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

-----Power MOSFET, IGBT etc.

Voltage, $V_{sw}$

Current, $I_{sw}$

Turn-on

Turn-off

-----Power Diode

Voltage, $V_{sw}$

Current, $I_{sw}$

Turn-on

Turn-off
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）
传导（Conducted EMI）

差模噪声耦合路径

图示电路中的 LISN、D1、D2、D3、D4、S 和 C_B 部分。电路中带红色标记的路径表示差模噪声的耦合路径。
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；
Frequency jittering which leads to better EMI performance.

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

$65\text{kHz}\pm 6.5\%$

~4dB improvement

Better EMI Performance
传导（Conducted EMI）

- **RBW 9 kHz**
- **Att 0 dB Auto**
- **MT 100ms**
- **PREAMP OFF**

**FREQUENCY**: 30.0000000 MHz

**LEVEL PK+**: 46.01 dBµV

**AV**: 35.72 dBµV

**Limit Check**: 1 MHz PASS

**Line 55015MOP**: PASS

**Line 55015MAY**: PASS

Date: 21.NOV.2016 17:38:38
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.

Test Condition: $V_{in}=230V_{AC}$, Output=20V/2.25A

$L=365\mu H$, $N=7$, $K_{90V_{AC}}=I_{\text{ripple}}/I_{\text{peak}}=1$.  
$L=740\mu H$, $N=8$, $K_{90V_{AC}}=I_{\text{ripple}}/I_{\text{peak}}=0.7$.  

- **4 cycles**
- **2 cycles**
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 choosing smaller K can reduce the cycles.

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

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

传导EMI在3MHz段有~5dB改善
改善效果快速判定方法

案例 1

案例 2

改变VDS的上升/下降斜率来改善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
• 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
Effects of terminal position on conducted EMI noise

Original design

Modified design

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

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

Point 1: Hot-voltage terminal
• 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
• Cancels out the P-E noise mechanism

• Generally uses around \( \frac{1}{2} \) 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
• 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
The following test results is based on the same SCH except the different transformer structure.
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）

\[
\begin{align*}
N_a & : 0.15\text{mm}\times1\text{P}\times13\text{Ts} \\
N & : 0.15\text{mm}\times2\text{P}\times20\text{Ts}
\end{align*}
\]
Xformer #3 W/O any cancellation or balance winding
Test conditions:
220Vac input
5.3V/0.7A output
L line
传导（Conducted EMI）

Xformer #1

Xformer #2

传导至少有4~5dB改善#1, #2 Vs #3

Xformer #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
减小传导电磁干扰途径四 – 改变变压器结构

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）

1#

+10dB improvement

2#
AC/DC Flyback regulator with integrated MOSFET, up to 40W

- **MP020A-5**
  - CC/CV PSR
  - 700V, 10Ω, <8W

- **MP024-10**
  - CC/CV PSR
  - 700V, 5Ω, <12W

- **HF500-7**
  - CCM, SSR
  - 700V, 10Ω, <7W

- **HF500-15**
  - CCM, SSR
  - 700V, 4.5Ω, <15W

- **HF500-30**
  - CCM, SSR
  - Frequency Jittering
  - 700V, 1.4Ω, <30W

- **HF500A-20**
  - CCM, SSR
  - Frequency Jittering
  - 700V, 2.5Ω, <20W

- **HF500-40**
  - CCM, SSR
  - Frequency Jittering
  - 700V, 0.9Ω, <40W

- **HF500A-30**
  - CCM, SSR
  - Frequency Jittering
  - 700V, 1.4Ω, <25W

- **HF900**
  - Frequency Jittering
  - 900V, 13Ω, <7W

- **HF920/A**
  - 900V, 15Ω, <7W, Frequency Jittering

- **HF920B**
  - Frequency Jittering, Radiated EMI improved

- **HF920/A**
  - 900V, 10Ω, Frequency Jittering

- **HF920/A**
  - 900V, 10Ω, Frequency Jittering, Radiated EMI improved

**MPS**

- Released
- Sampling
- Under
- Concept
AC/DC Flyback Controller, up to 140W

- **Primary Side**
  - **HFC0100**
    - QR
    - SSR Flyback
  - **MP023**
    - CC/CV control
    - PSR Flyback
  - **HFC0500**
    - CCM/DCM
    - Frequency Jittering
    - SSR Flyback
  - **HFC0511**
    - CCM/DCM
    - 130kHz
    - Frequency Jittering
    - SSR Flyback
  - **HFC0502**
    - CCM/DCM
    - DC input
    - Frequency Jittering
    - SSR Flyback
  - **HFC0650**
    - QR Flyback controller
    - Frequency Jittering

- **Specialty**
  - **HF81**
    - X-capacitor bleeder
  - **MPX2001**
    - Flyback+SR+4.5kVac
    - ISO
    - SOIC20W
  - **MPX2002/3**
    - CCM&QR
    - Frequency Jittering
    - 65kHz/130kHz
    - SOIC16W
  - **HFC0502**
    - CCM/DCM
    - DC input
    - Frequency Jittering
    - SSR Flyback

- **Released**
- **Sampling**
- **Under**
- **Concept**
Q&A