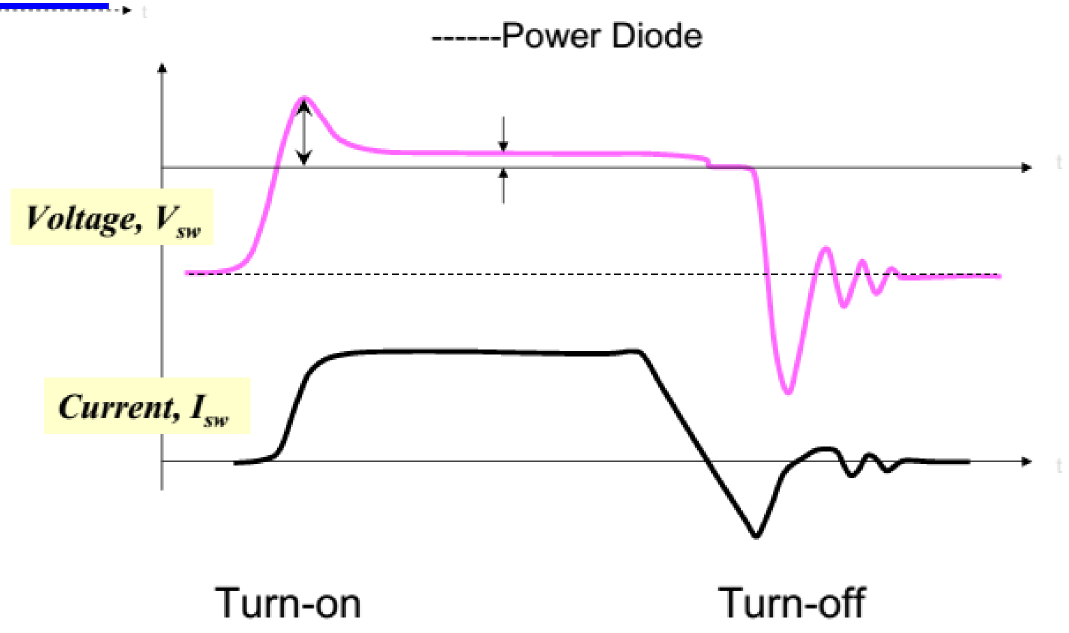
Noise Source ⇨ Coupling Path ⇨ Receptor



Suppress noise source	Cut off coupling path	Make receptor insensitive

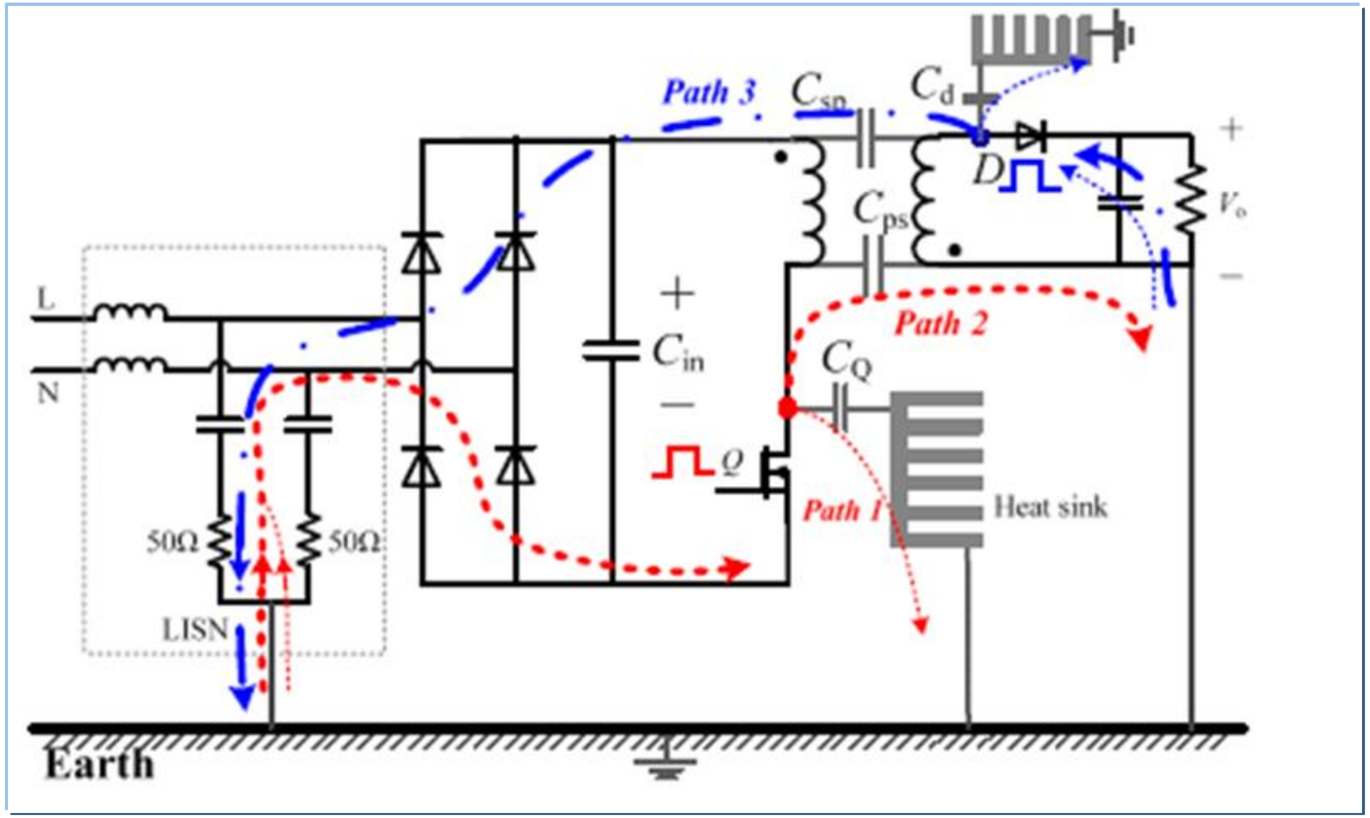
开关电源中的主要噪声源





传导（conducted EMI）

The main noise sources and coupling paths in flyback converter



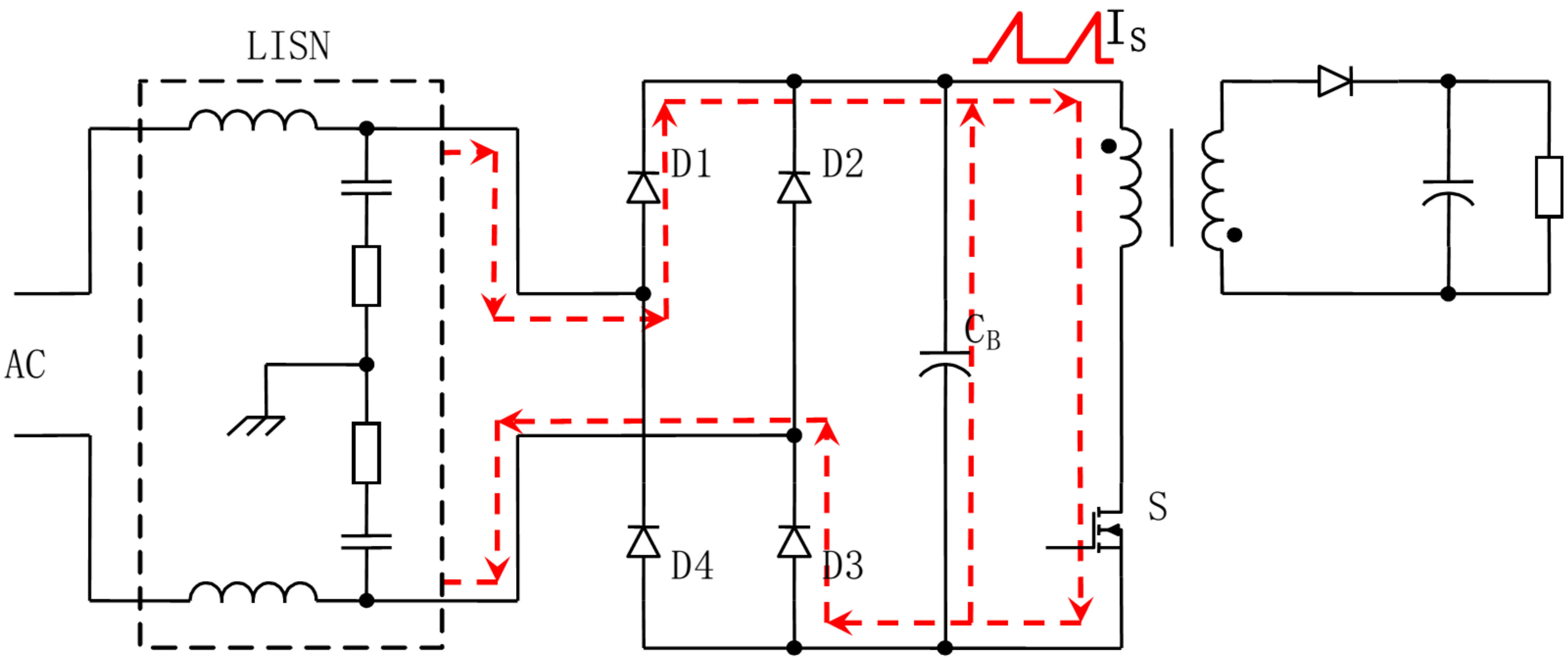
Noise Source: MOSFET, Diode

Coupling path: parasitic capacitance, PCB routing

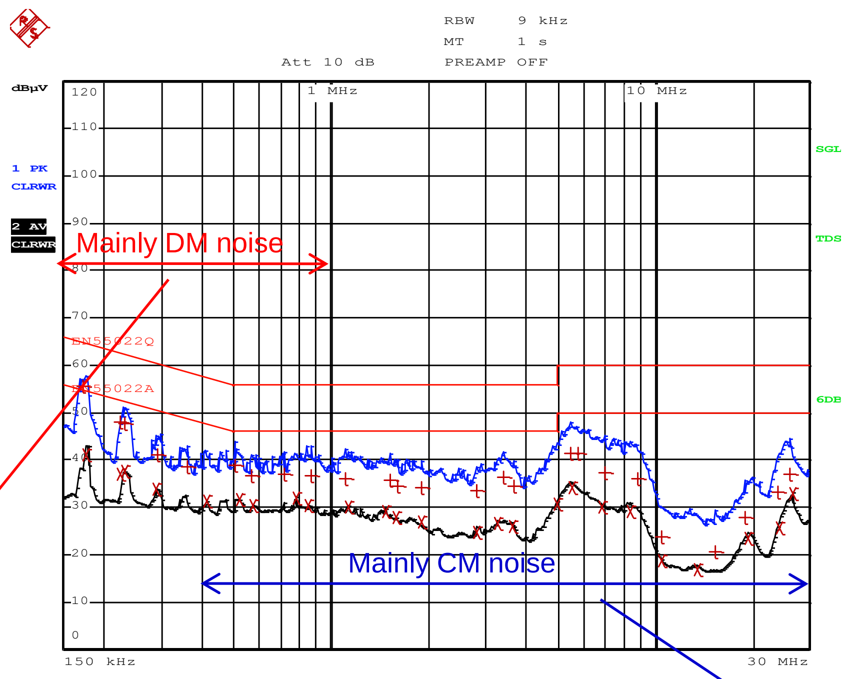
Load: 25Ω resistor

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**

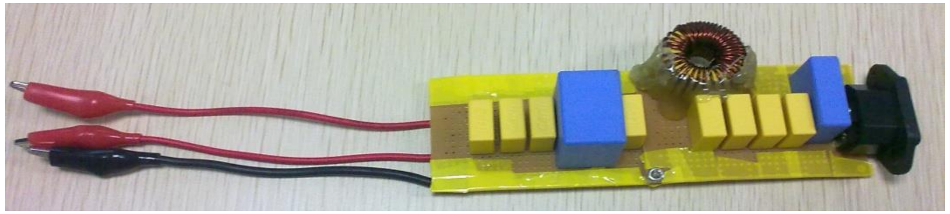
Common mode noise is mainly voltage phenomenon and is driven by rapidly changing voltage signals

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

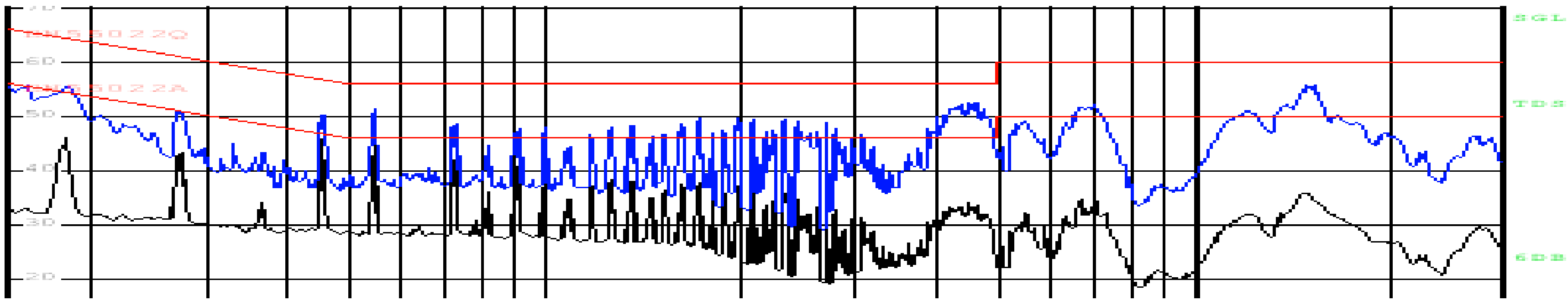
传导（Conducted EMI）

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
- …

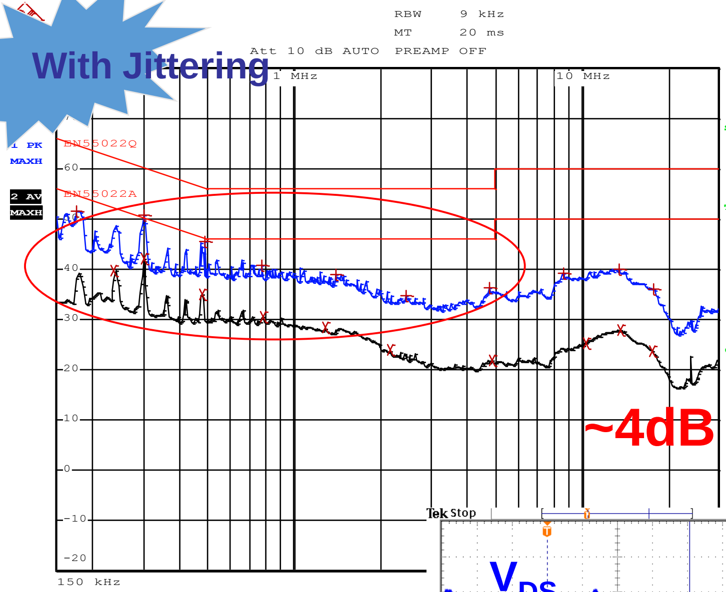
- 共模
- 近场干扰
- 高频振荡
- 开关上升下降沿
- 二极管反向恢复
- Layout
- …

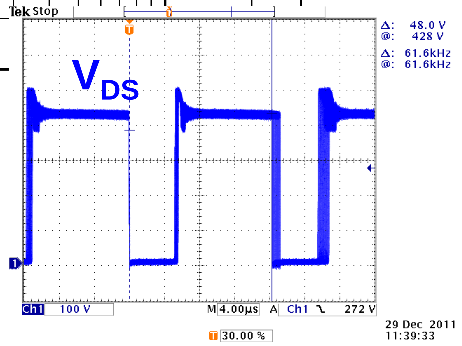
传导（Conducted EMI）

Frequency Jittering

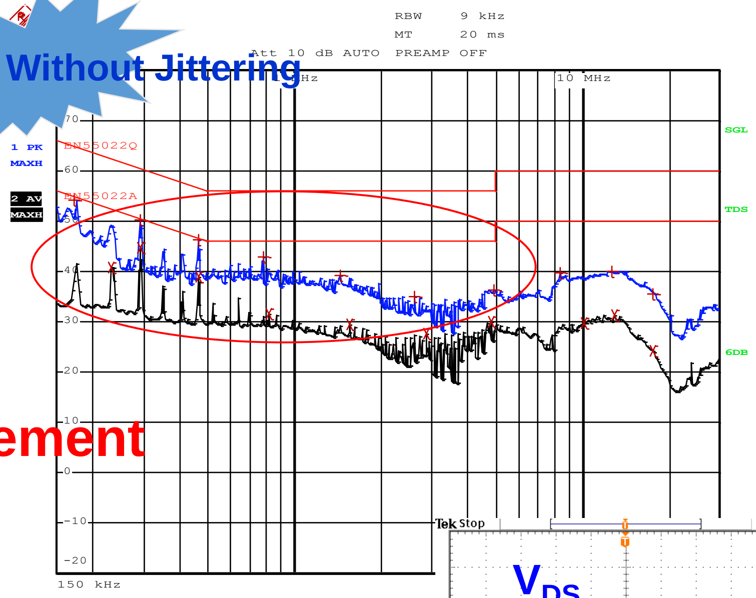
Test condition: V_{IN}=220VAC/50Hz, V_O=12V, I_O=3A

With Jittering



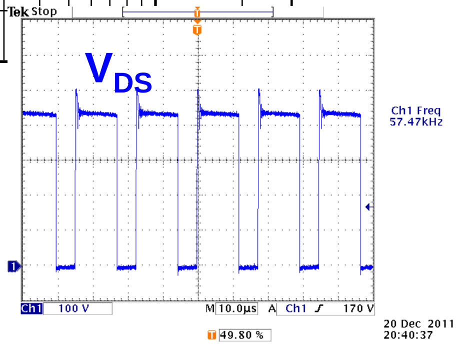


Without Jittering



~4dB improvement

Date: 20.DEC.2011 21:12:41

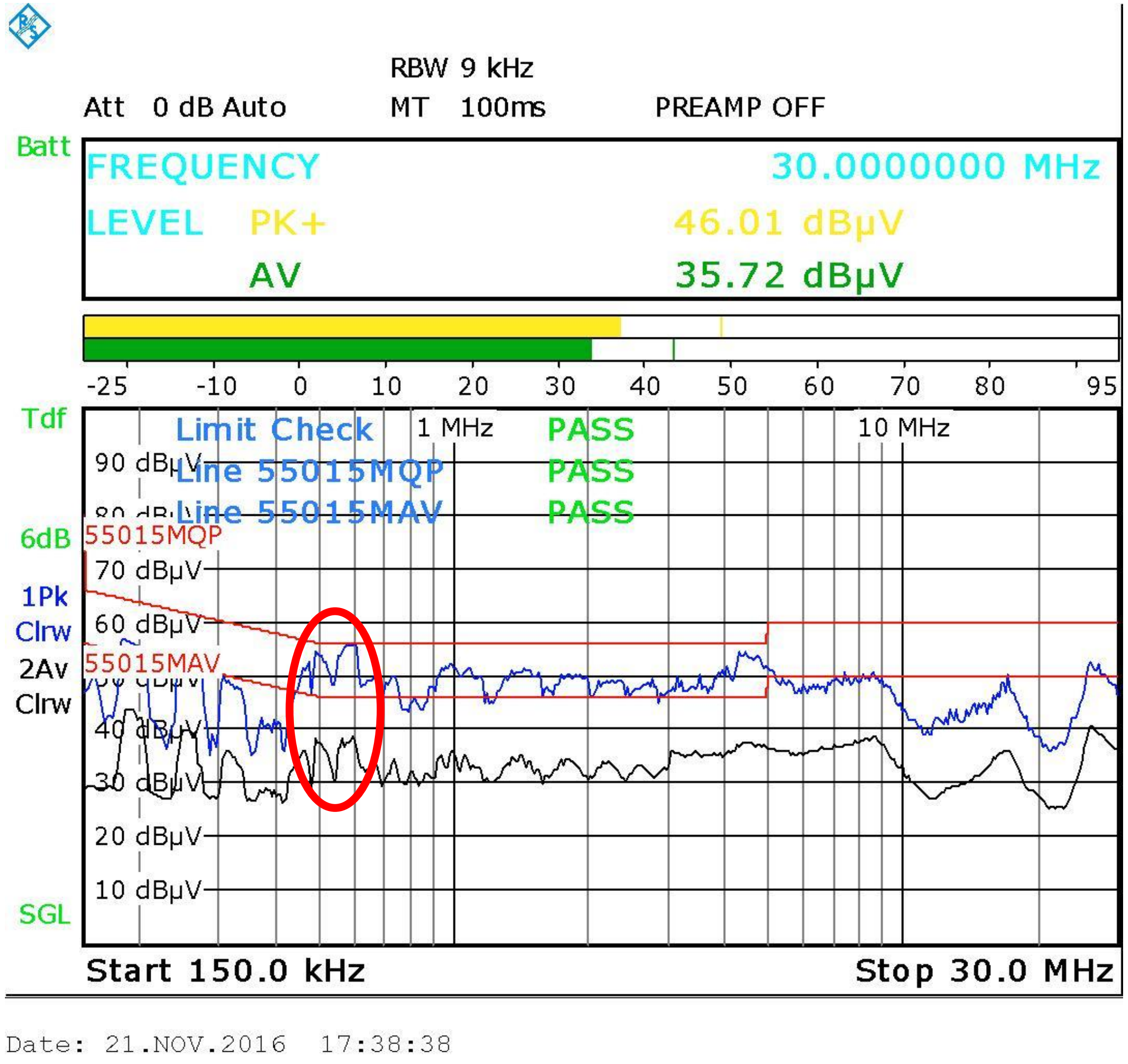


Better EMI Performance

65kHz±6.5%

Frequency jittering which leads to better EMI performance.

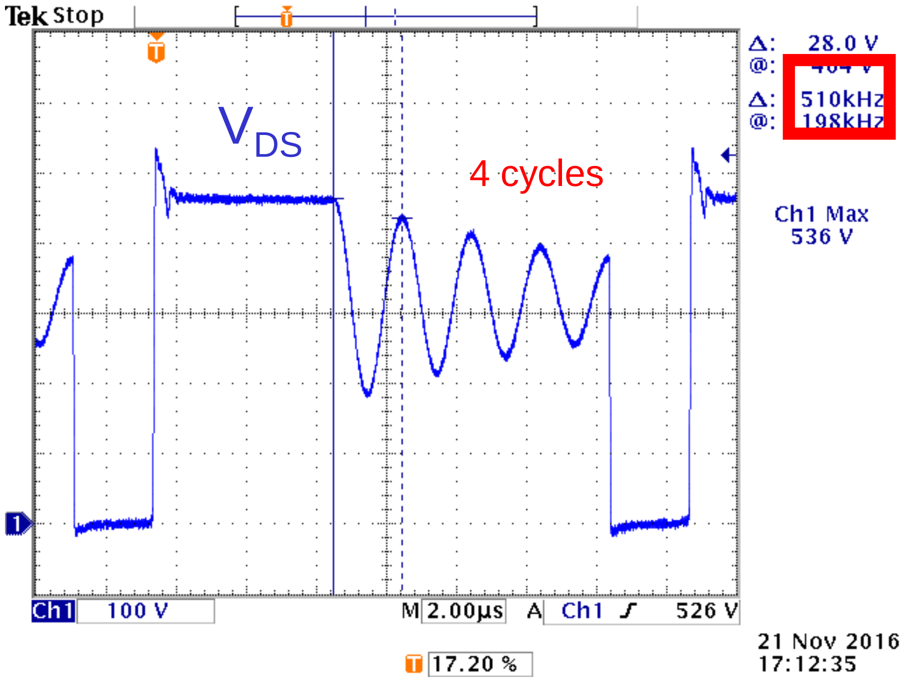
传导（Conducted EMI）



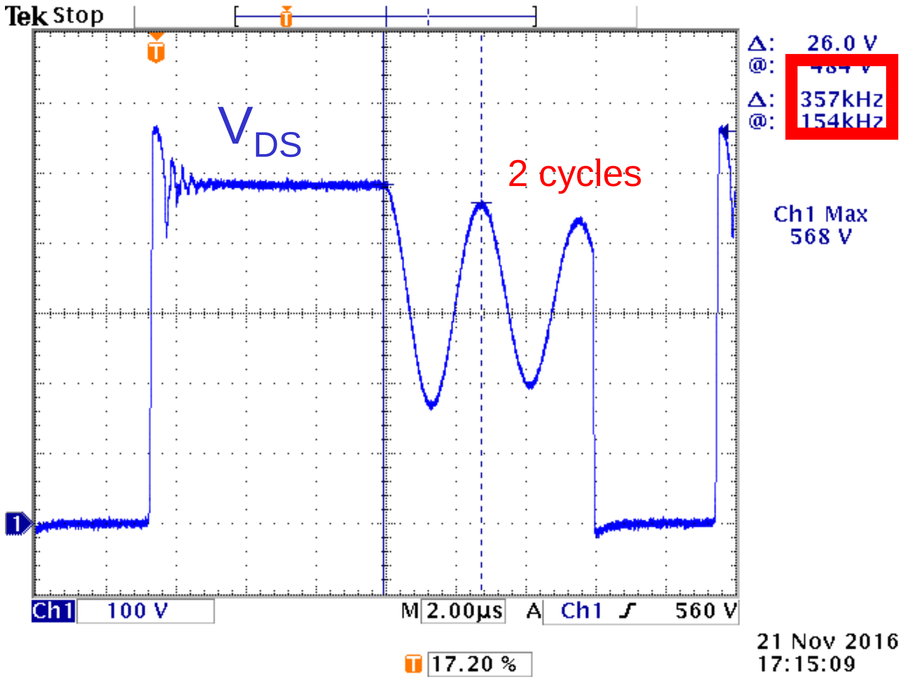
传导（Conducted EMI）

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.

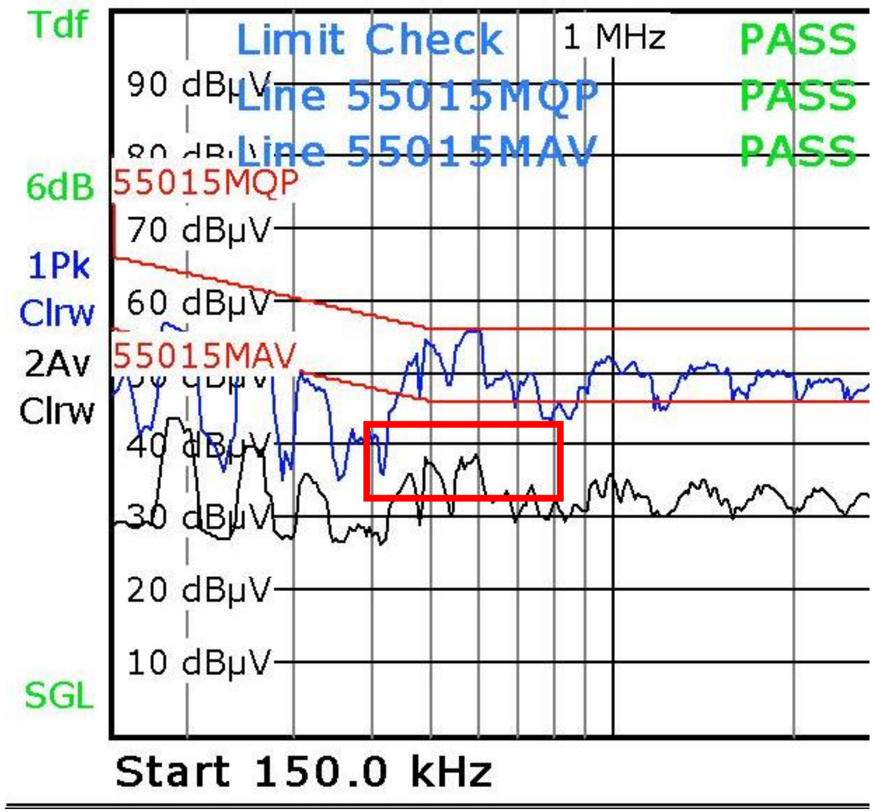


When the system enter DCM, the oscillation is determined by primary inductance L and parasitic capacitor (MOS and transformer).
The oscillation frequency is hundreds kHz, it's hard to get enough EMI margin.

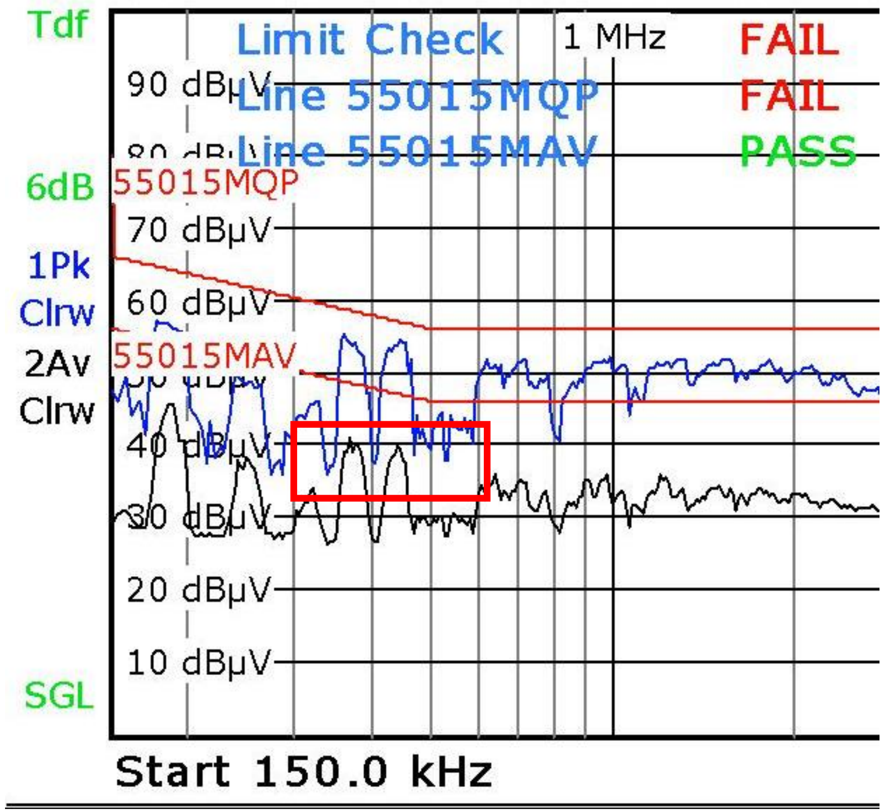
传导（Conducted EMI）

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

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



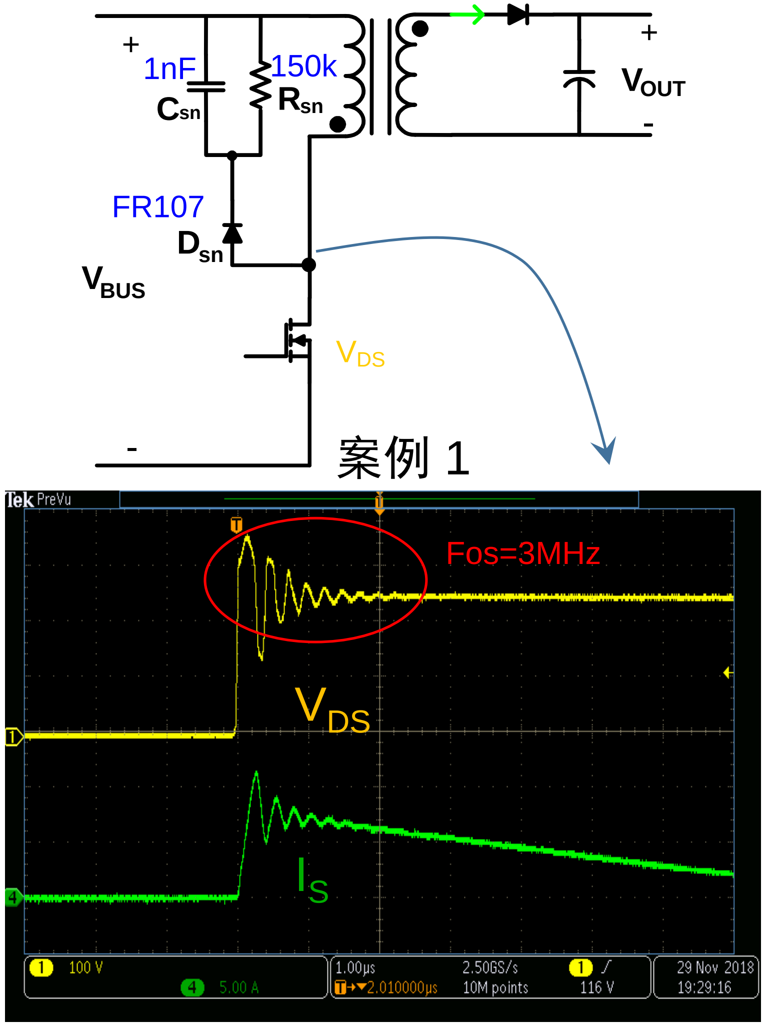
L=740uH, N=8, K@90VAC=I_{ripple}/I_{peak}=0.7.

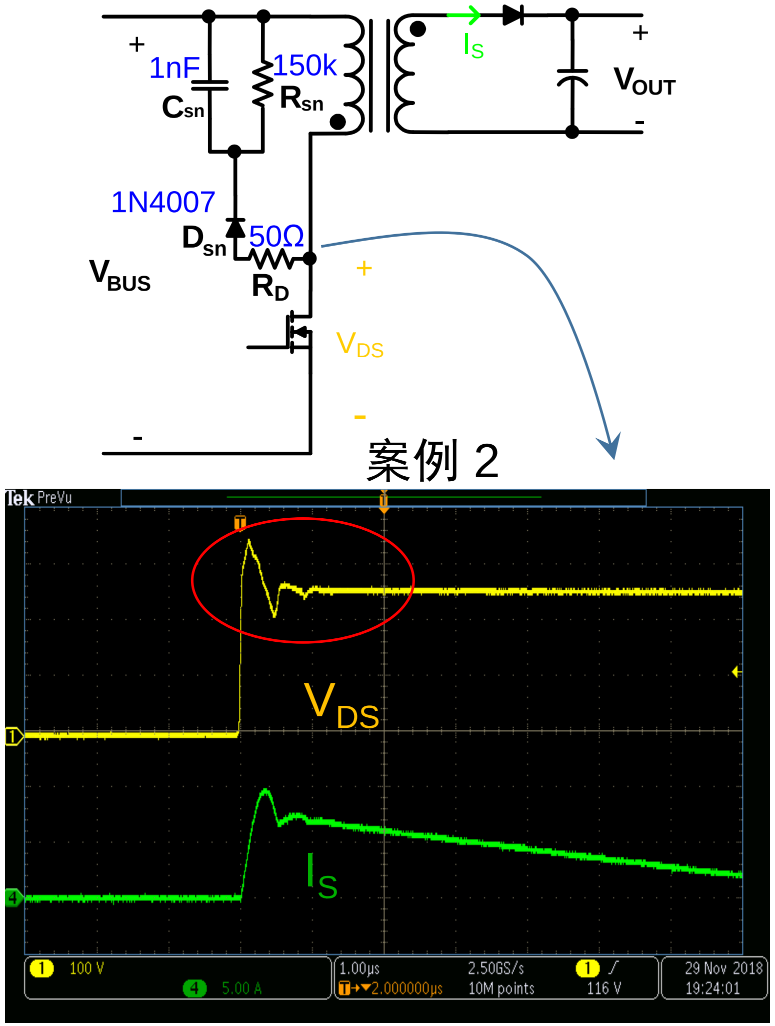


Increasing inductor can reduce frequency, and chooses smaller K can reduce the cycles.

传导（Conducted EMI）

❖ 改善效果快速判定方法



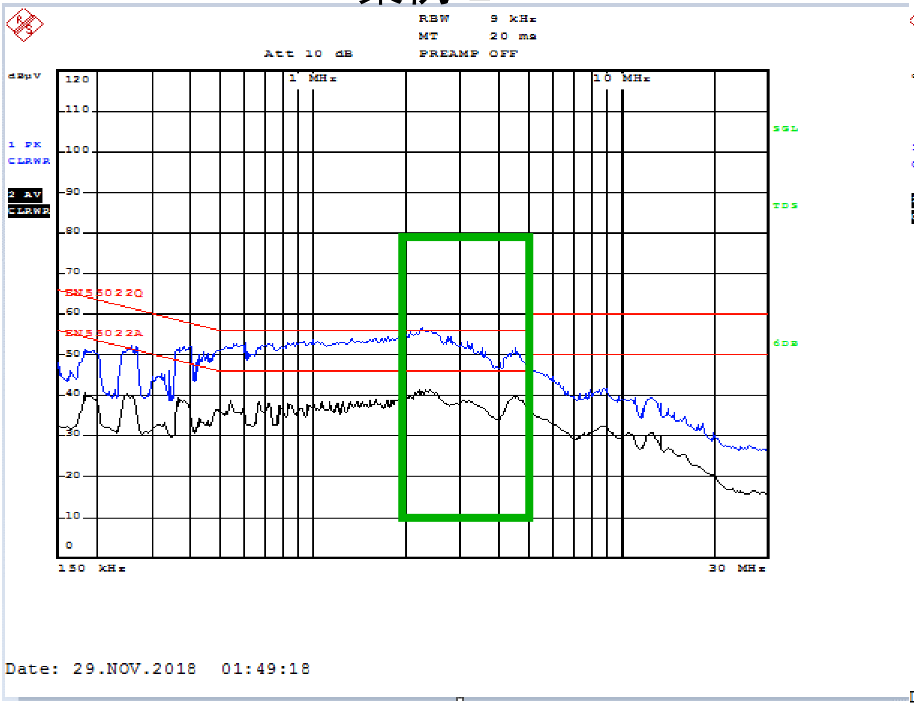


通过改变原边Mosfet关断时VDS的震荡来改善EMI

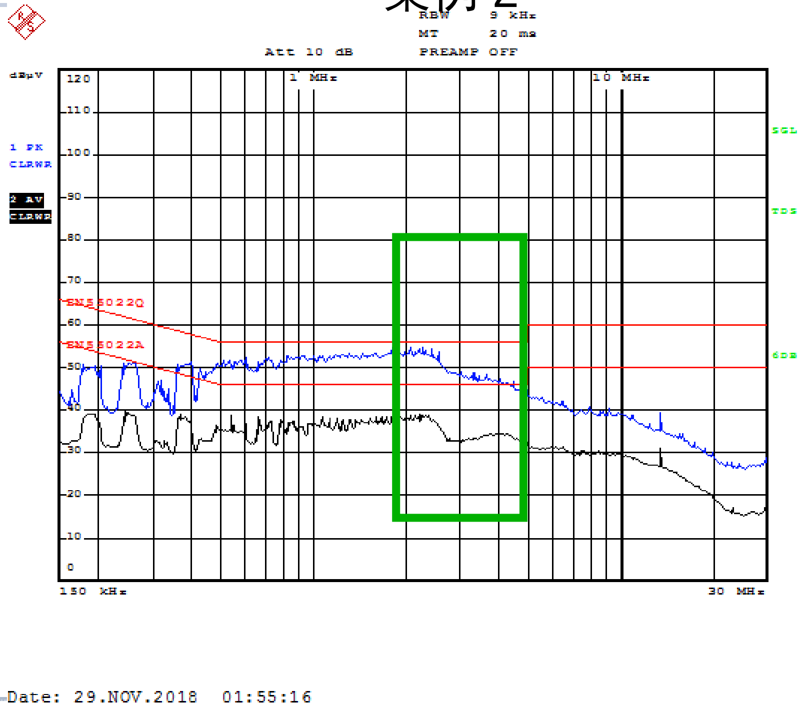
传导（Conducted EMI）

❖ 改善效果快速判定方法

案例 1



案例 2

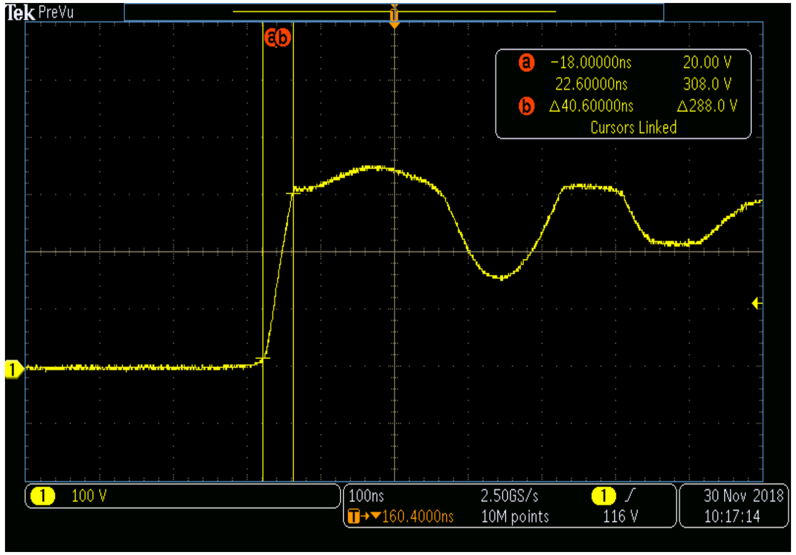


传导EMI在3MHz段有~5dB改善

传导（Conducted EMI）

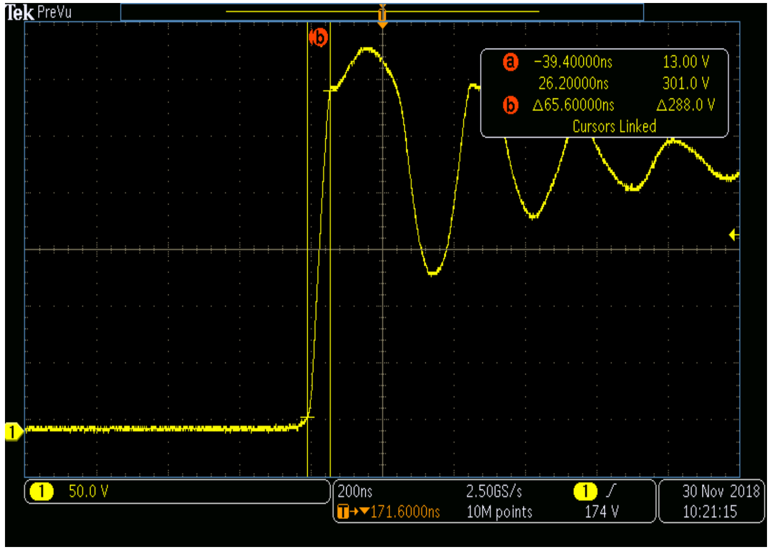
❖ 改善效果快速判定方法

案例 1



7.8MHz

案例 2



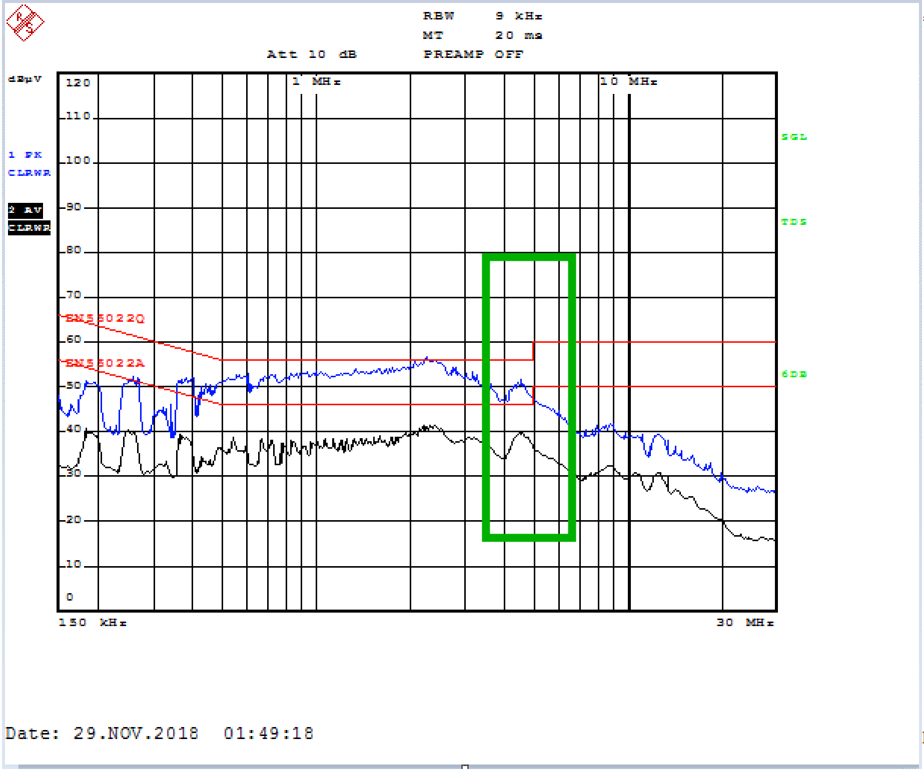
4.9MHz

改变VDS的上升/下降斜率来改善EMI

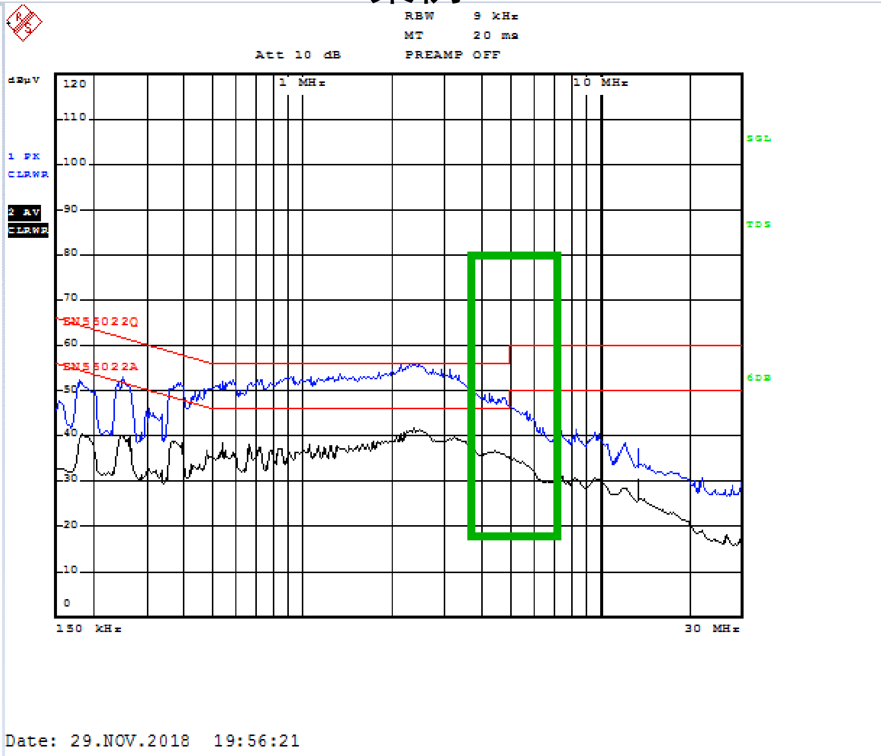
传导（Conducted EMI）

❖ 改善效果快速判定方法

案例 1



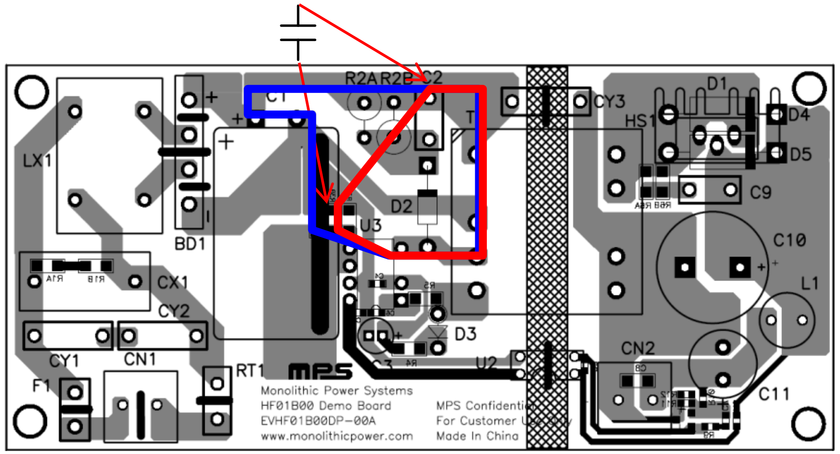
案例 2

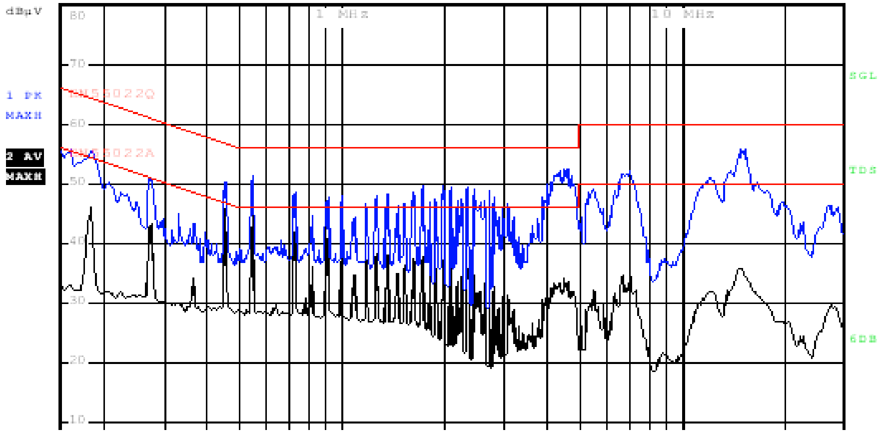


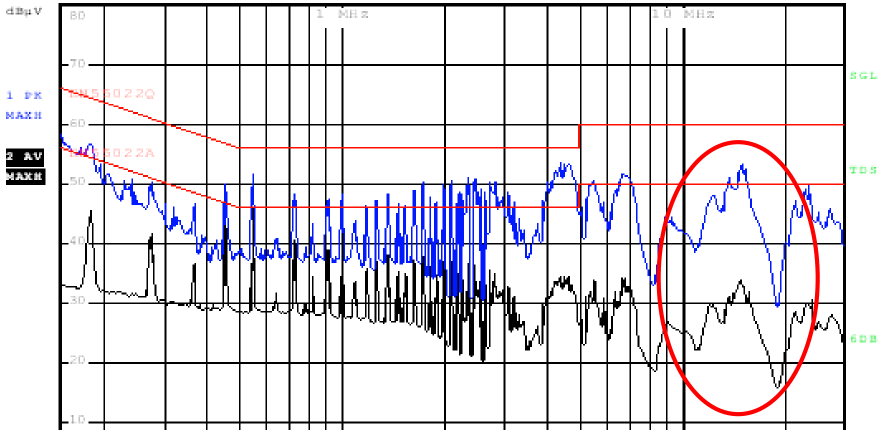
传导EMI在5MHz段有~3dB改善

传导（Conducted EMI）

❖ 减小传导电磁干扰途径一 – 改善电路板的布线







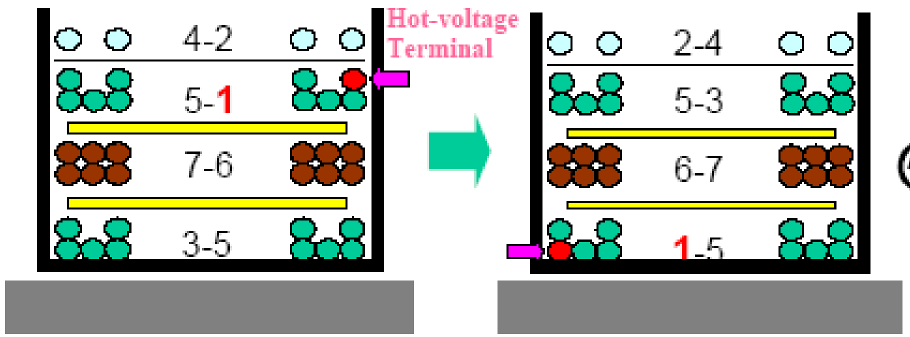
传导EMI在10MHz+段有~3dB改善

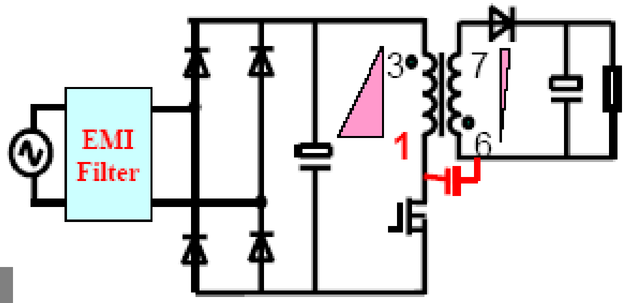
传导（Conducted EMI）

- 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

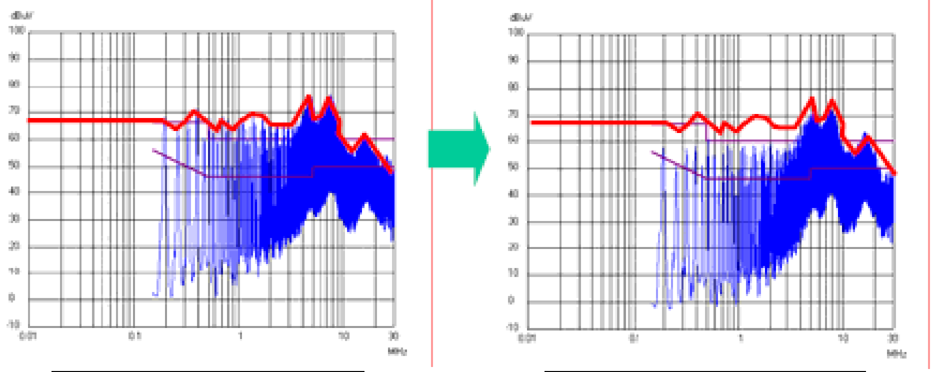




Original design

Modified design

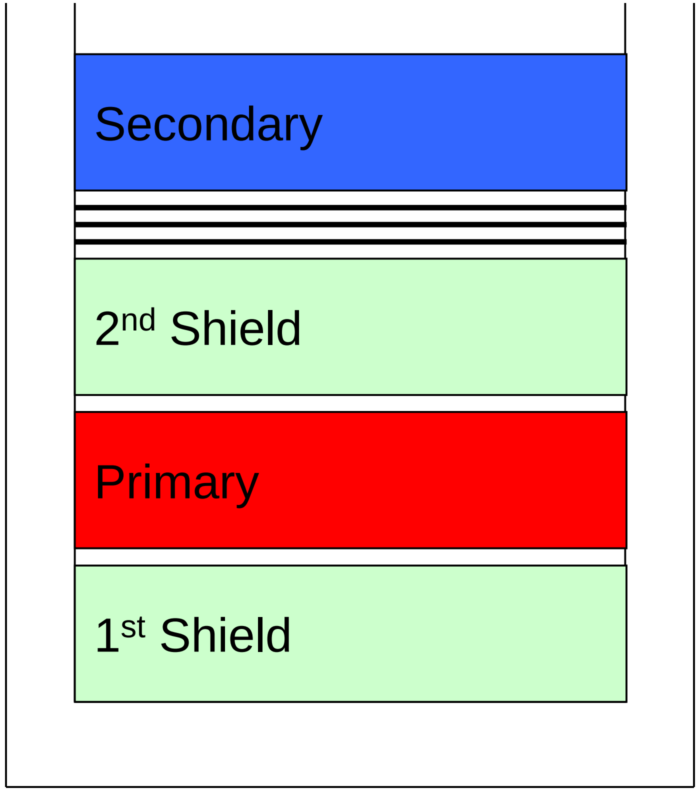
Point 1: Hot-voltage terminal



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

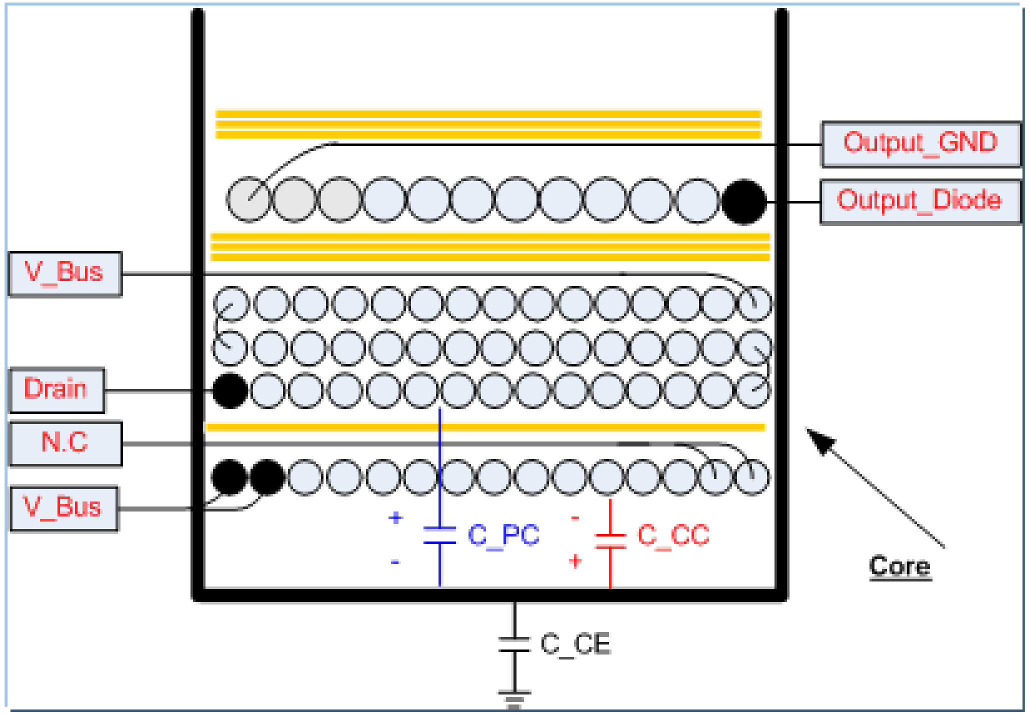
CL Filter:
Y cap: 1000pf
L: 1.23mH

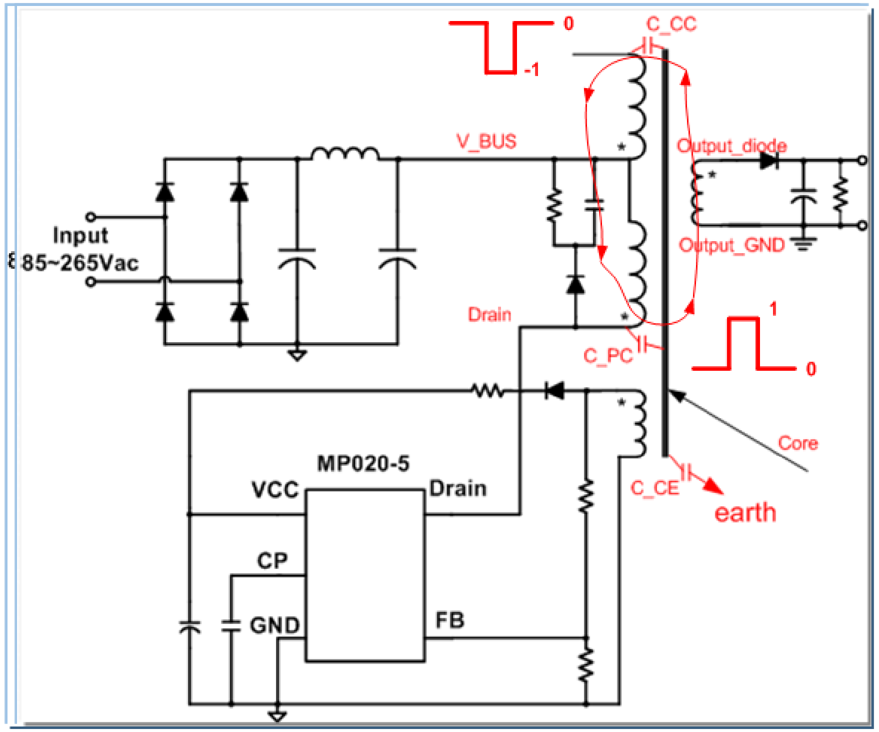
传导（Conducted EMI）



- 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

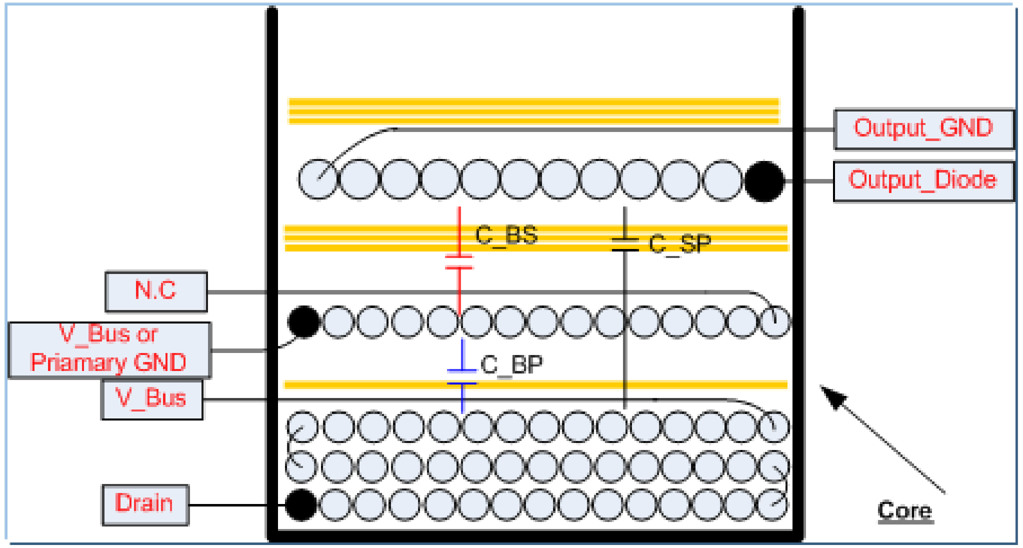
传导（Conducted EMI）

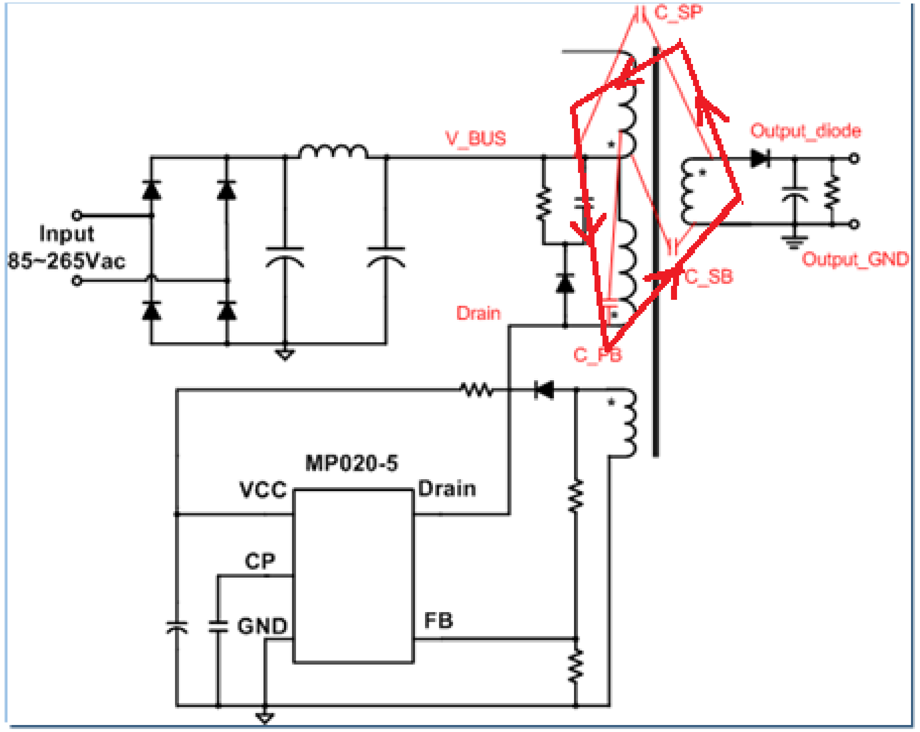




- Cancels out the P-E noise mechanism
- Both the primary and cancellation windings induce displacement currents in opposite directions, leading to "cancellation" of displacement currents within the LISN

传导（Conducted EMI）



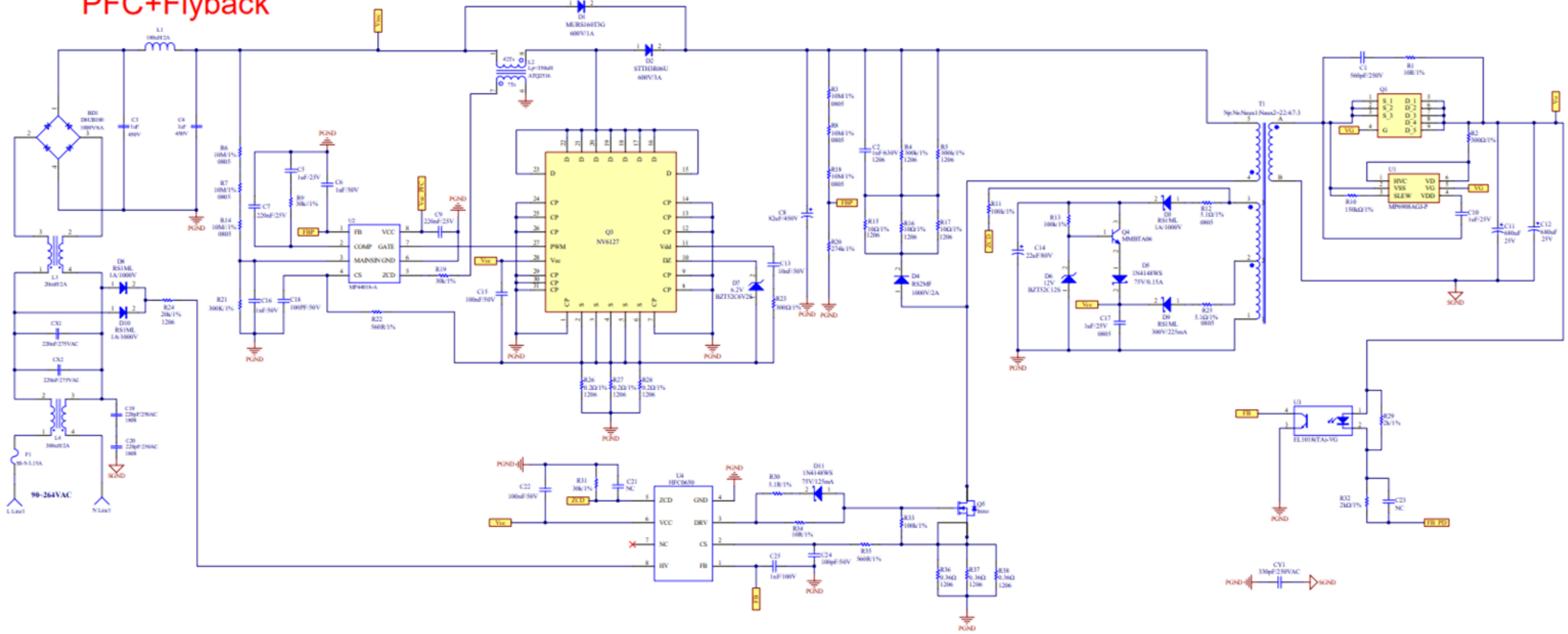


- Used to reduce P-S coupling mechanism
- Principle is to “balance” the potential at the primary & secondary side thereby reducing noise coupling

传导（Conducted EMI）

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

PFC+Flyback



传导（Conducted EMI）

Xformer #1

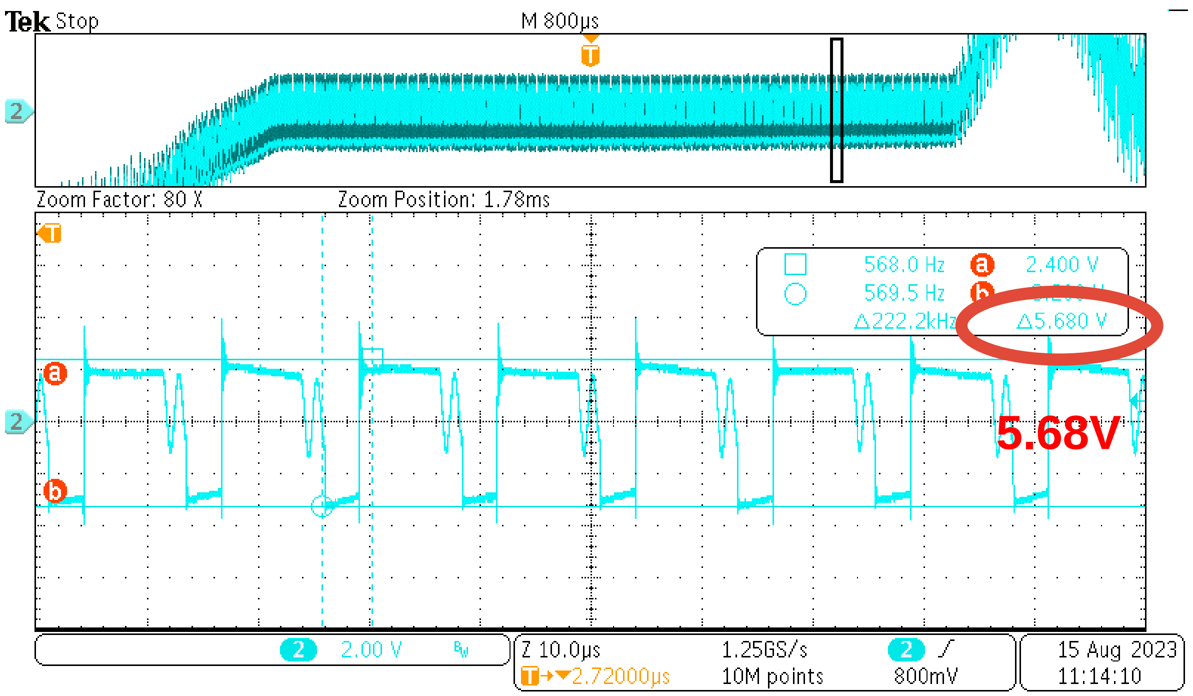
绕组	始末脚位	线径(φ)	圈数(T)
Np1	4—〉X	0.1mm*12	14.5
NC1	1—〉NC	0.18mm*2	**15**
Ns1	A—〉B	(0.1mm*90) T.I.W	5
Naux1	3—〉2	0.18mm*2	8
Naux2	2—〉1	0.18mm*2	5
Np2	X—〉5	0.1mm*12	14.5
NC2	1—〉NC	0.18mm*2	**15**
Ns2	A—〉B	(0.1mm*90) T.I.W	5

Xformer #2

绕组	始末脚位	线径(φ)	圈数(T)
Np1	4—〉X	0.1mm*12	14.5
NC1	1—〉NC	0.18mm*2	**10**
Ns1	A—〉B	(0.1mm*90) T.I.W	5
Naux1	3—〉2	0.18mm*2	8
Naux2	2—〉1	0.18mm*2	5
Np2	X—〉5	0.1mm*12	14.5
NC2	1—〉NC	0.18mm*2	**10**
Ns2	A—〉B	(0.1mm*90) T.I.W	5

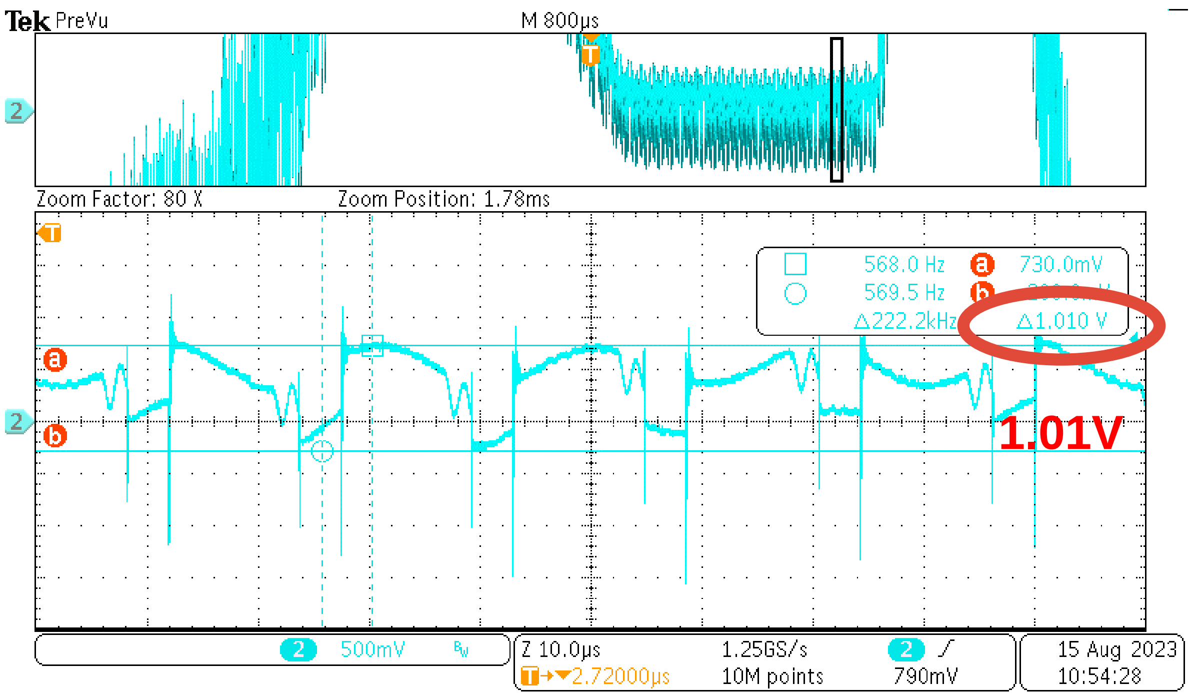
传导（Conducted EMI）

Xformer #1



MDO3014 - 2:52:50 PM 8/15/2023

Xformer #2



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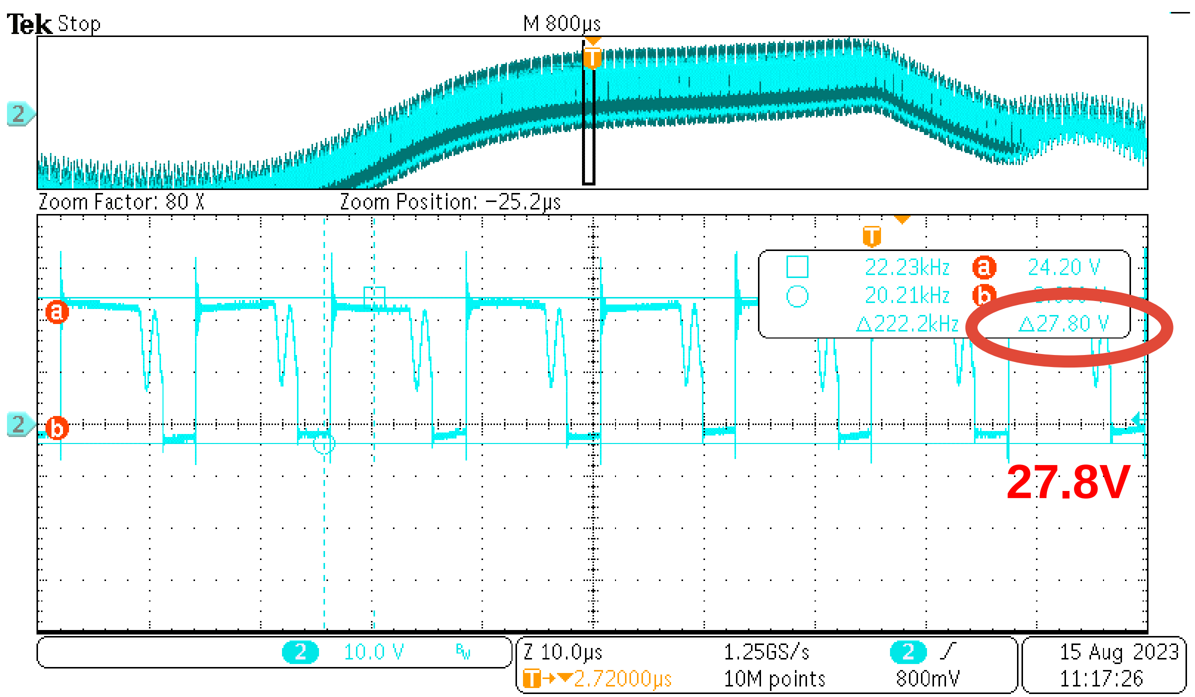
Test Method: 100k电阻＋470pF Y cap

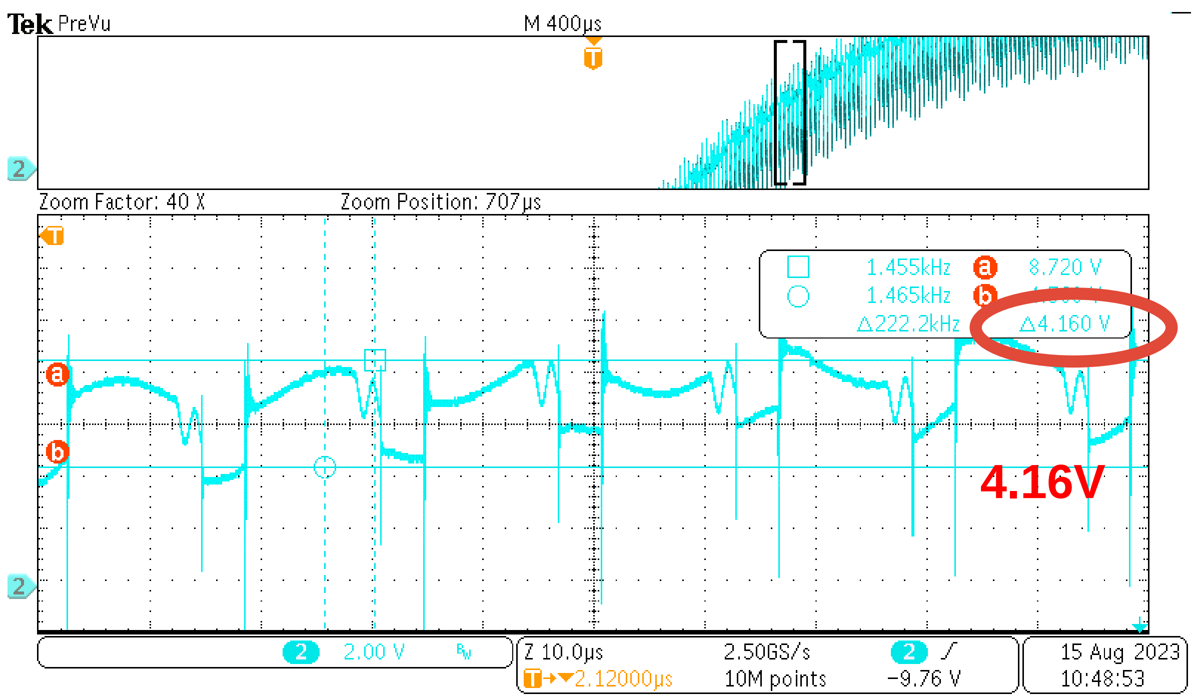
传导（Conducted EMI）

Xformer #1



MDO3014 - 2:56:05 PM 8/15/2023

Xformer #2

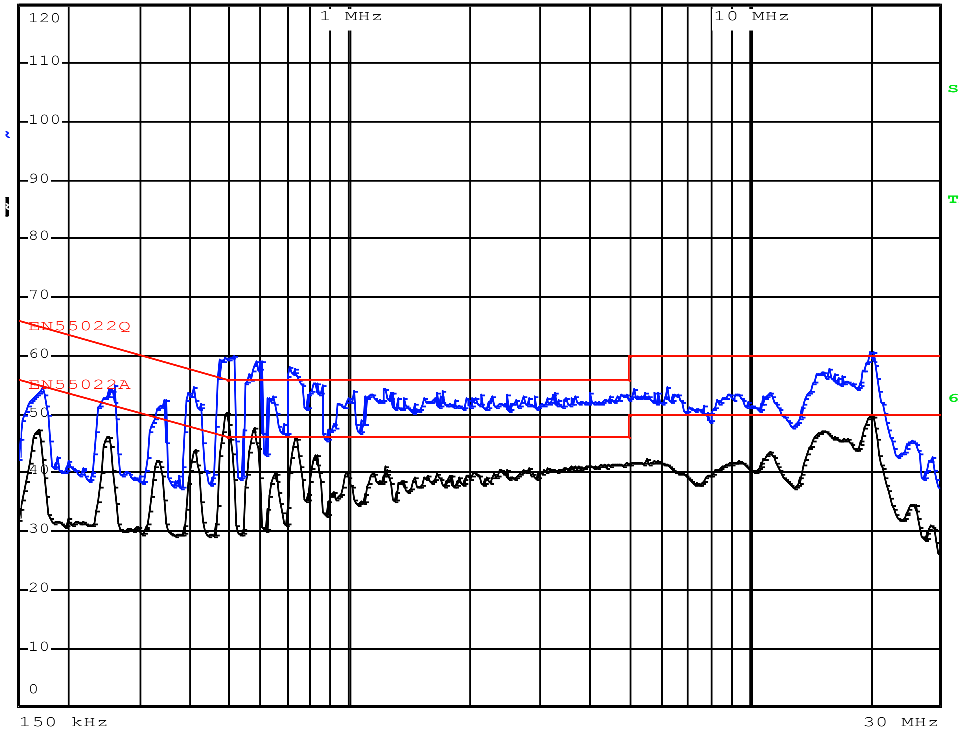


MDO3014 - 2:27:32 PM 8/15/2023

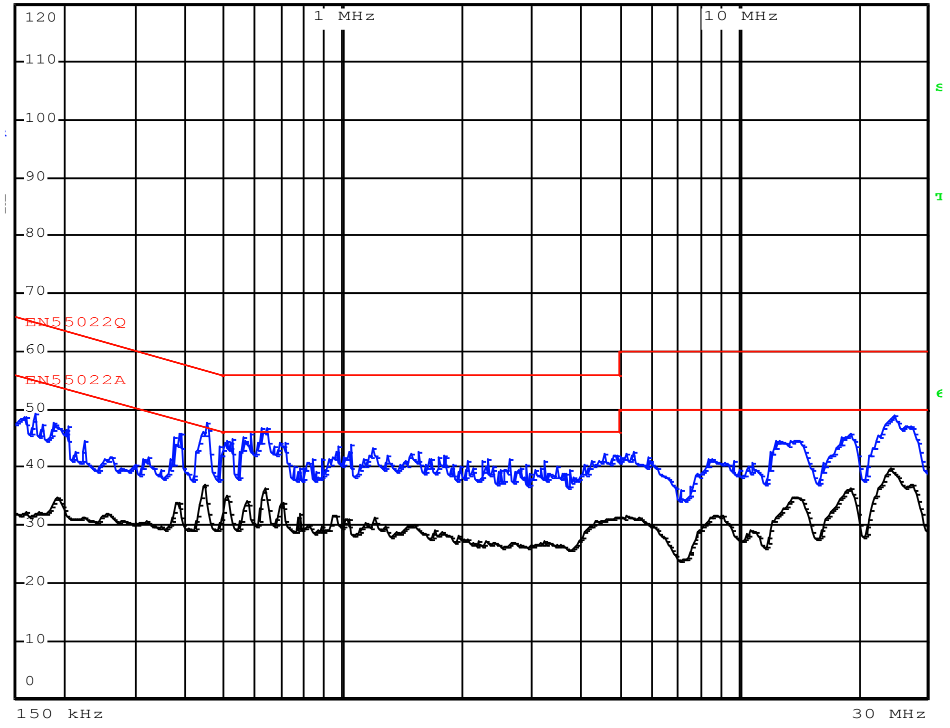
Test Method: 无电阻＋无 Y cap

传导（Conducted EMI）

Xformer #1



Xformer #2

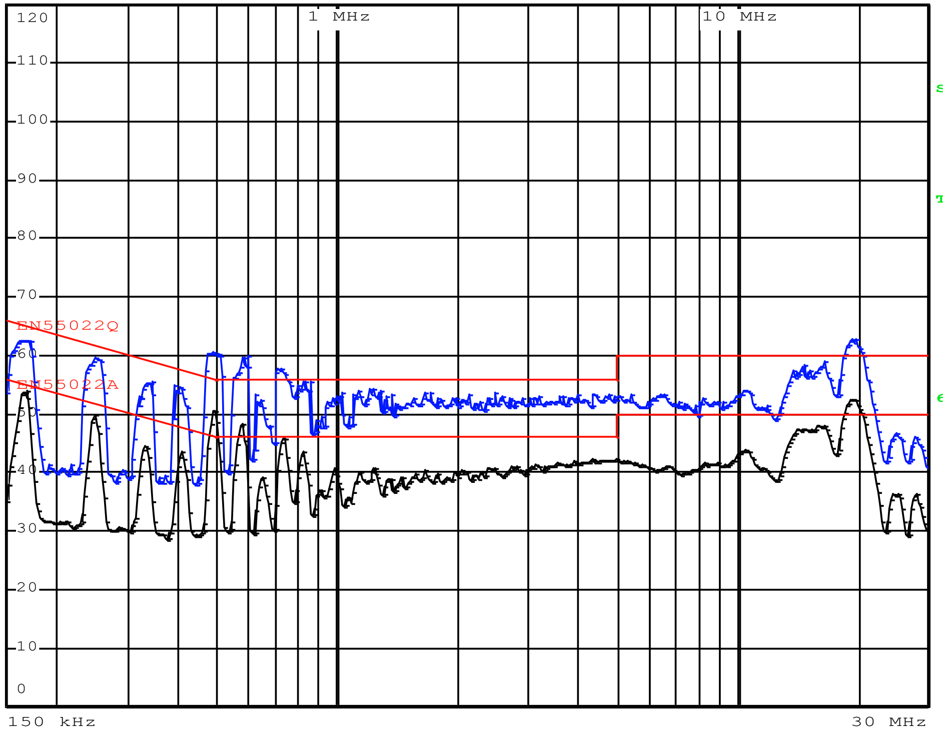


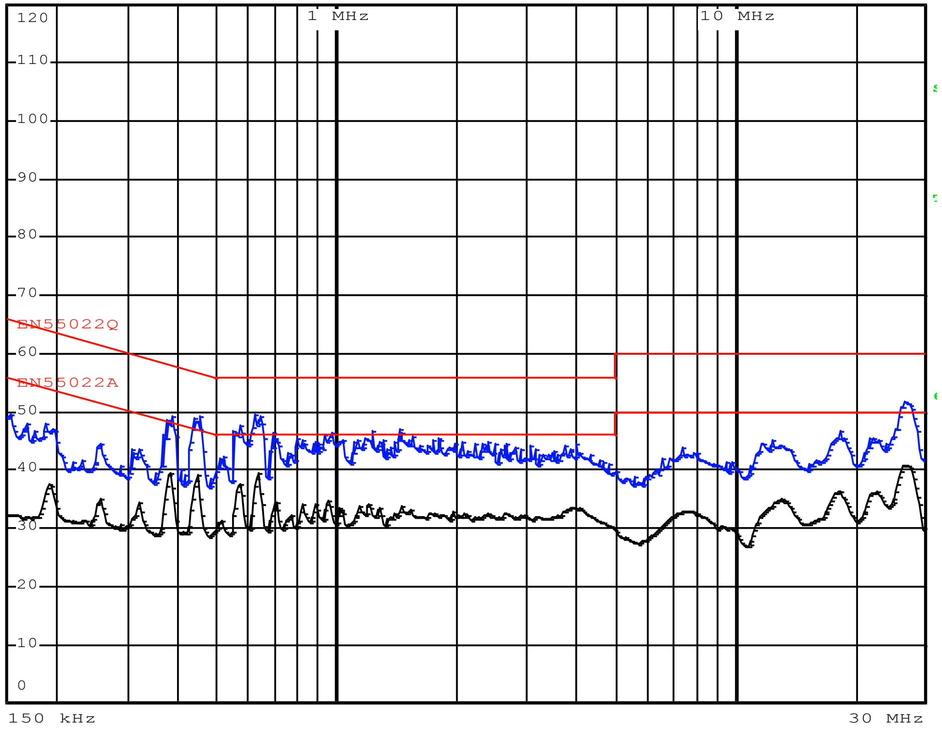
Test conditions:

230Vac input,20V/5A output

L line

传导（Conducted EMI）





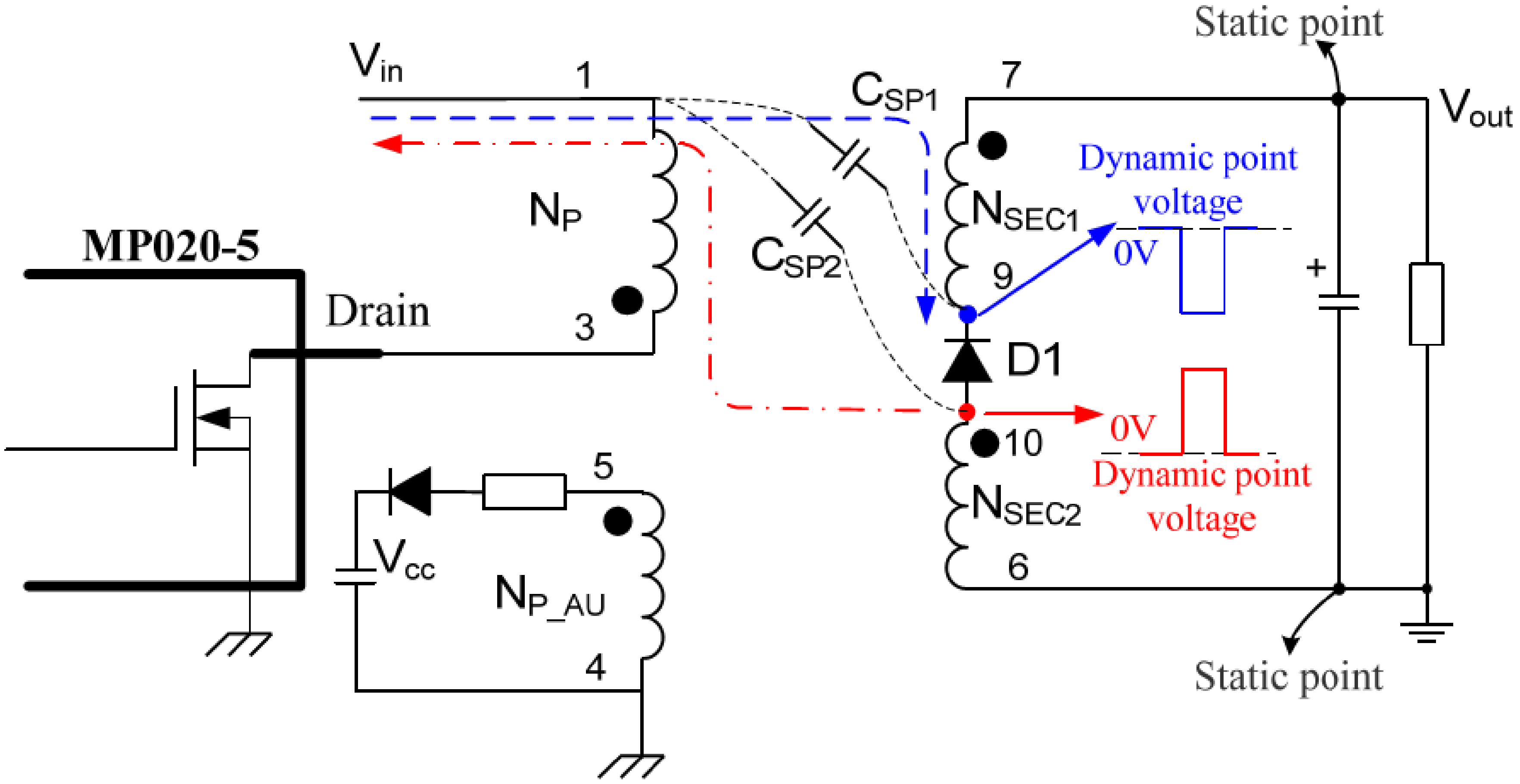
Test conditions:

230Vac input,20V/5A output

N line

传导（Conducted EMI）

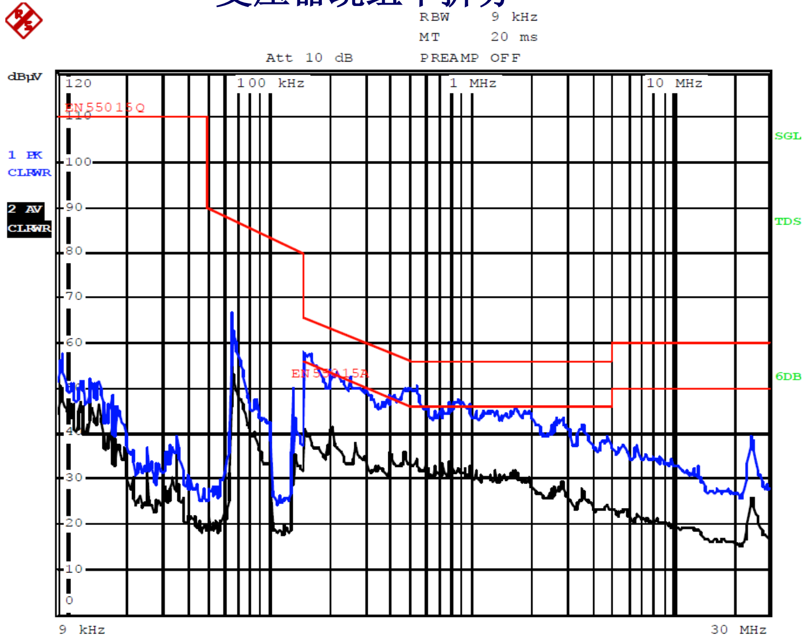
❖ 减小传导电磁干扰途径 – 改变变压器结构



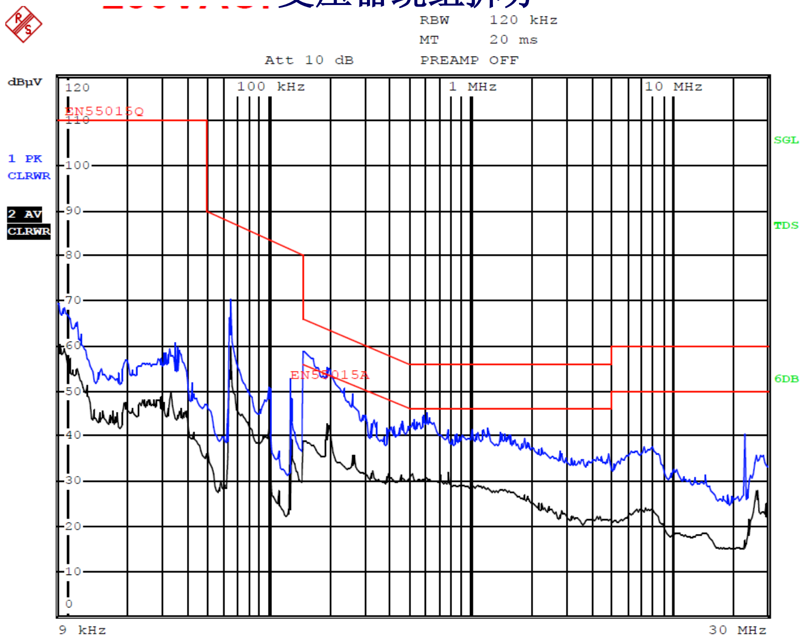
传导（Conducted EMI）

❖ 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



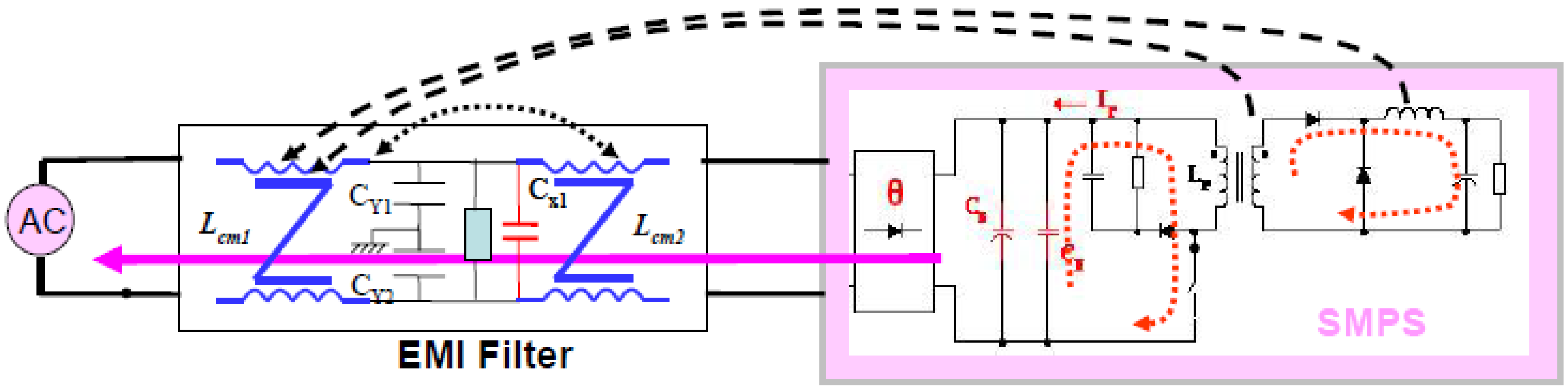
变压器绕组拆分



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

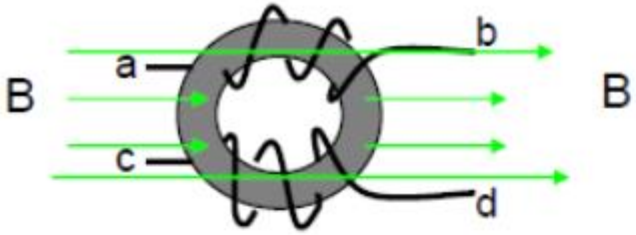


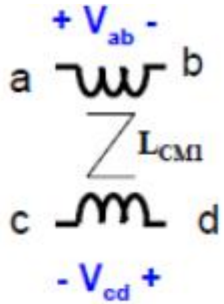
☐ Coupling inside EMI filter: CMC to CMC, CMC to Cap, Cap to Cap.

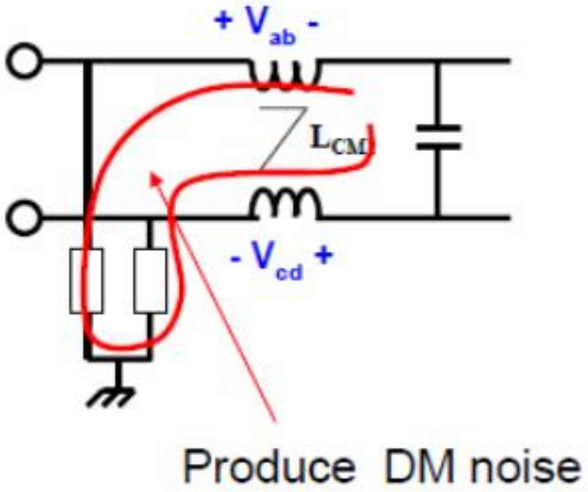
☐ Coupling between EMI filter and transformer/inductor.

传导（Conducted EMI）

❖ 近场耦合效应



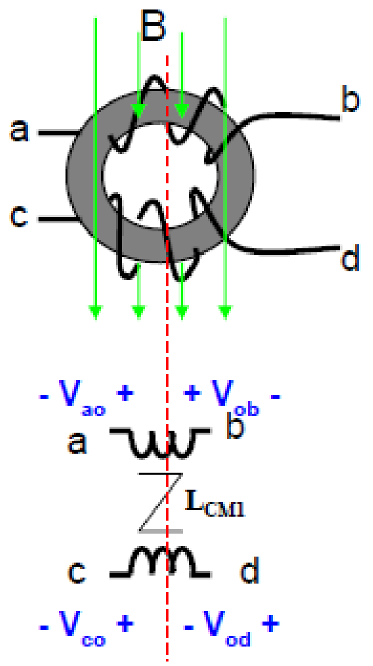




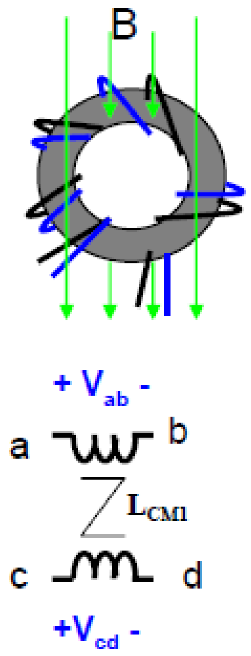
传导（Conducted EMI）

❖ 近场耦合效应

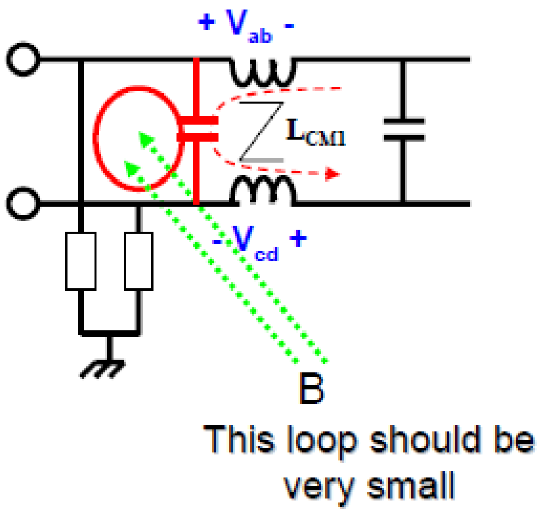
方案1
改变共模电感方向



方案2
共模电感双线并绕



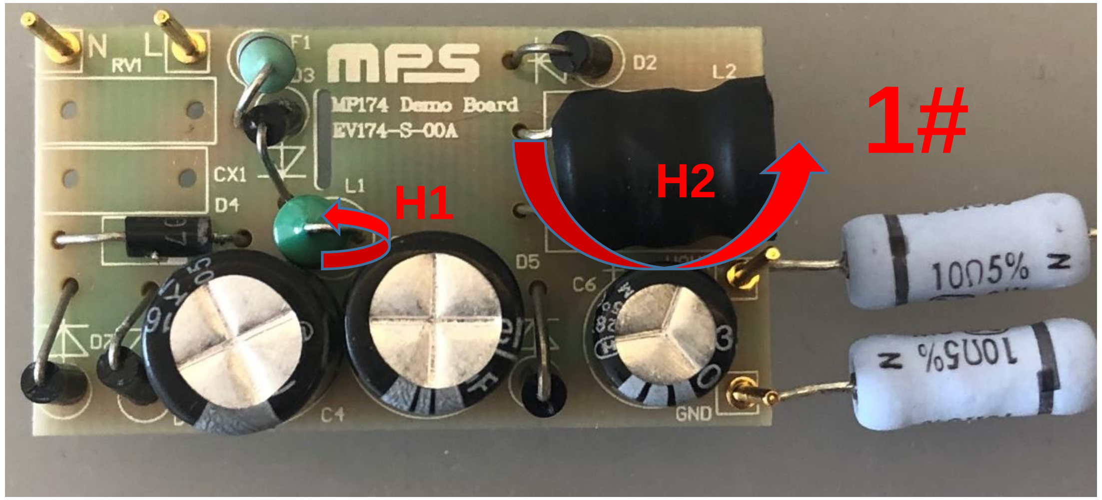
方案3
共模电感前加电容



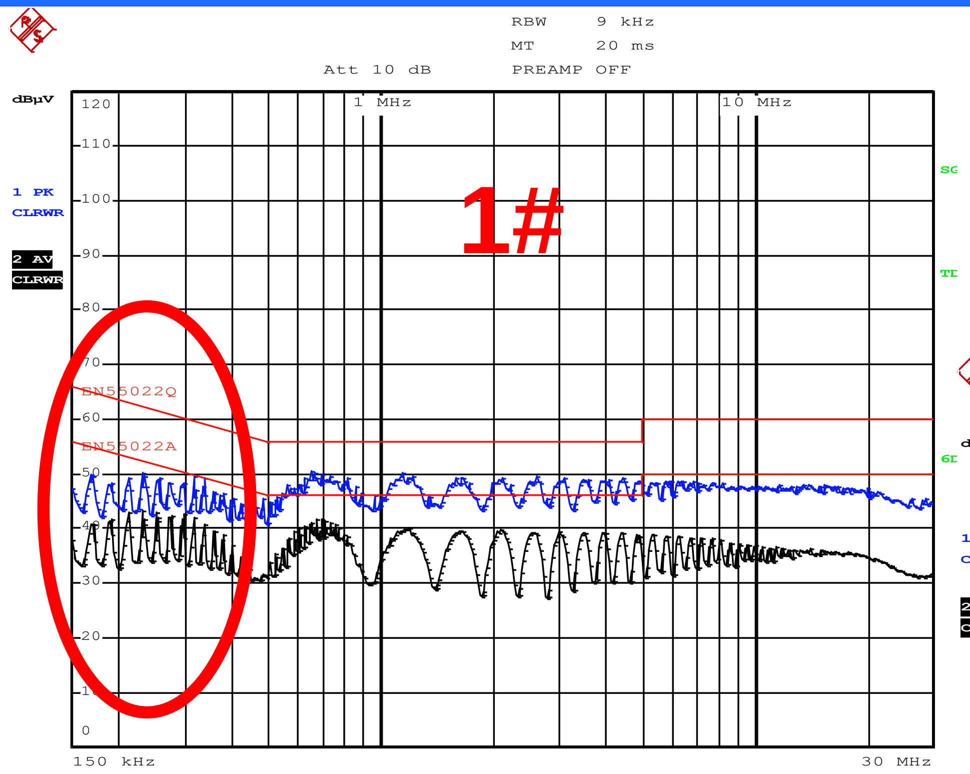
MPS

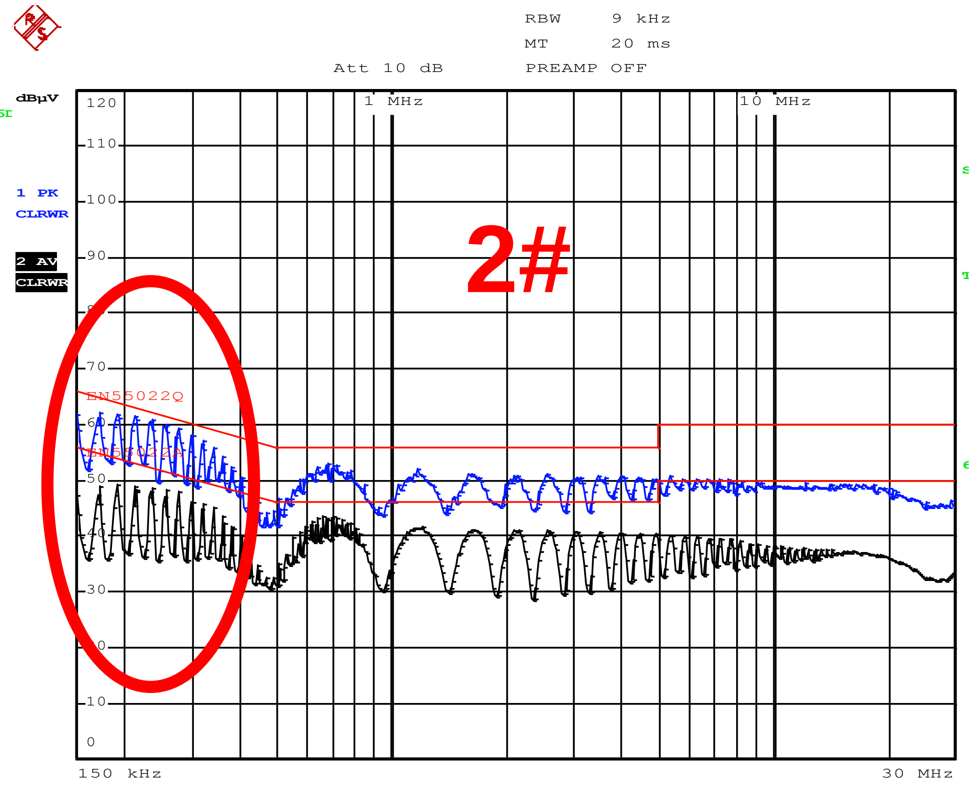
传导（Conducted EMI）

❖ 近场耦合效应



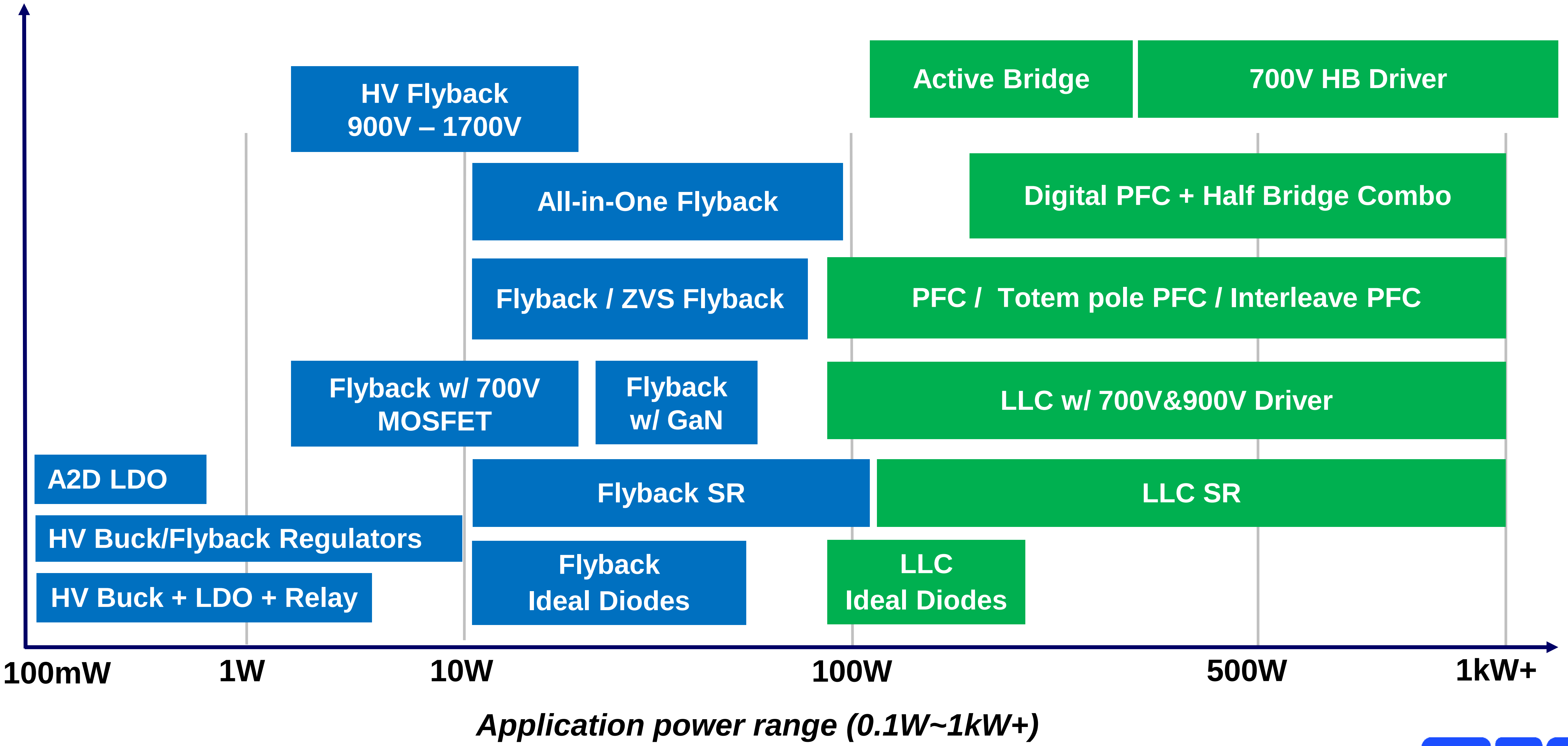
传导（Conducted EMI）





+10dB improvement

MPS AC/DC Product Families



AC/DC Flyback regulator with integrated 700V MOSFET

All in ONE

MPXP0200
All-in-One integrated
700V FET, up to 60W

MPXP0300
All-in-One integrated
700V FET, up to 50W

MPXP0600
All-in-One integrated
700V FET, up to 40W

MPXP0900
All-in-One integrated
700V FET, up to 30W

SSR

MP020A-5
CC/CV w/o opto
700V, 10Ω, <8W

MP024-10
CC/CV w/o opto
700V, 5.5Ω, <12W

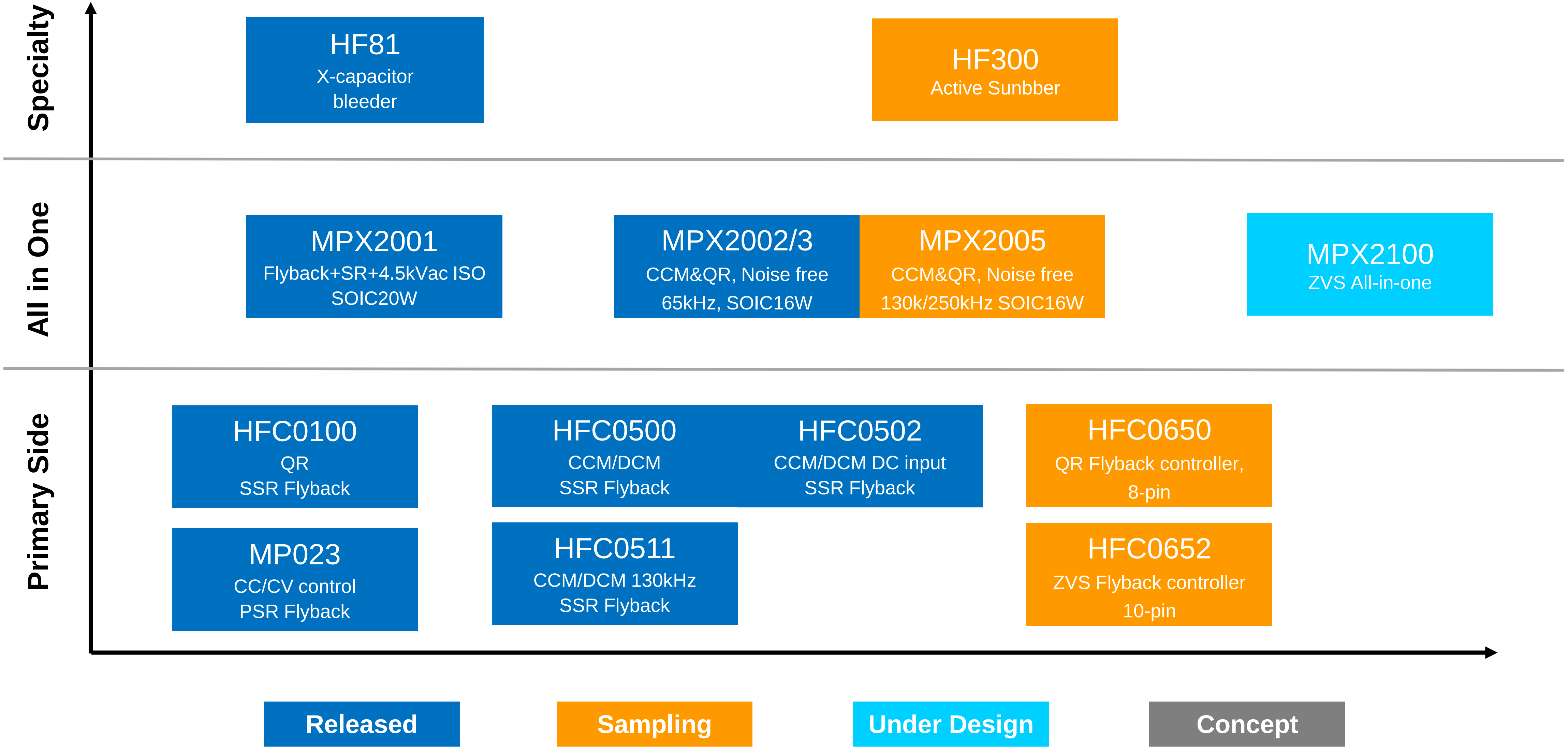
SSR

HF500-7/15/20/30/40
CCM/DCM
700V, 0.9-10Ω, up to 40W

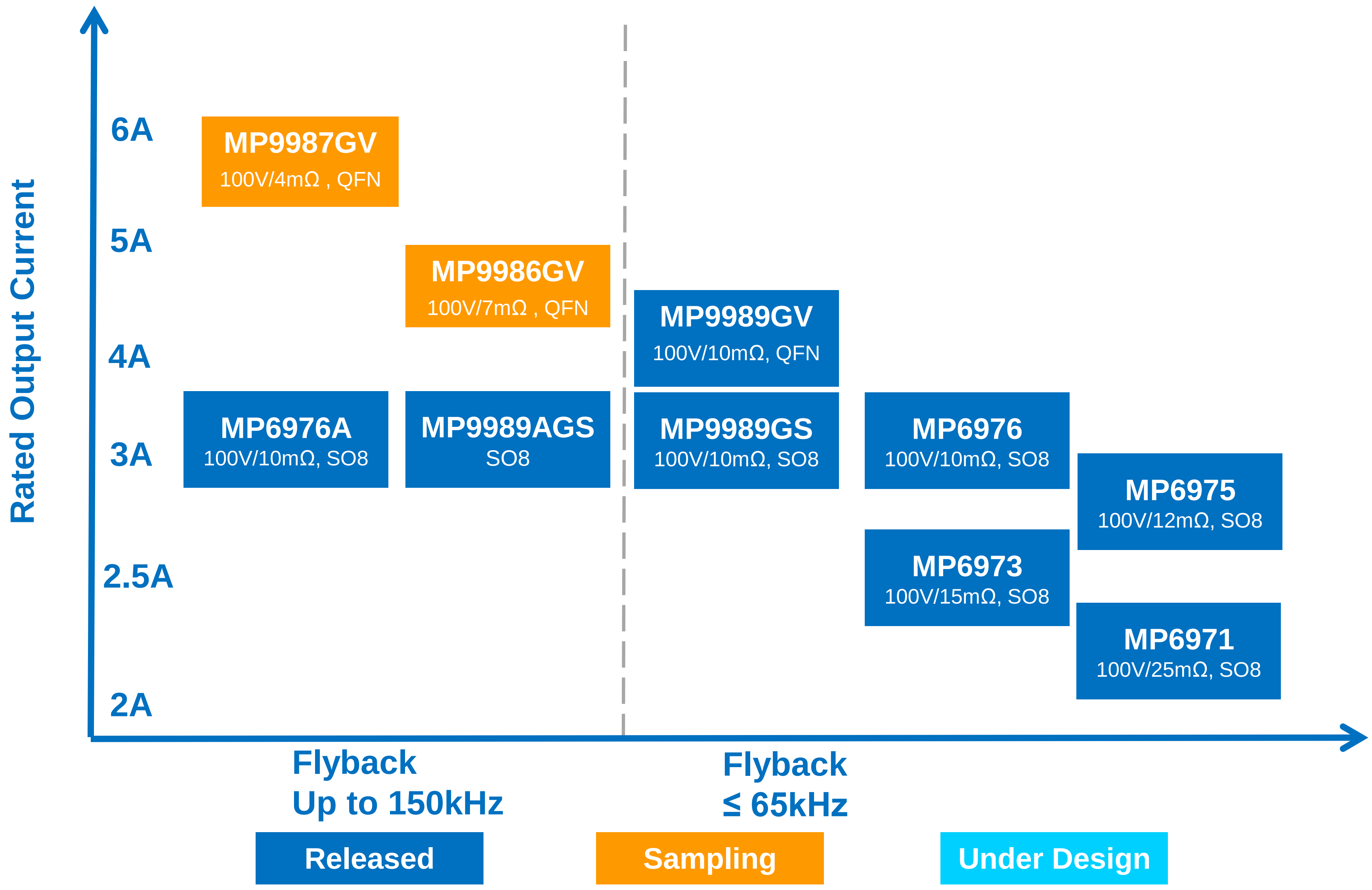
HF600-40
CCM/QR SSR
700V, 0.9Ω, <40W

Released **Sampling** **Under Design** **Concept**

AC/DC Flyback Controllers



Flyback ideal diode



High Power Digital Controllers

250W to 1000W

HR1008
Digital LLC
SOIC16

- 900V driver
- Input voltage compensation

MP45010
Digital Totem Pole PFC
QFN28

- CrM/DCM, with CCM for peak power
- 4 drivers integrated

MP44030/1
Digital Interleave PFC
SOIC16

- CrM/DCM, with CCM for peak power
- 4 drivers integrated

HR1210/1/2/3/5
Digital PFC+LLC
SOIC / TSSOP-20

- CCM/DCM PFC
- Current mode LLC

HR1280
Digital PFC+LLC
SOIC / TSSOP-20

- Programmable PGI
- Improved light load efficiency

HR1230
Digital PFC+LLC
SOIC16 / TSSOP-20

- EMM™ PFC control w/ the best efficiency
- Peak power enhanced

90W to 400W

HR1275
Digital PFC+LLC
SOIC-20 / TSSOP-20

- CrM / DCM PFC
- PF/THD compensation
- <75mW no load loss

HR1275L
Digital PFC+LLC
SOIC-20 / SOIC-16

- Fast Start-up

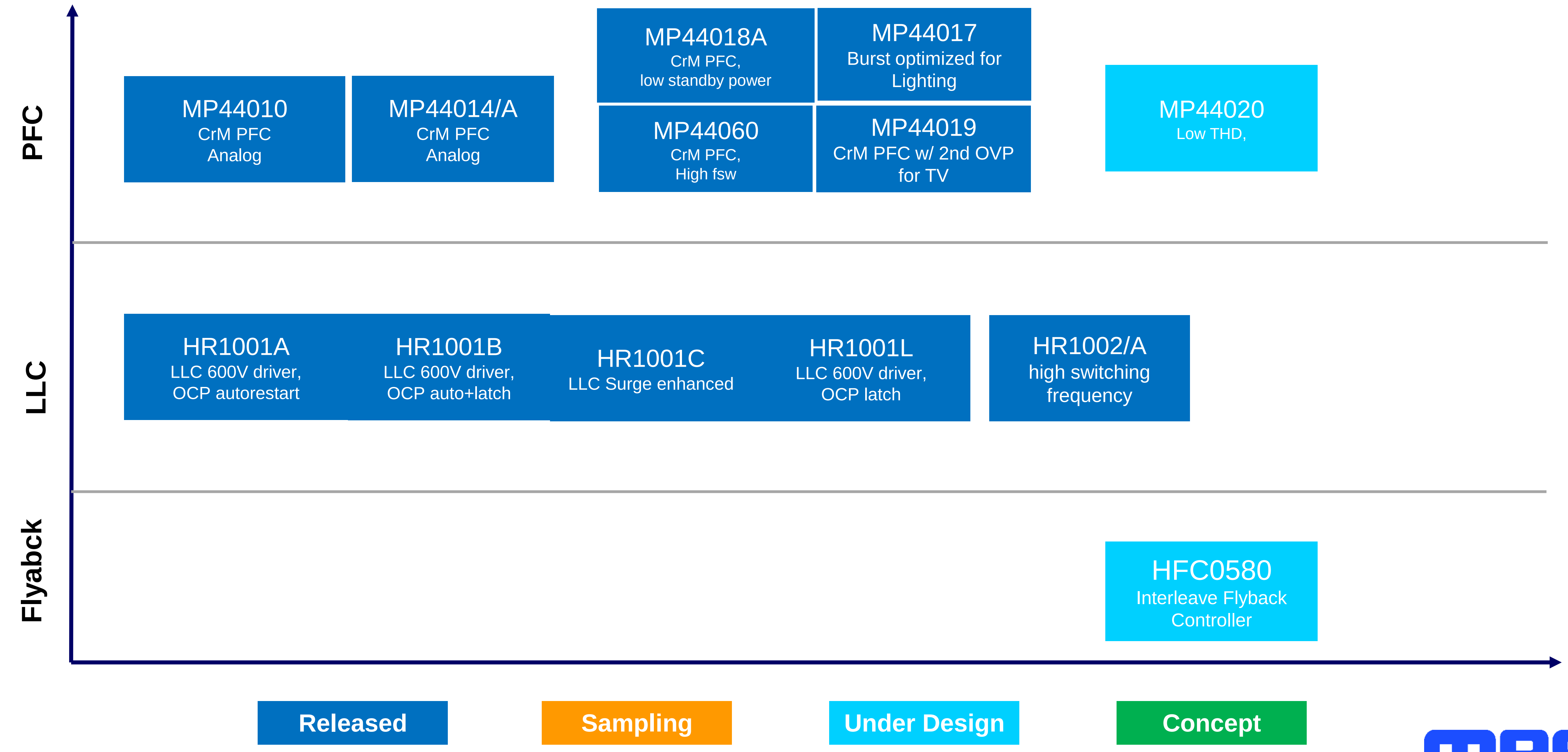
HR112x
Digital PFC+ AHB
TSSOP20

- CrM /DCM PFC
- Hybrid Flyback
- <75mW no load loss
- Support PD3.1 directly up to 240W

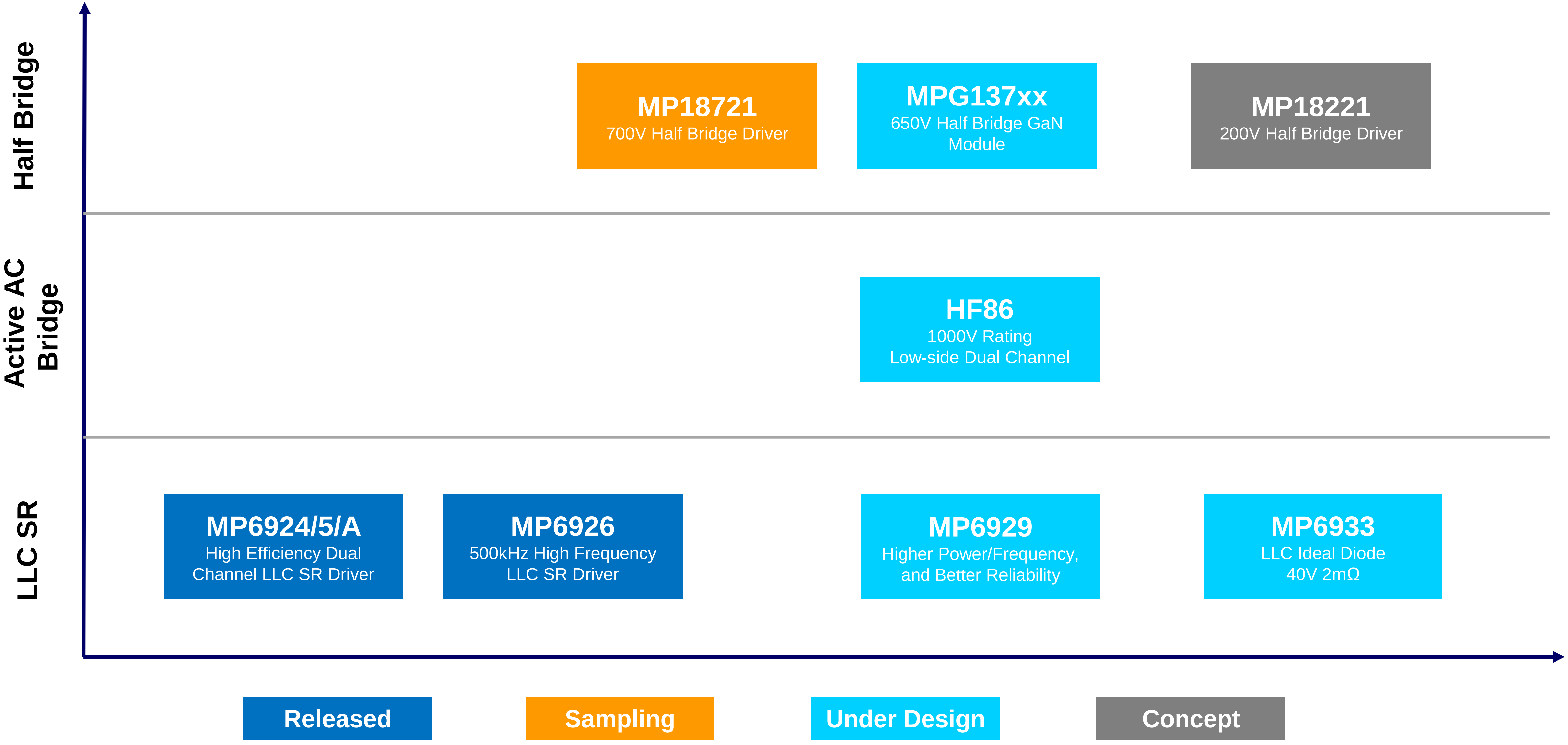
Released | **Sampling** | **Under Design** | **Concept**

MPS

High Power Analog Controllers



Standalone Drivers and More



Q&A