安森美半导体
ON Semiconductor®

半桥驱动器：
采用变压器还是全硅驱动？

Half-Bridge Drivers
A Transformer or an All-Silicon Drive?

议程 Agenda

- 使用半桥配置的拓扑结构 Topologies using a half-bridge configuration
- 软开关与硬开关的区别 The difference between soft and hard-switching
- 门驱动变压器 The gate-drive transformer
- 全硅方案 The all-silicon-solution
- 比较 Comparison
- 总结 Summary

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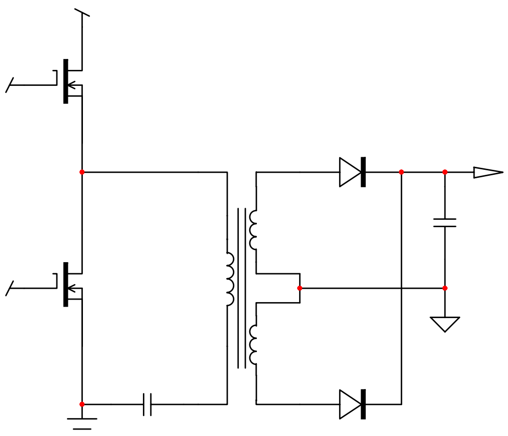
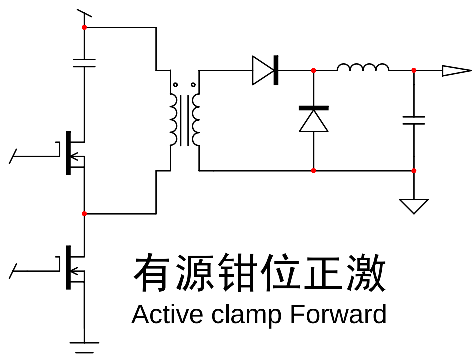
高能效拓扑结构趋势
Topology Trend for High Efficiency

- 硬开关 Hard Switching
  - 反激 Flyback
  - 正激 Forward
  - 双开关反激 2-sw flyback
  - 双开关正激 2-sw forward
  - 全桥 Full bridge

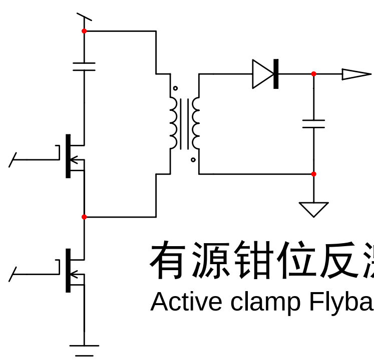
- 软开关 Soft Switching
  - LLC半桥谐振 LLC-HB resonant
  - 有源钳位正激 Active clamp forward
  - 有源钳位反激 Active clamp flyback
  - 不对称半桥(AHB) Asymmetrical half-bridge
  - 相移全桥 Full bridge with phase shift



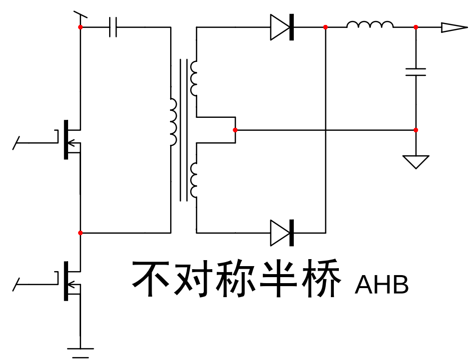
双电感加单电容半桥
LLC-HB



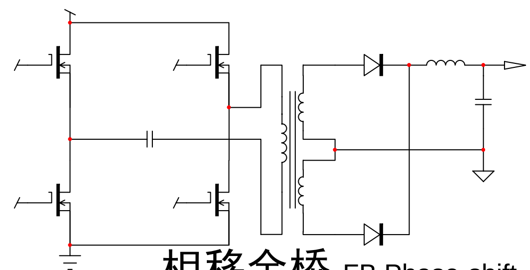
有源钳位正激
Active clamp Forward



有源钳位反激
Active clamp Flyback



不对称半桥 AHB



相移全桥 FB Phase-shift

高端开关 The High-Side Switch

- 要提供高能效，首选带零电压开关(**ZVS**)特性的拓扑结构 To achieve high efficiency, the topologies with ZVS (Zero-Voltage Switching) behavior are preferred.
- 所有软开关拓扑结构应用带浮点参考引脚的电源开关，如MOSFET的源极引脚 All the soft switching topologies implement the power switch with floating reference pin, e.g. the source pin of MOSFET.
- 为什么软开关应用中使用MOSFET？ Why are MOSFETs used in soft switching applications?
  - 高频工作 High frequency operation
  - 体二极管(ZVS电流环路) Body diode (current loop for ZVS)

→ 如何驱动高端MOSFET?
How to drive the high side MOSFET?

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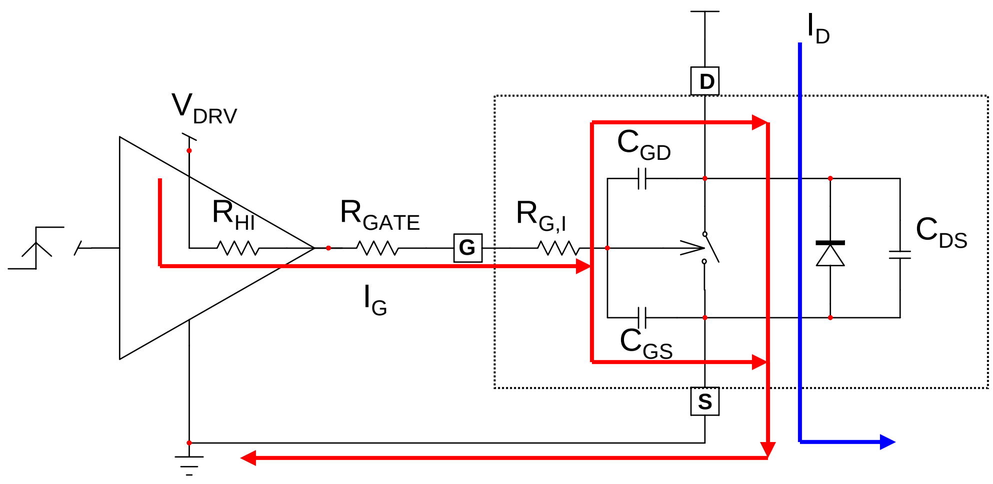
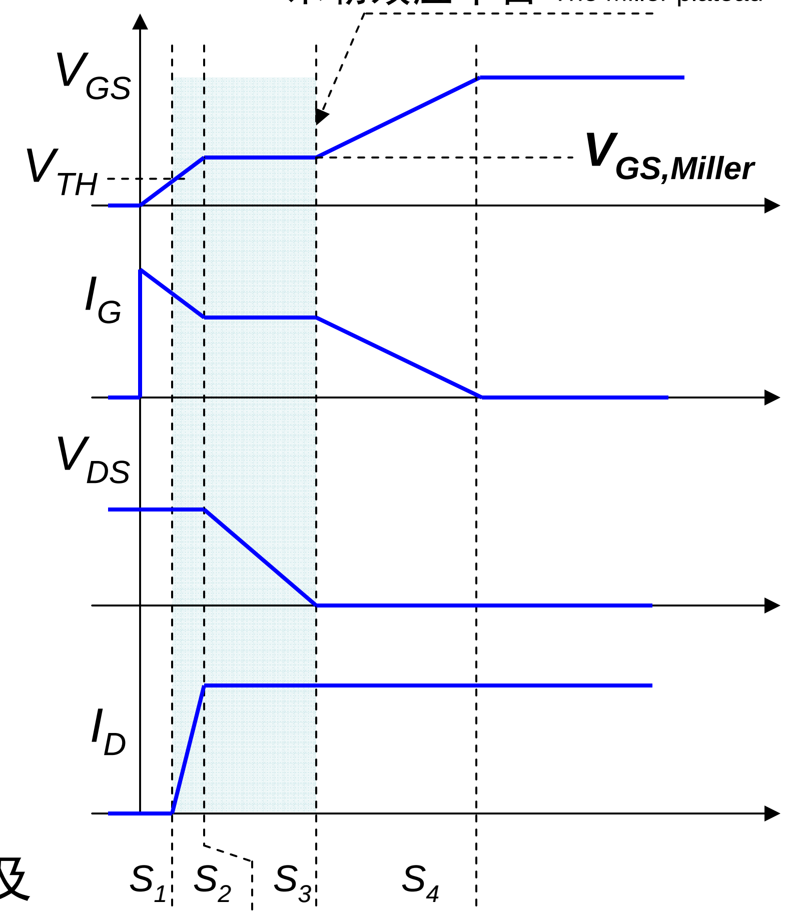
硬开关导通过程
Turn-on Procedure for Hard-switching



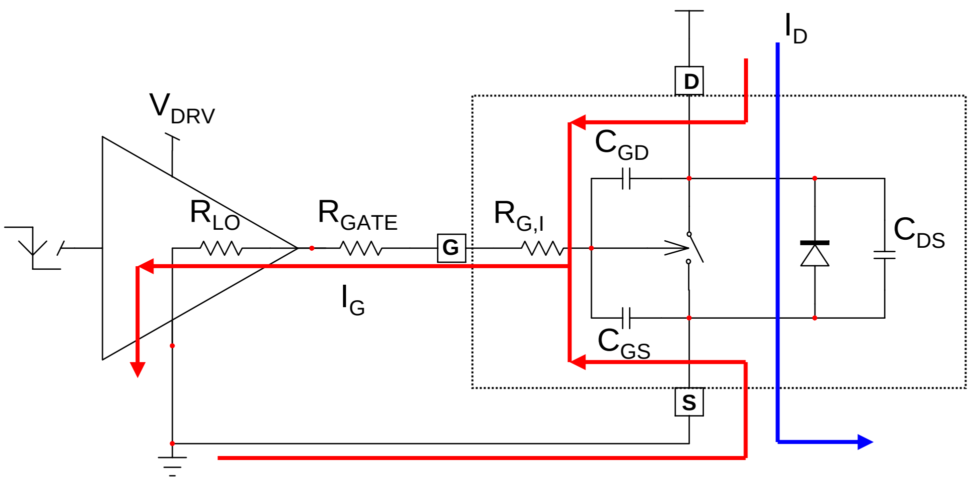
米勒效应平台由C_{GD}导致
The miller plateau is caused by C_{GD}



- 第二(S2)、第三(S3)阶段占MOSFET及驱动器开关损耗的主要部分 Stages 2 and 3 dominate the switching losses of MOSFET and driver.
- V_{GS}接近$V_{GS, Miller}$时驱动器(DRV)的源极能力很重要 DRV's source capability as V_{GS} is around $V_{GS,Miller}$ is important.

硬开关的关闭过程

Turn-off Procedure for Hard-switching



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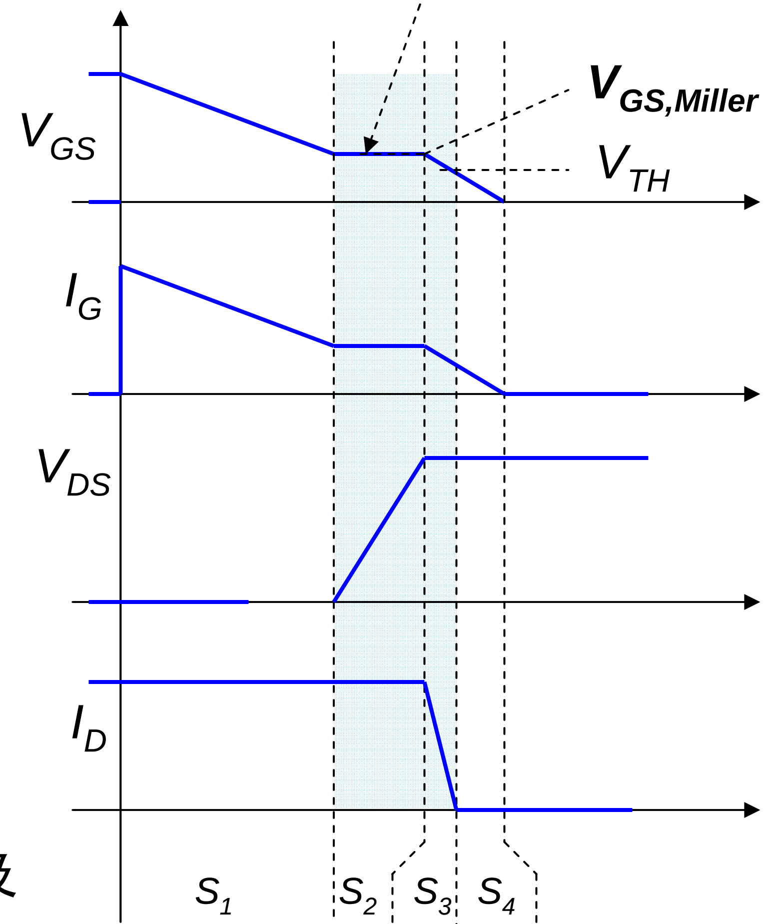

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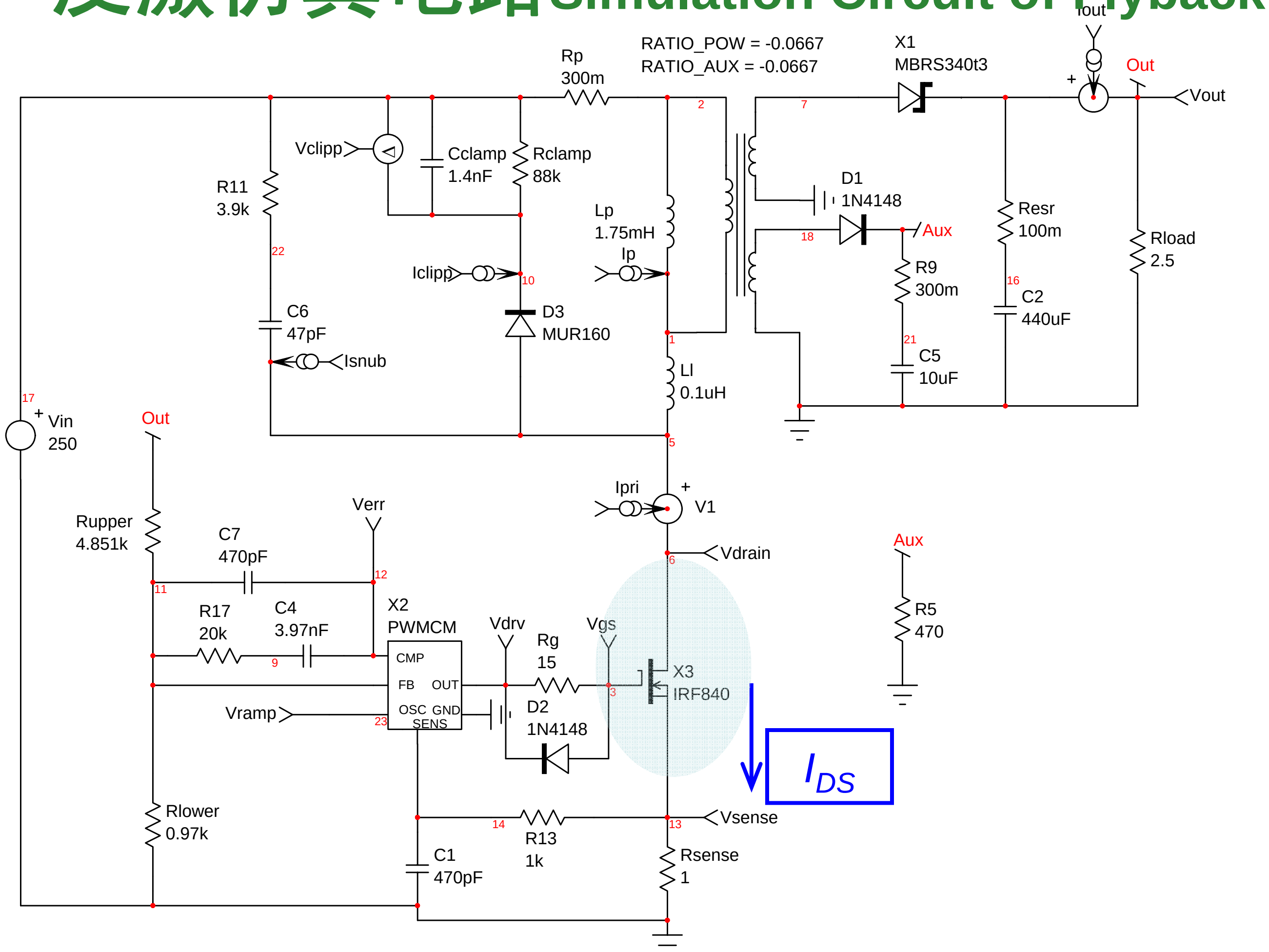
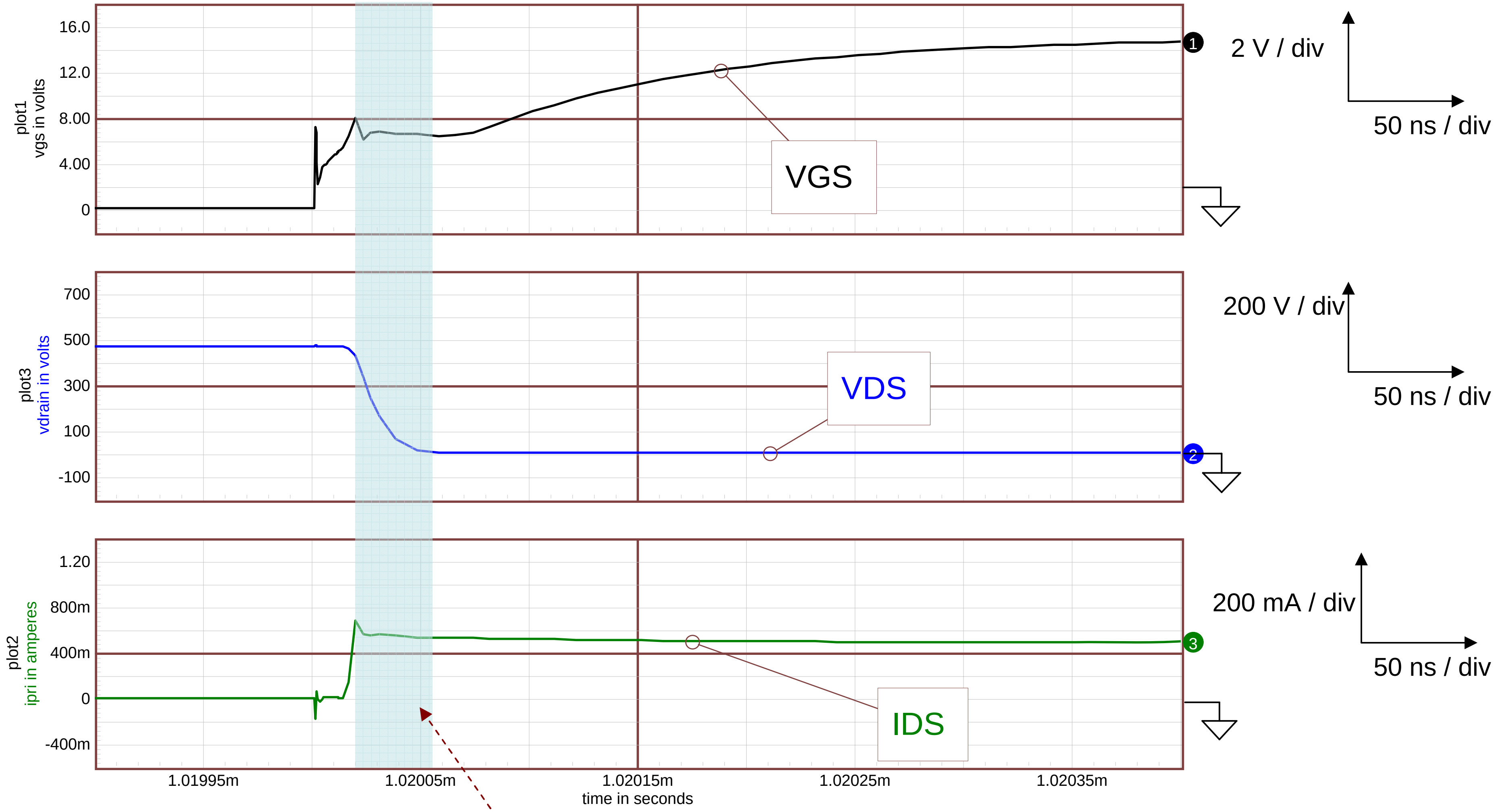
- V_{GS}接近$V_{GS,\ Miller}$时驱动器(DRV)的汲极能力很重要 DRV's sink capability as *VGS* is around *VGS,Miller* is important.

反激仿真电路Simulation Circuit of Flyback



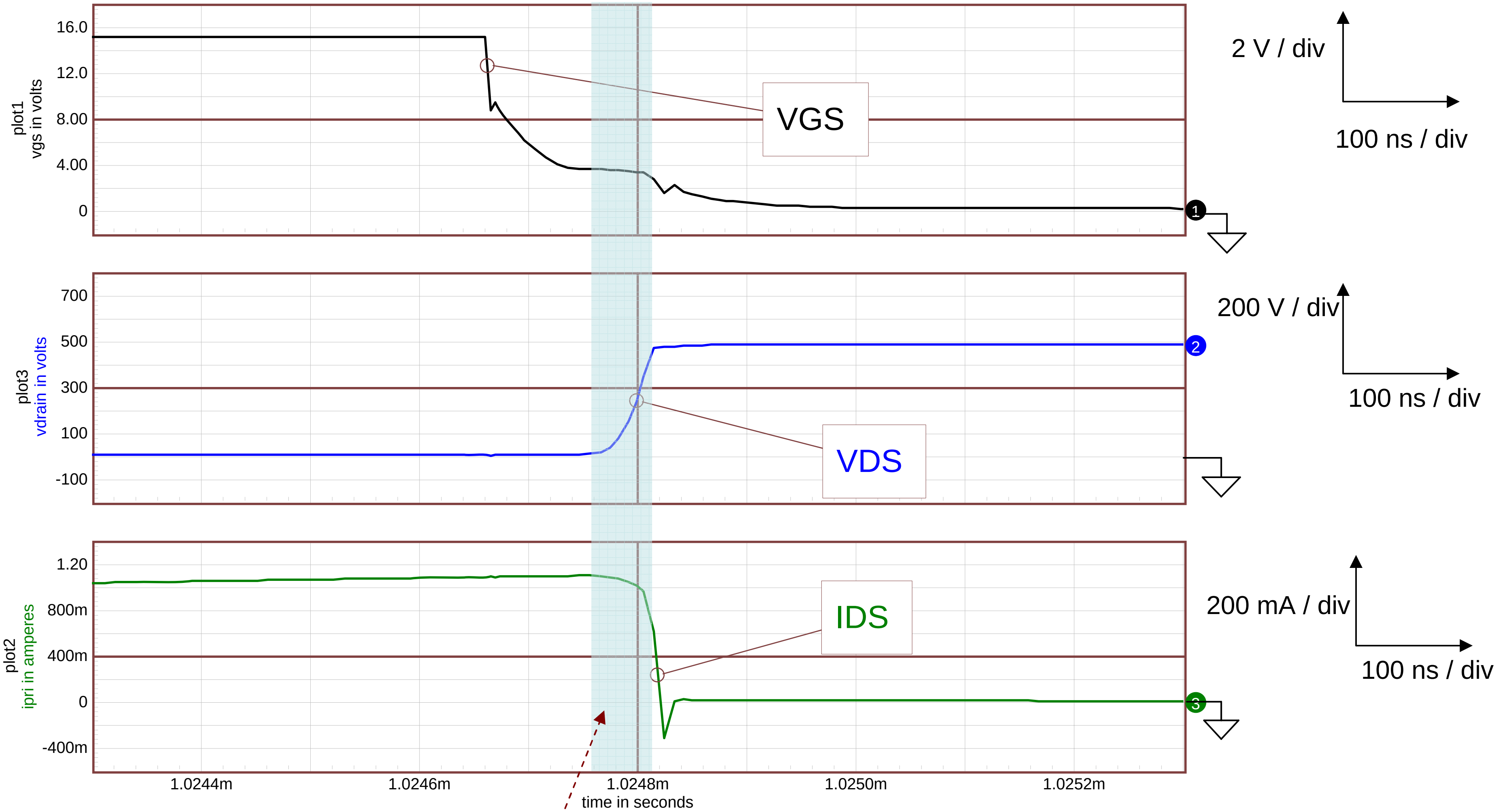
- 仿真反激电路上的V_{GS}、V_{DS}及I_{DS} Simulate the V_{GS}, V_{DS}, and I_{DS} on Flyback.

反激电路导通仿真 Turn-on Simulation of Flyback



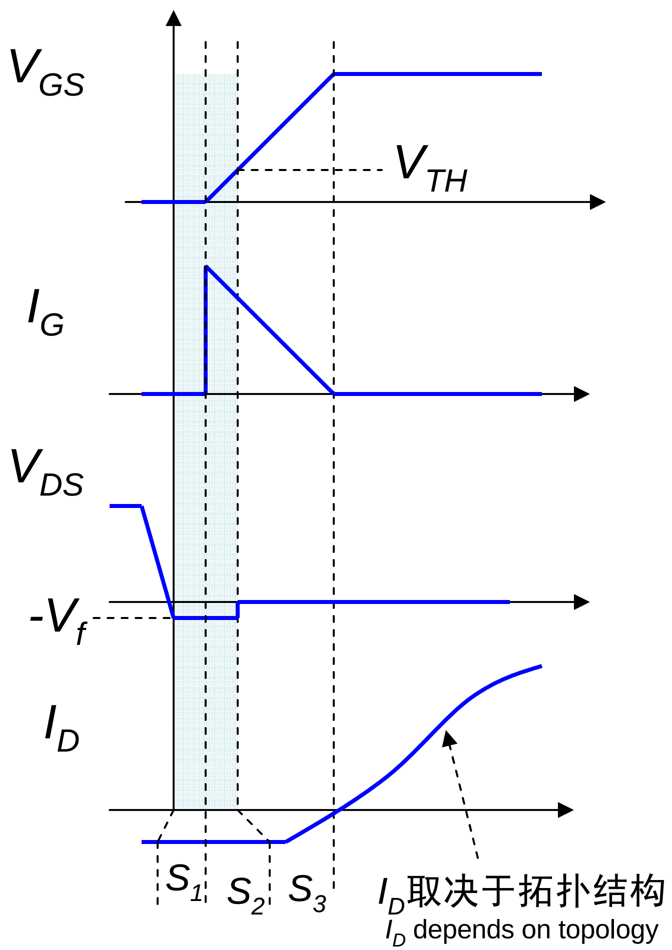
- V_{GS}上升时有米勒效应 V_{GS} rises with Miller effect.

反激电路关闭仿真 Turn-off Simulation of Flyback



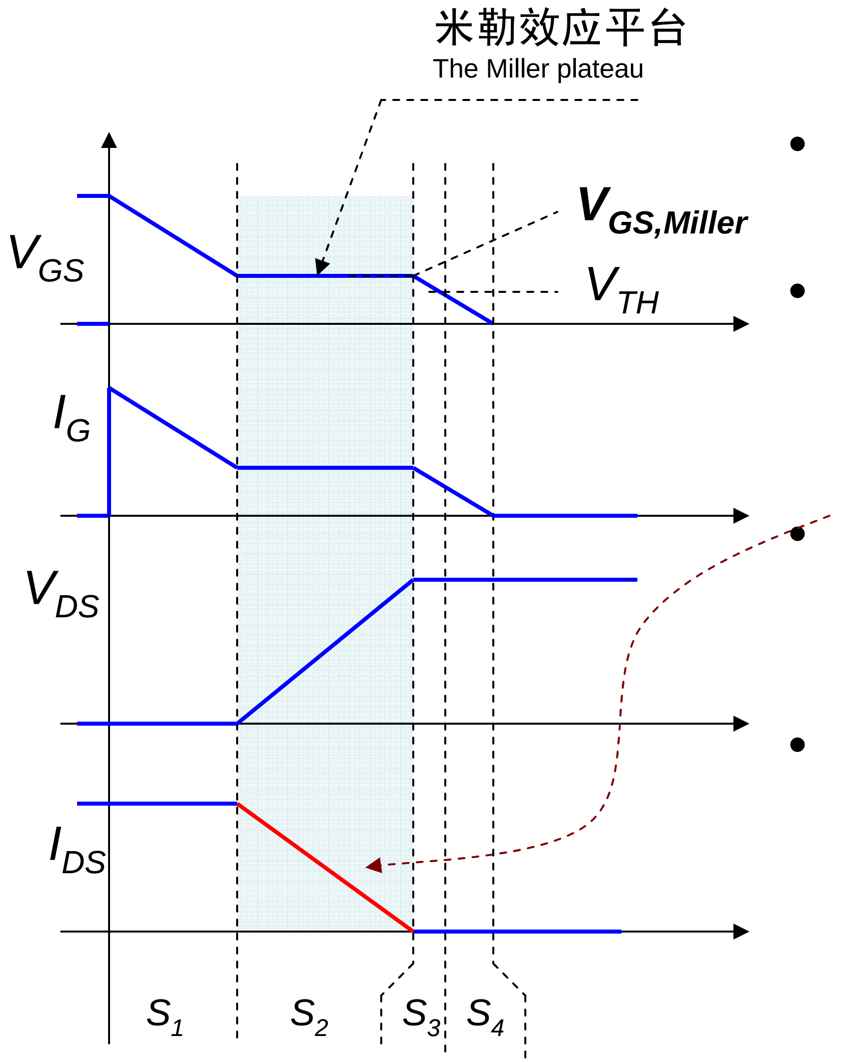
- 关闭时存在米勒效应 Turn off with Miller effect.

软开关导通过程 Turn-on Procedure for Soft-switching



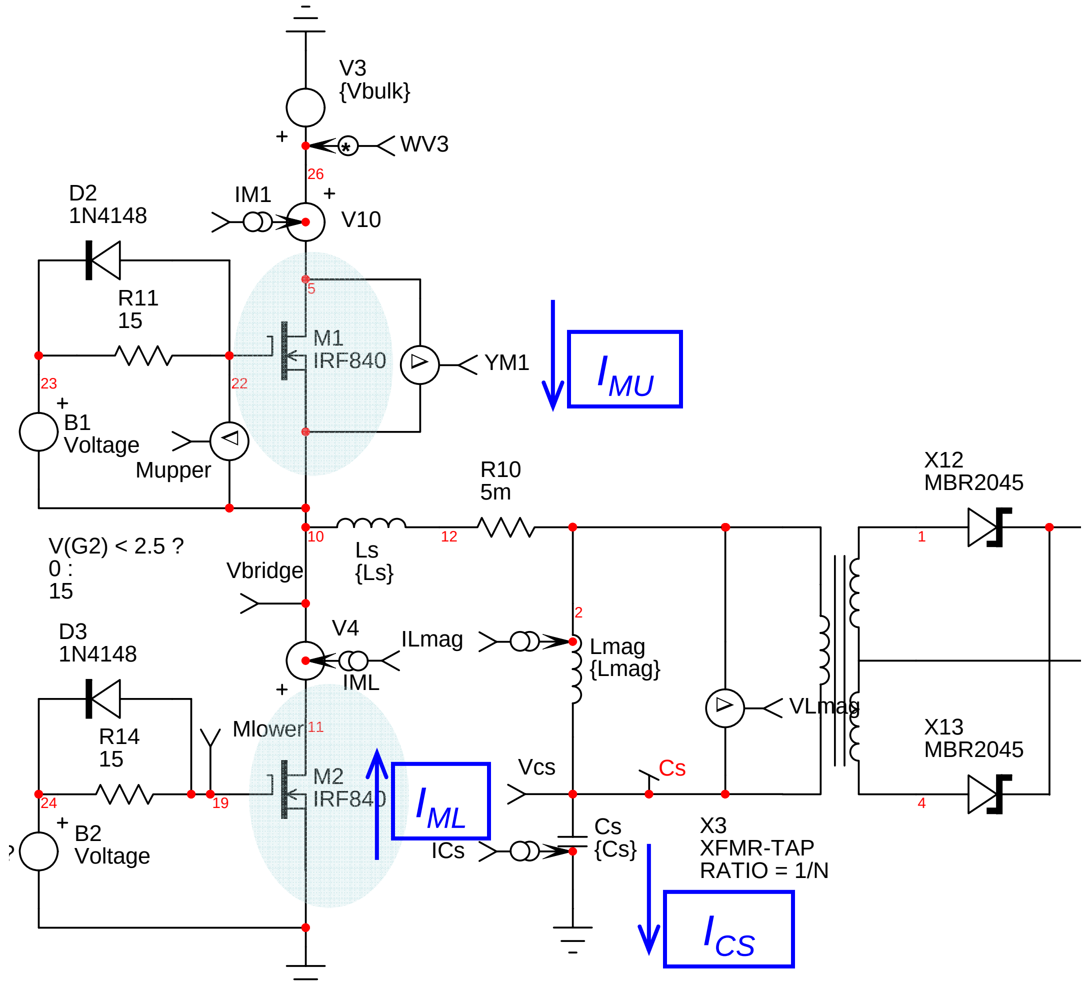
- 由于零电压开关(ZVS)，导通时没有米勒效应 Because of ZVS, there is no Miller effect as turning on.
- 开关损耗的主要决定因素 The switching losses are dominated by
  - 死区时间(以缩短S_1)，及 The dead time (to reduce S_1), and
  - 给C_{GS}充电以缩短S_2的电源供应能力 Source capability to charge C_{GS} to reduce S_2
- 驱动能力要求较低 Less driver capability requirement.

软开关关闭过程 Turn-off Procedure for Soft-switching



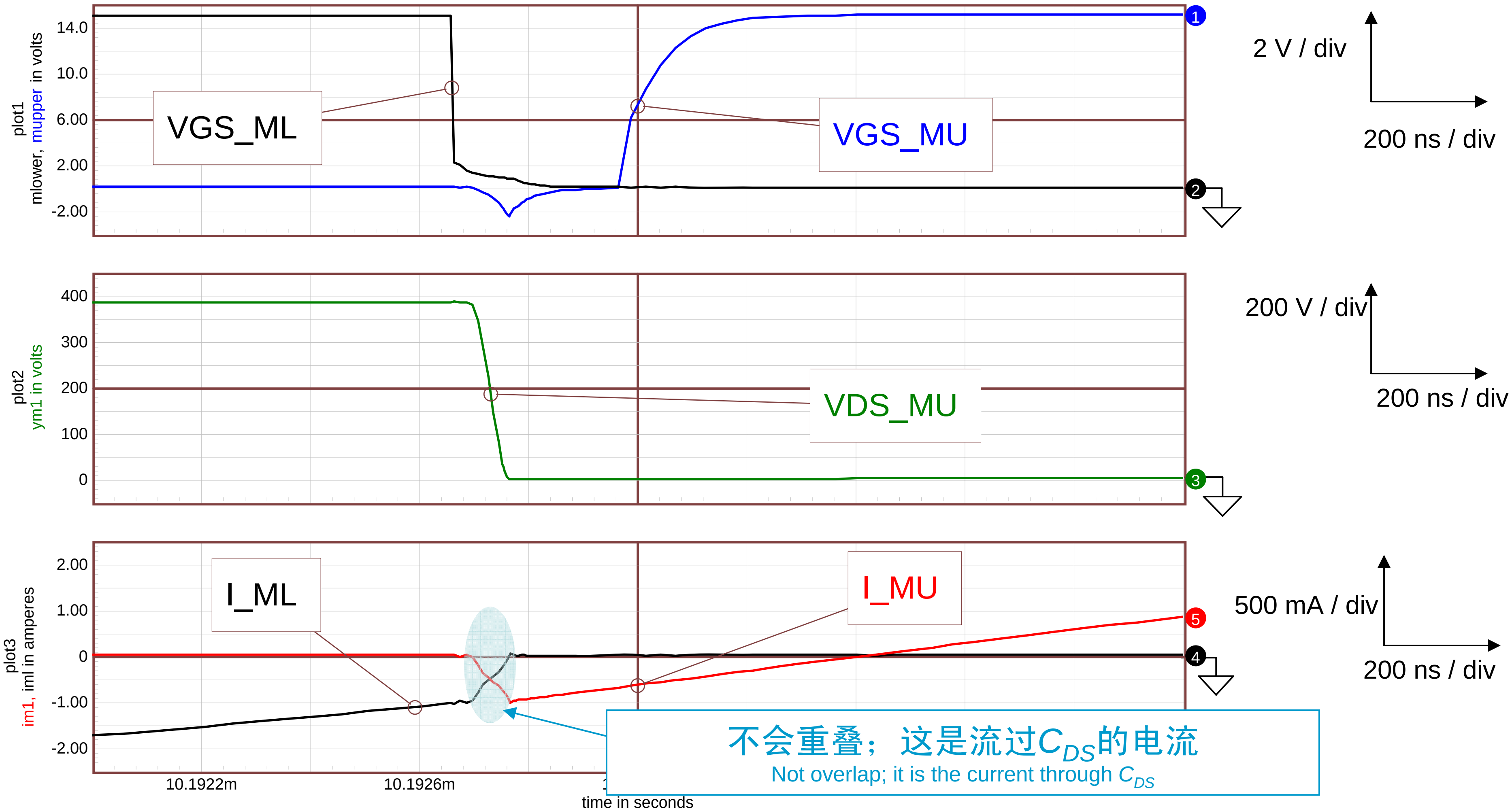
- 类似于硬开关：关闭时存在米勒效应 Similar as hard-switching: The Miller plateau exists as turning off.
- 区别在于I_{DS}在关闭期间还降低，因为在V_{DS}改变时I_{DS}将经过相反方向的MOSFET The difference is that I_{DS} also reduces at this duration since I_{DS} will go through the opposite MOSFET as V_{DS} changes.
- 为了避免2个MOSFET之间的相位交迭，将S_1 ~ S_4的持续时间减至最短 To avoid overlap between 2 MOSFETs, minimize the duration of S_1 ~ S_4.
- 需要强大的DRV汲极能力 Strong DRV's sink capability is needed.

LLC半桥仿真电路 Simulation Circuit of LLC-HB



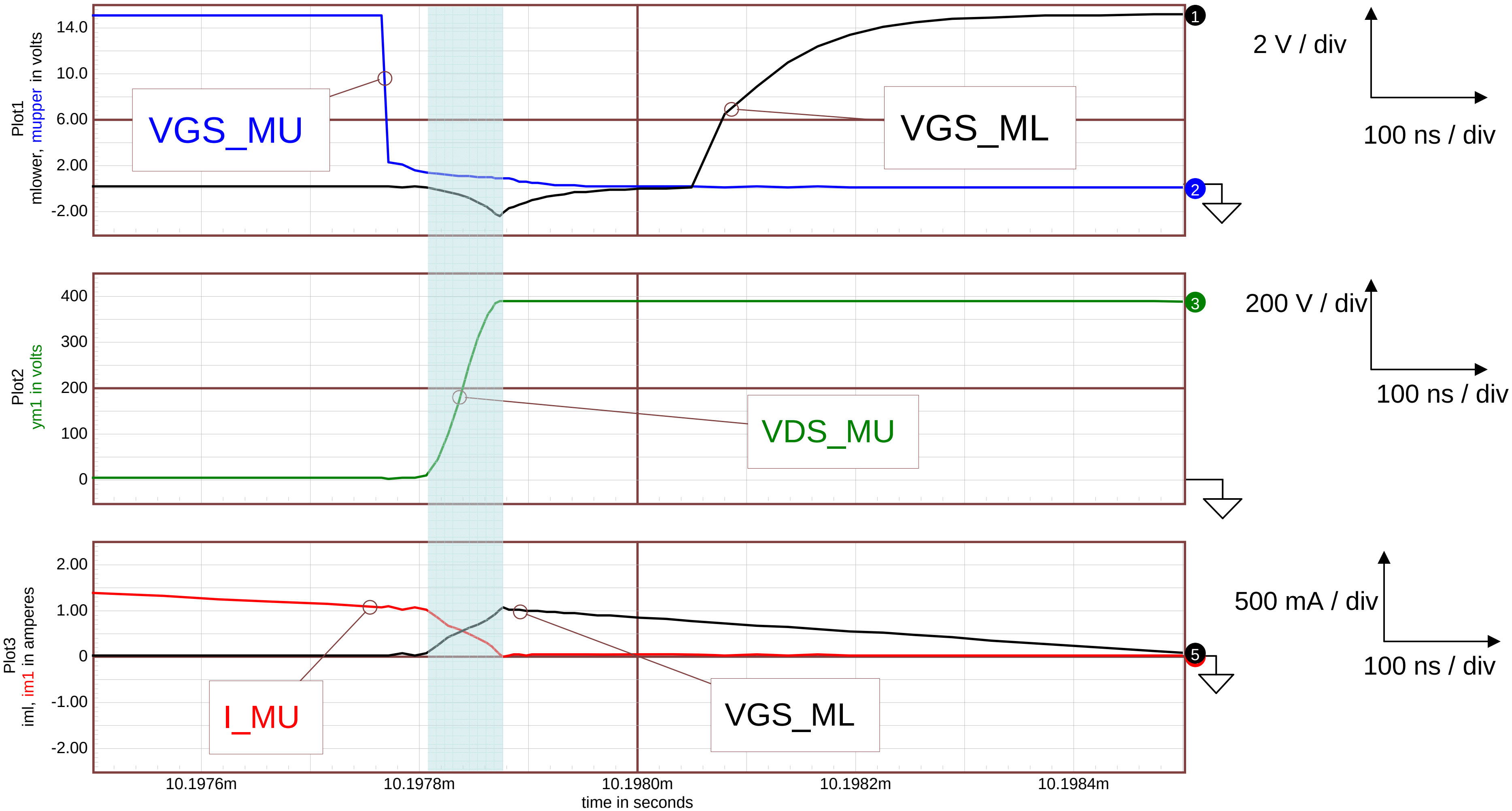
- 仿真LLC-HB上的V_{GS_MU}、V_{DS_MU}及I_{MU} Simulate the V_{GS_MU}, V_{DS_MU}, and I_{MU} on LLC-HB
- 为简化电流读取，I_{MU}和I_{ML}的方向参考I_{CS} To ease the reading of current, the direction of I_{MU} and I_{ML} is referred to I_{CS}.

LLC半桥导通仿真 Turn-on Simulation of LLC-HB



- V_{GS_ML}关闭，I_{CS}减小V_{DS}，用于ZVS V_{GS_ML} off, I_{CS} reduces V_{DS_MU} for ZVS.
- V_{DS_MU}在V_{GS_MU}之前到达0 V，因此V_{GS_MU}平滑上升 V_{DS_MU} is 0 V BEFORE V_{GS_MU}, so V_{GS_MU} rises smoothly.

LLC半桥半闭仿真 Turn-off Simulation of LLC-HB



- 要示强大的关闭能力 Strong turn off capability is required.

驱动器硬开关与软开关比较
Driver Comparison Between Hard-Switching and Soft-Switching

	硬开关 **Hard-switching**	软开关 **Soft-switching**
源极能力要求 Source capability requirement	中等 Medium	低 Low
汲极能力要求 Sink capability requirement	高 High	高 High
死区时间精度要求 Dead time accuracy requirement	精确 Accurate	精确 Accurate

高端驱动器方案
The Solutions for High-Side Driver

- 基于变压器的方案 Transformer-based solution
  - 单DRV输入 Single DRV input
  - 双DRV输入 Dual DRV inputs
- 硅集成电路驱动器：双输出 Silicon integrated circuit driver: dual outputs
  - 单DRV输入 Single DRV input
  - 双DRV输入 Dual DRV inputs

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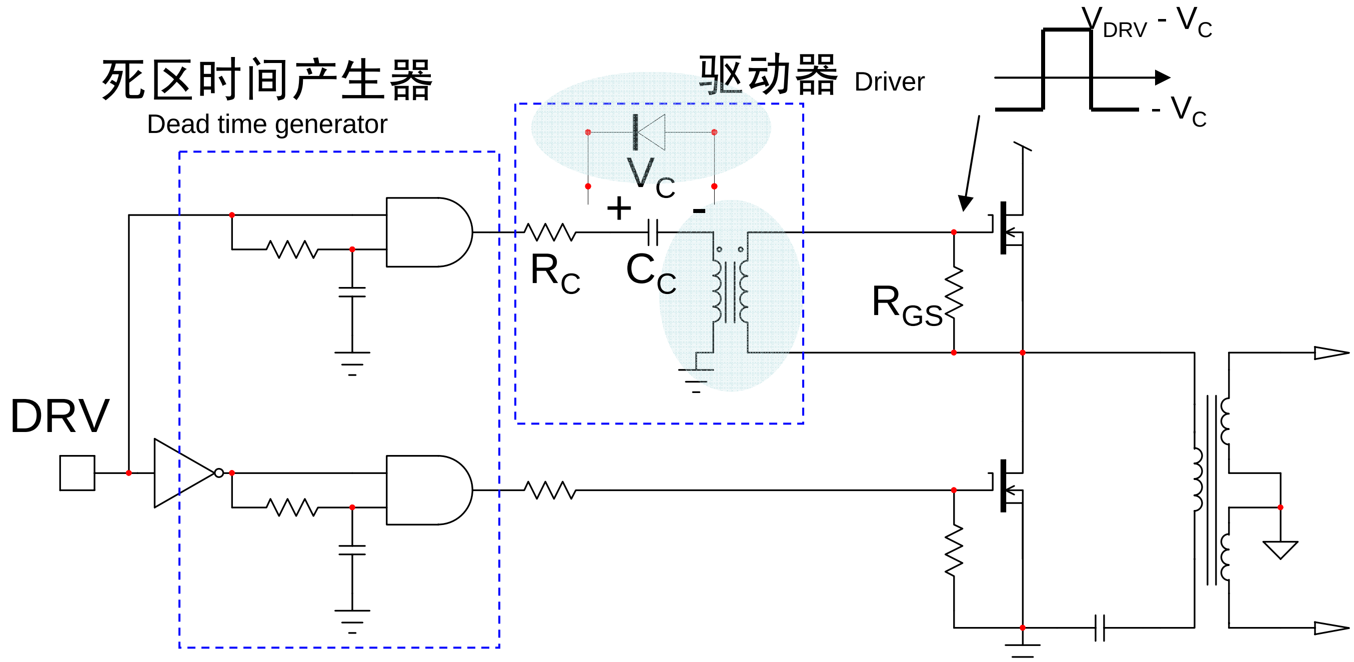
驱动变压器设计考虑因素
Consideration as Designing Driver Transformer

- 对地参考点的浮动驱动-如果存在400 V预稳压功率因数校正(PFC)电路，则保持500 V隔离 Ground-referenced floating drive – keep 500-V isolation if a 400-V pre-regulated PFC exists.
- 将漏电感减至最小-输出与输入绕组间的延迟可能会损坏功率管MOSFET Minimize the leakage inductance - the delay between output and input windings may kill the power MOSFETs.
- 遵守法拉第定律-保持V*T恒定，否则会饱和 Follow Faraday's law – keep V*T constant, otherwise, saturate.
- 保持足够裕量，防止饱和-尤其在交流(AC)高压输入和瞬态负载的情况下 Keep enough margin from saturation – the worst case happens with transient load at high line.
- 使用高磁导率铁芯-将I_M降至最低 High permeability ferrite – minimize the I_M.
- 保持高汲电流能力，以加快开关功率管 Keep high sink current capability

单驱动器输入 Single DRV Input



$$V_C = DV_{DRV}$$

$$Q > \frac{1}{R_C}\sqrt{\frac{L_M}{C_C}} = 0.5$$

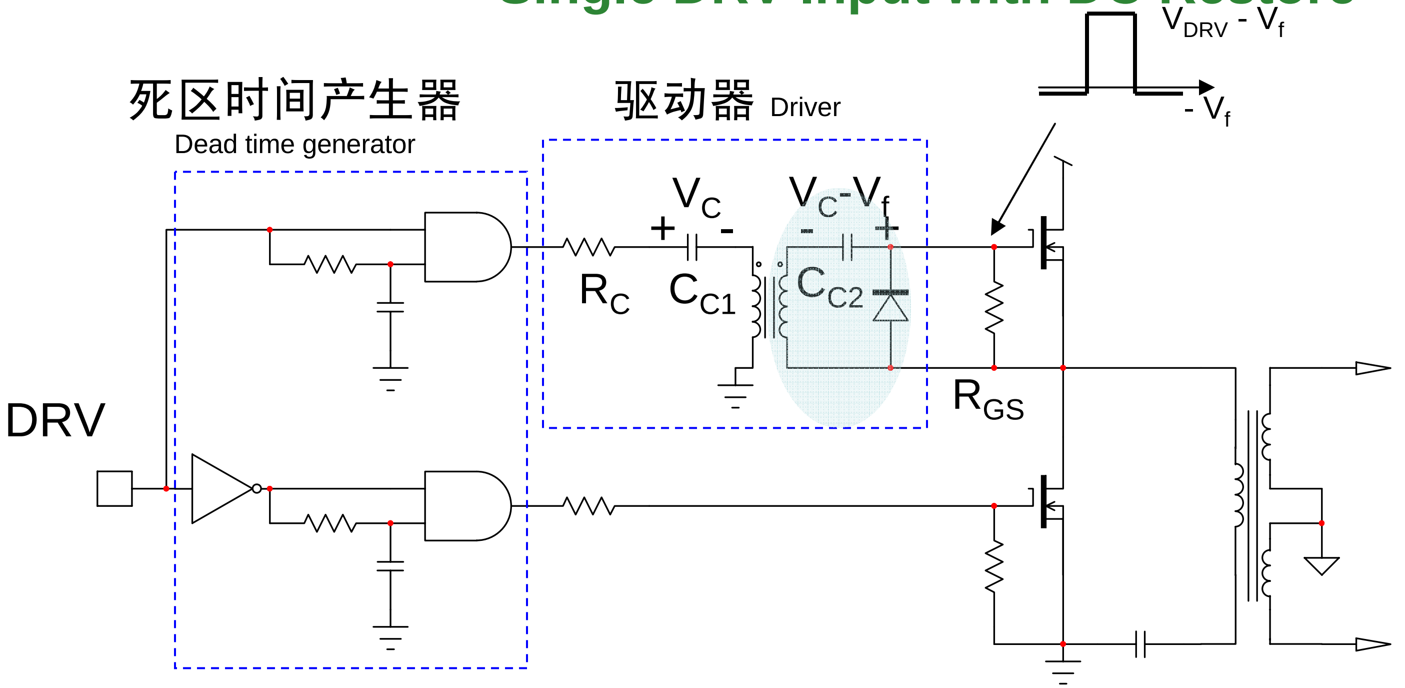
$$R_C \ge \frac{1}{Q}\sqrt{\frac{L_M}{C_C}} = 2\sqrt{\frac{L_M}{C_C}}$$

C_C复位驱动器变压器，R_C抑制L-C谐振 C_C to reset the driver transformer and R_C to damp the *L-C* resonance.

- 需要加交流耦合电容(C_c)来复位驱动器变压器磁通 An ac coupling capacitor (C_C) is needed to reset the driver transformer flux.
- V_{GS}幅度取决于占空比 The amplitude of V_{GS} is dependent on duty. ☹
- 稳态时-V_C关闭，而在启动时汲电流能力受限 With (-V_C) to turn off at steady state, but the sink capability is limited at start-up. ☹
- 需要快速的时间常数(L_M//R_{GS} * C_C)，防止由快速瞬态导致的磁通走漏 Need a fast time constant (L_M//R_{GS} * C_C) to avoid flux walking due to the fast transient.
- 留意跳周期模式或欠压锁定(UVLO)时C_C与驱动变压器之间的振铃，需要使用二极管来抑制振铃 Watch out the ringing between C_C and drive transformer at skip mode or UVLO, a diode is needed to damp the ringing.

带直流复位的单DRV输入

Single DRV Input with DC Restore

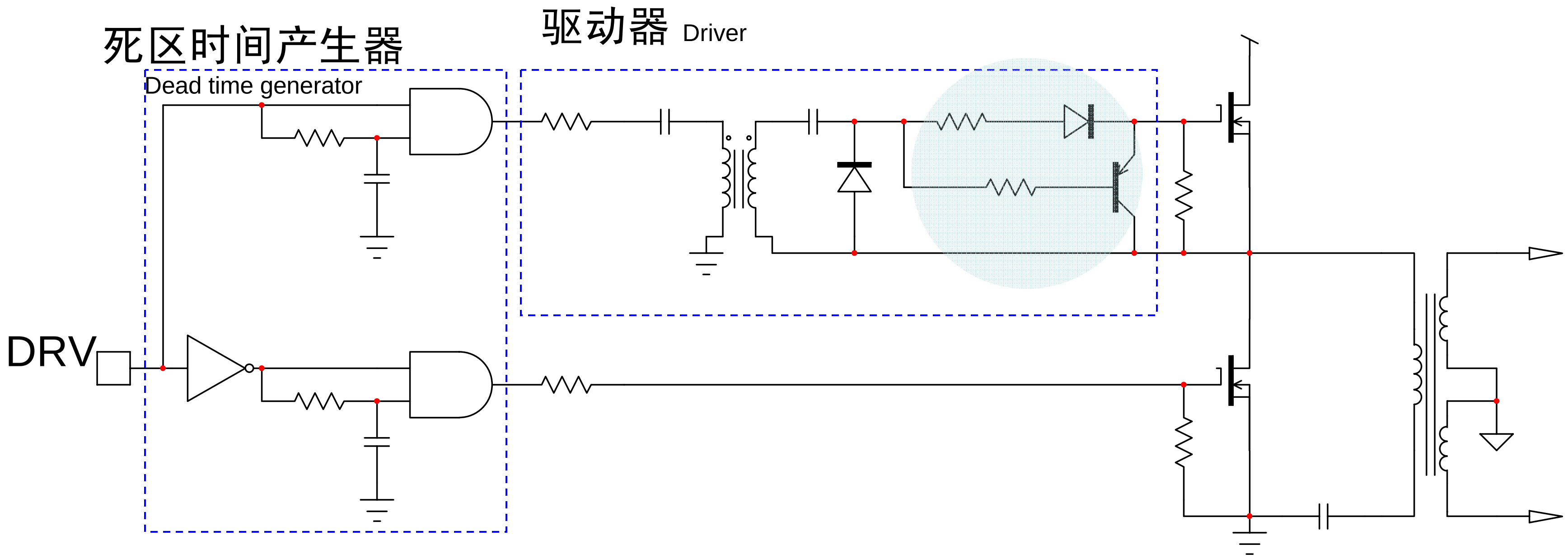


$$V_C = DV_{DRV}$$

$$R_C \geq 2\sqrt{\frac{L_M}{C_C}}$$

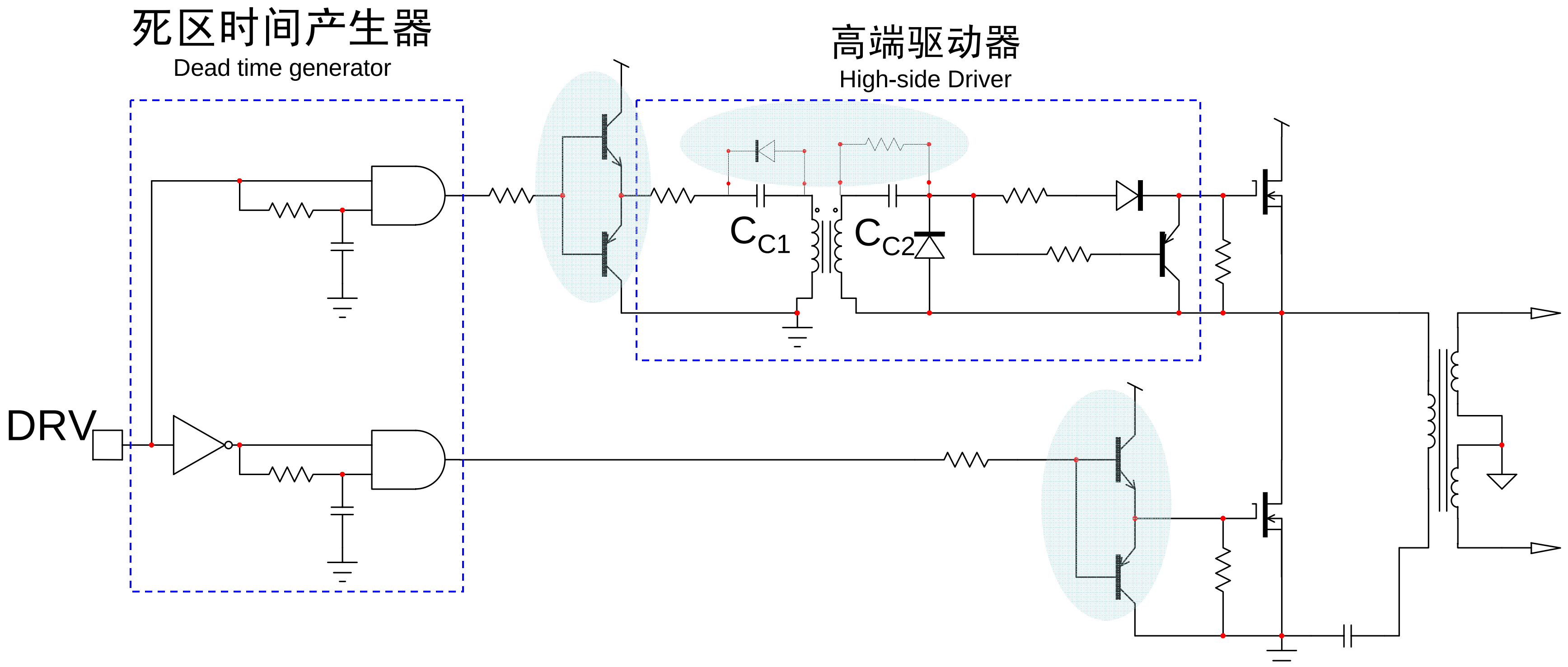
- *稳态*时V_{GS}幅度取决于占空比 V_{GS} amplitude is independent on duty ratio at steady state.
- 汲电流能力有限 Limited sink capability.

单DRV输入，带PNP关闭
Single DRV Input with PNP Turn-Off



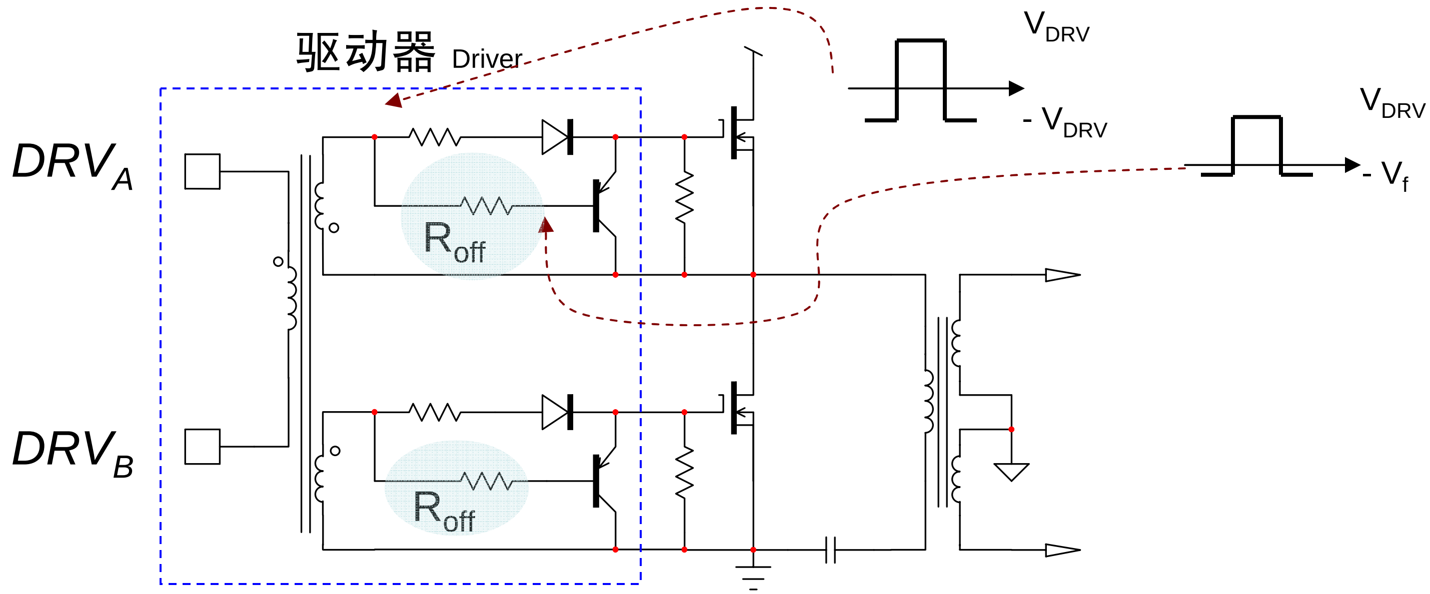
- PNP晶体管+二极管帮助改善关闭
  A pnp transistor + diode help to improve the switching off.

别忽略AND门 Don’t Forget the AND Gate



- 如果AND门驱动能力有限，增加图腾柱驱动器 Add the totem-pole drivers if output capability of AND gate is limited.
- 设计是否已经完成？ Is the design finished?
  ➔ 还没有。注意跳周期模式或欠压锁定(UVLO)时C_{C1}、C_{C2}及驱动变压器间的振铃 No, not yet. Pay attention to the ringing among C_{C1}, C_{C2} and driver transformer when skip or UVLO. A diode and resistor to damp the ringing. ☹

双极性对称DRV输入 Dual Polarity Symmetrical DRV Inputs



- DRV_A 与DRV_B极性相反，位置对称 DRV_A and DRV_B are opposite-polarity and symmetrical ➔无交流耦合电容 no ac coupling capacitor. ☺
- 适合推挽型电路，如LLC-HB，但不适合不对称电路，如非对称半桥(AHB)或有源钳位 This is suitable for push-pull type circuit, e.g. LLC-HB, but NOT for asymmetrical type, e.g. AHB or active clamp. ☹
- 注意线路/负载瞬态时的驱动器变压器磁通 Pay attention to the flux of driver transformer at line/load transient.
- 仍然需要强大的关闭能力 The strong turn off capability is still needed. ☹
- 注意由泄漏电感导致的延迟 Pay attention to the delay caused by the leakage inductance. ➔ 将泄漏电感减至最小，并使用双输出绕组而非单输出绕组 minimize the leakage inductance and use dual output windings instead of single output winding.
- 由R_{off}压降导致额外的损耗 Extra losses caused by voltage drop on R_{off}. ☹

驱动变压器 The Driver Transformer

- 优势 Pros
  - 变压器比裸片更强固！ A transformer is more robust than a die!
  - 对杂散噪声及高dV/dt脉冲较不敏感 Less sensitivity to spurious noise and high dV/dt pulses
  - 更便宜？ Cheap?
- 劣势 Cons
  - 电路复杂 Complicated circuits
  - 需注意极端线路/线路条件及关闭模式 Pay attention on extreme line/line condition & off mode ……
  - 需注意泄漏电感及隔离 Pay attention on the leakage inductance and isolation
  - 汲电流能力是否够强？ Is the sink capability strong enough?

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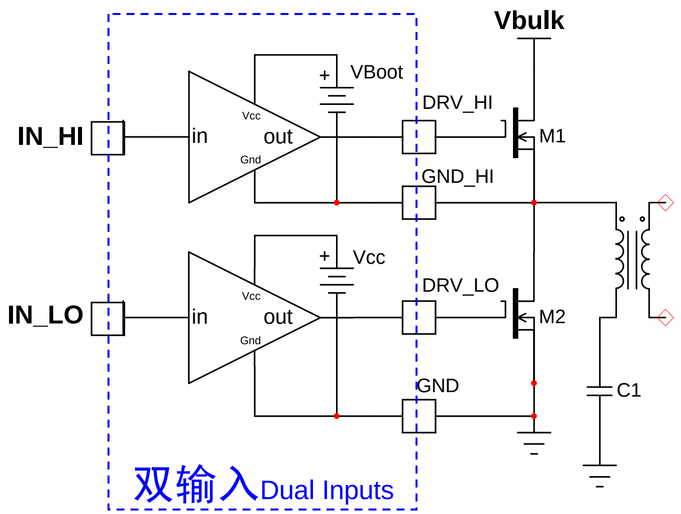
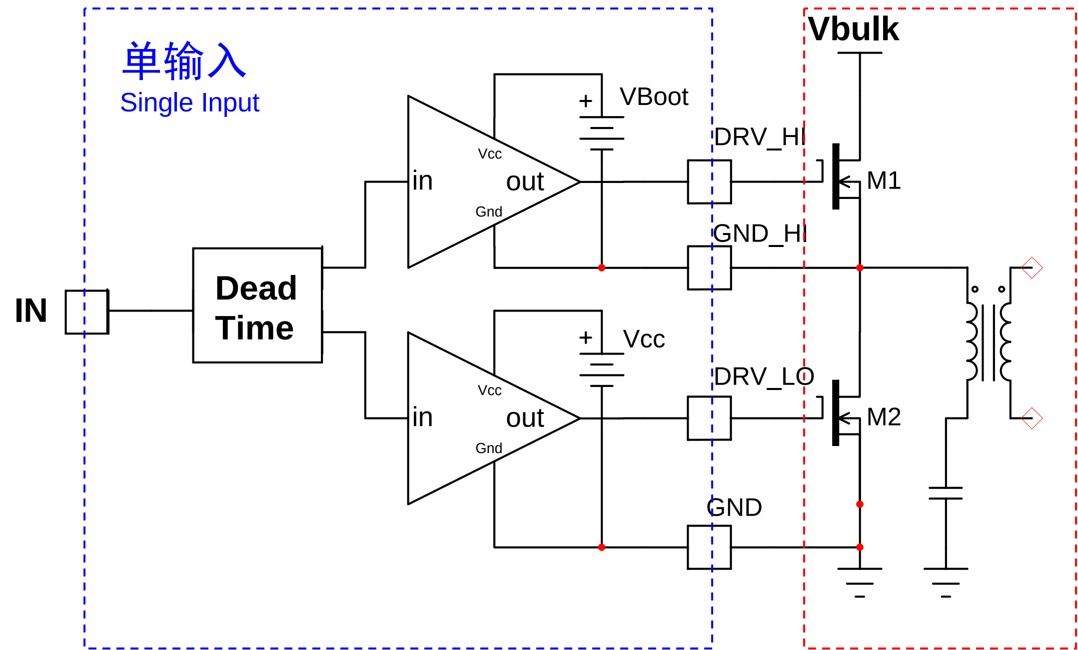
硅半桥驱动器原理
Silicon Half Bridge Driver Principle

- 原理 Principle
  - 单输入或双输入
    Single or dual inputs
  - 高端或低端驱动器
    High & low side driver

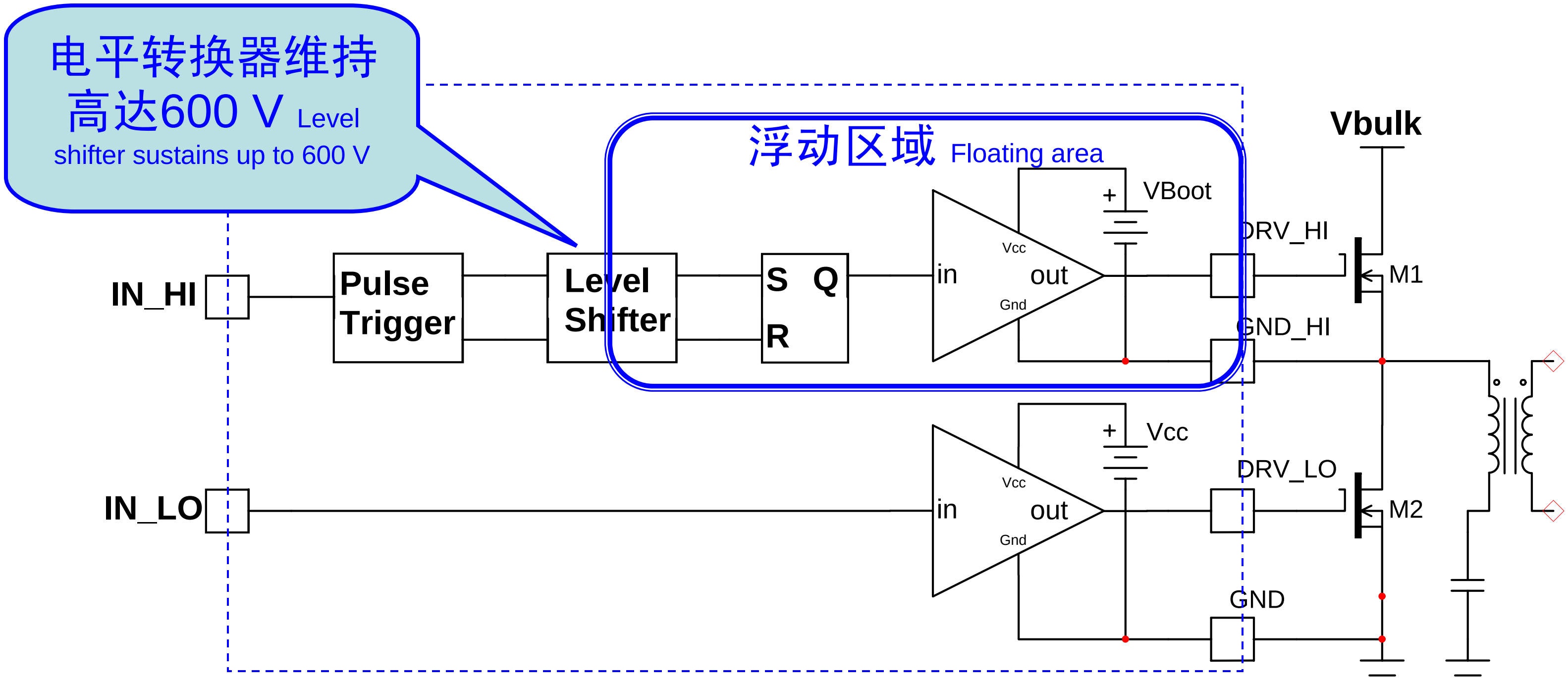




硅方案有何局限?
Silicon Solution, What are its Limits?

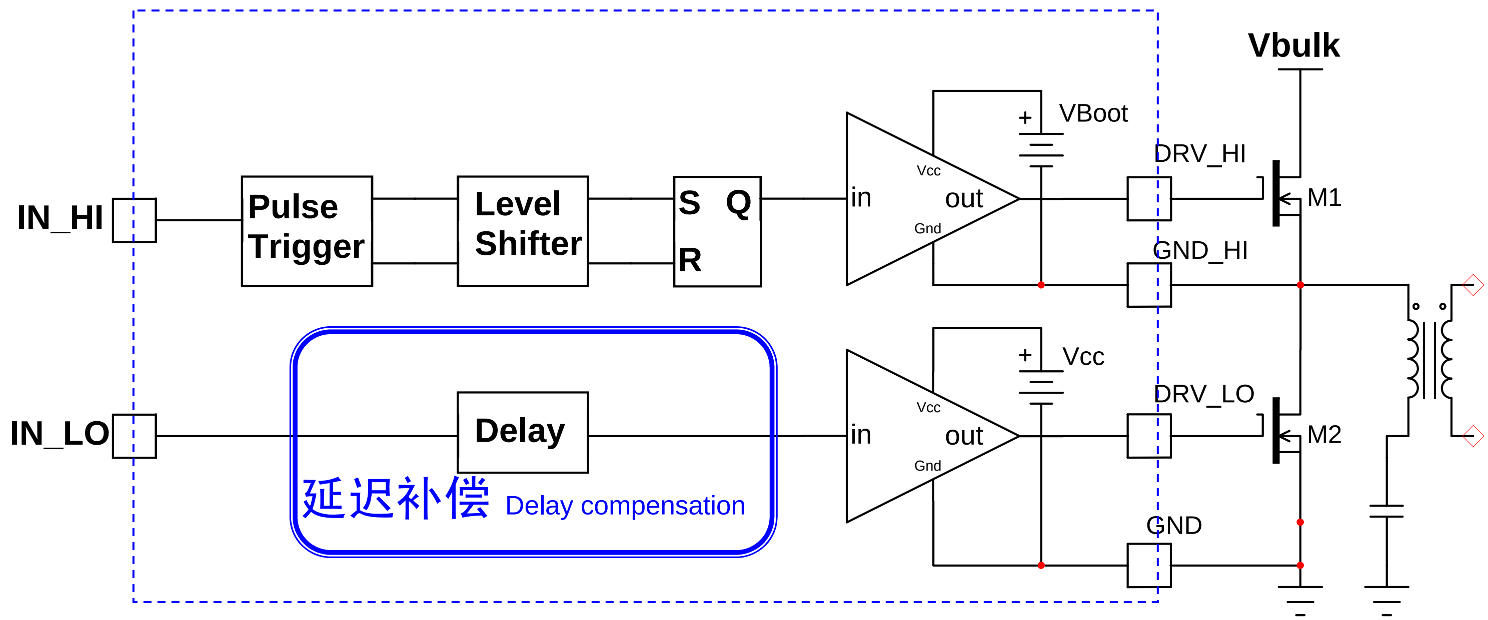
- 高端隔离-硅片内电压达600 V High-side isolation – 600 V is reached within the silicon.
- 高端与低端驱动间的匹配传播延迟 – 防止使用任何不平衡变压器 Matched propagation delay between high and low side drive Prevents any unbalanced transformer usage.
- 高端驱动器的工作电源-需要自举电源 High side driver supply – Bootstrap supply is requested.
- 高抗干扰性-高端驱动器的负电压强固性 Noise immunity – Negative voltage robustness of the high side driver.

硅方案，高压隔离 Silicon Solution, High Voltage Isolation



- 脉冲触发器：在IN_HI输入的每个边沿产生脉冲 Pulse trigger: generates pulse on each edge from IN_HI input.
- 电平转换器：将脉冲从GND参考转换至GND_HI参考 Level shifter: shifts pulses from GND reference to GND_HI reference.
- 同步整流触发器：闩锁源自电平转换器的脉冲信息 SR flip flop: latches pulses information from the level shifter.

硅方案，匹配传播延迟
Silicon Solution, Matched Propagation Delay

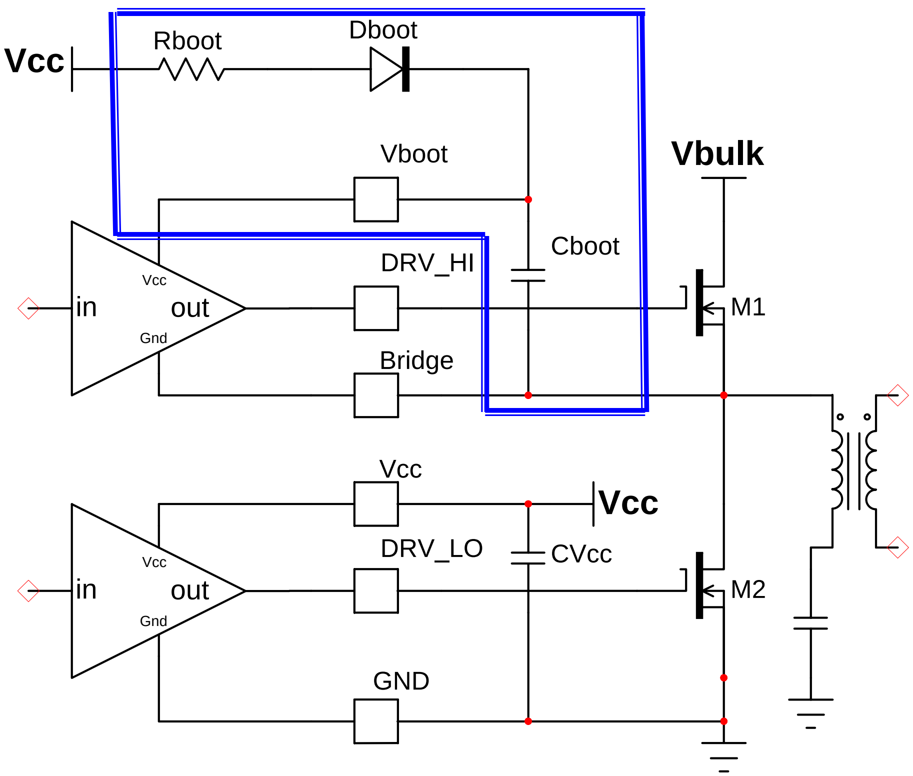


- 在低端驱动器通道上加入延迟时间 Delay is inserted on the fastest path: Low side driver path

  ➔ 去补偿高端延迟：脉冲触发器+电平转换器和同步整流触发器延迟 to compensate: Pulse trigger + level shifter and SR flip-flop delays.

硅方案，高端驱动器电源
Silicon Solution, High Side Driver Supply

启动电路连接至V_{CC} Bootstrap connected to Vcc



启动步骤 Bootstrap Step:

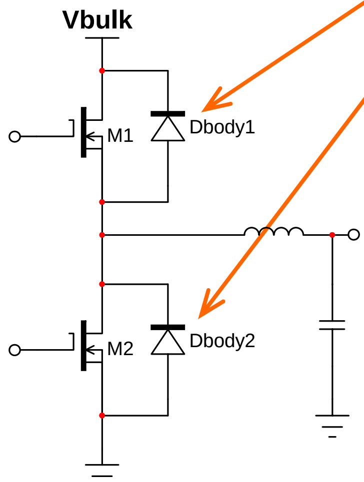
- 步骤1 Step 1：M2关闭 M_2 is closed ➔ C_{boot}接地：C_{boot}通过V_{CC}充电 C_{boot} is grounded: C_{boot} is refueled via V_{cc}.
- 步骤2 Step 2: M_1 & M_2开路 M_1 & M_2 are opened ➔ 桥引脚浮动，D_{boot}阻断，C_{boot}为浮动区域供电 Bridge pin is floating, D_{boot} is blocked & C_{boot} supplies floating area.
- 步骤3 Step 3: M_1关闭 M_1 is closed ➔ 桥引脚转换至大电平，D_{boot}仍然阻断，C_{boot} 为浮动区域供电 bridge pin moved to bulk level, D_{boot} is still blocked & C_{boot} supplies floating area.

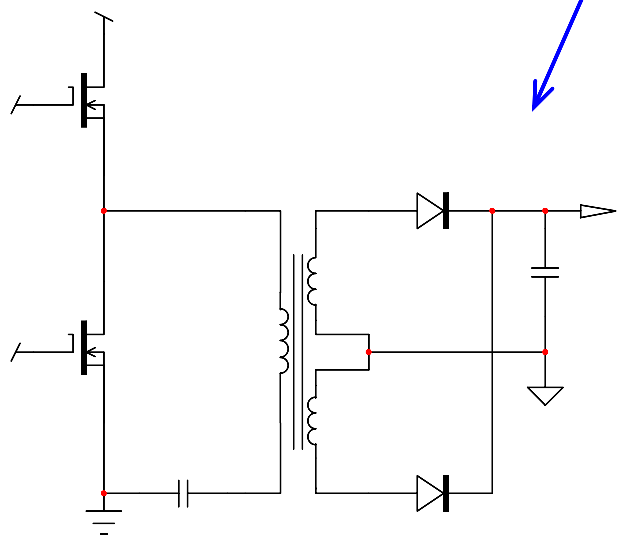
- 自举电源电路技术用于为高端驱动器供电
  Bootstrap technique is used for supplying the high side driver

高端驱动器负载电压的根源何在？

Root of High Side Driver Negative Voltage?

- 着重关注半桥支路 Let's focus on the half-bridge branch:
  - 连接至半桥支路的负载是电感型负载 the load connected to a half-bridge branch is inductive:
  - 类似于LLC半桥 like an LLC-HB
  - 或者在最简单的情况下是同步降压结构(红色箭头所指的是MOSFET体二极管) Or with the most simple case in a synchronous buck (where body diodes of the mosfet are represented).

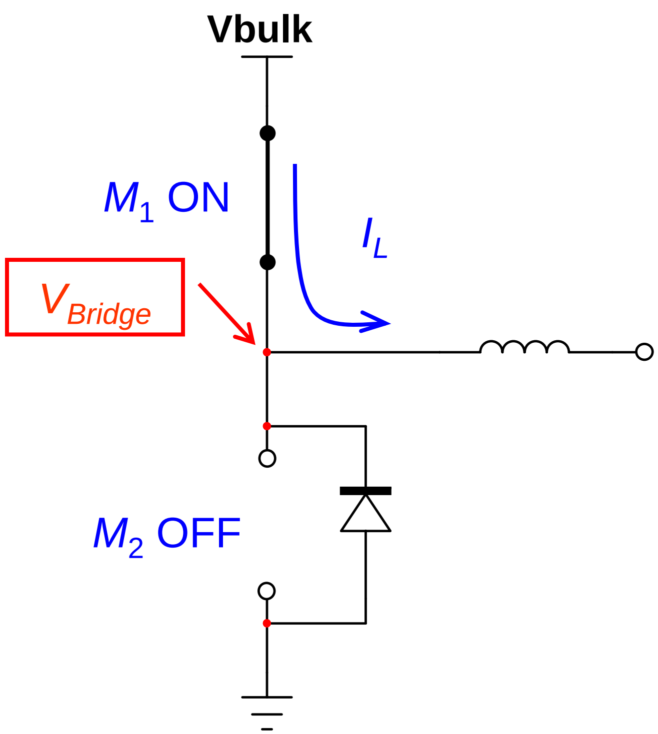


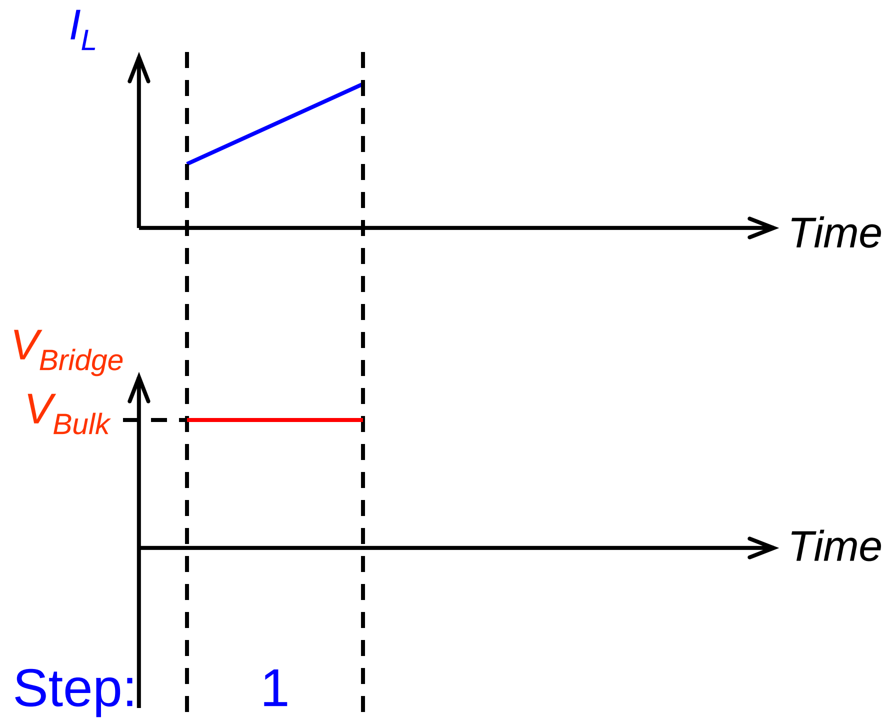


LLC-HB

理论：降压转换器工作
Theory: Buck Converter Operation

- 降压转换器工作的第一阶 1st step of the buck converter:





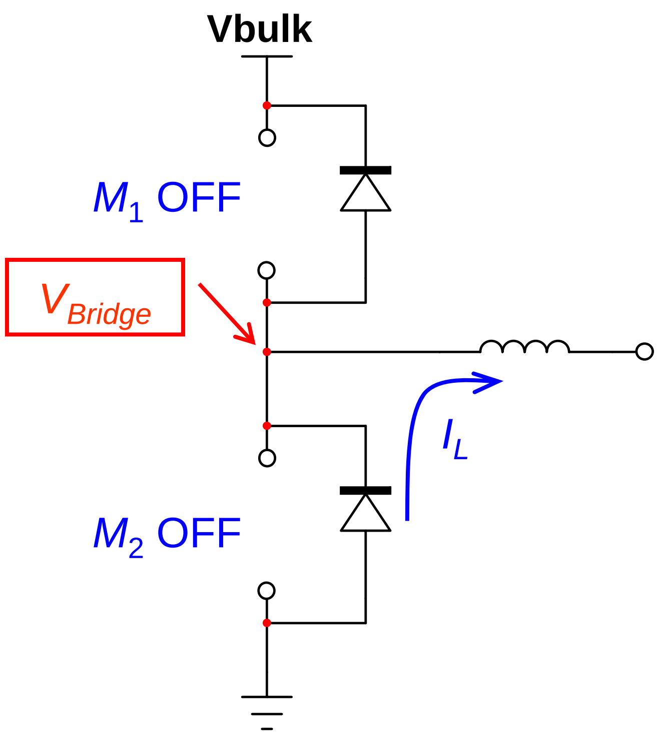
Step 1:

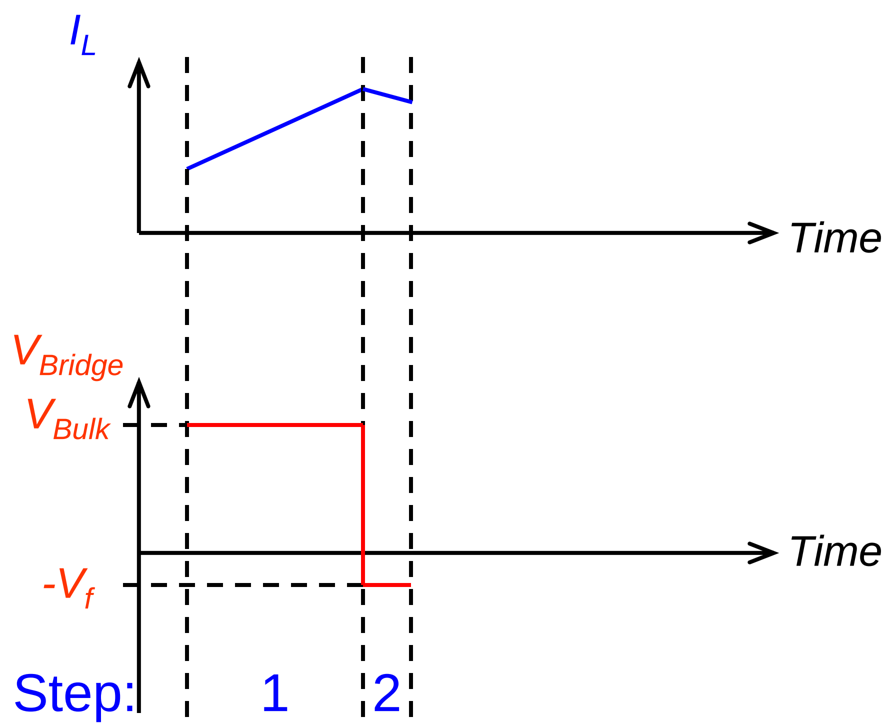
M_1导通 ON

M_2关闭 OFF

理论：降压转换器工作
Theory: Buck Converter Operation

- 降压转换器工作的第二阶 2nd step of the buck converter:





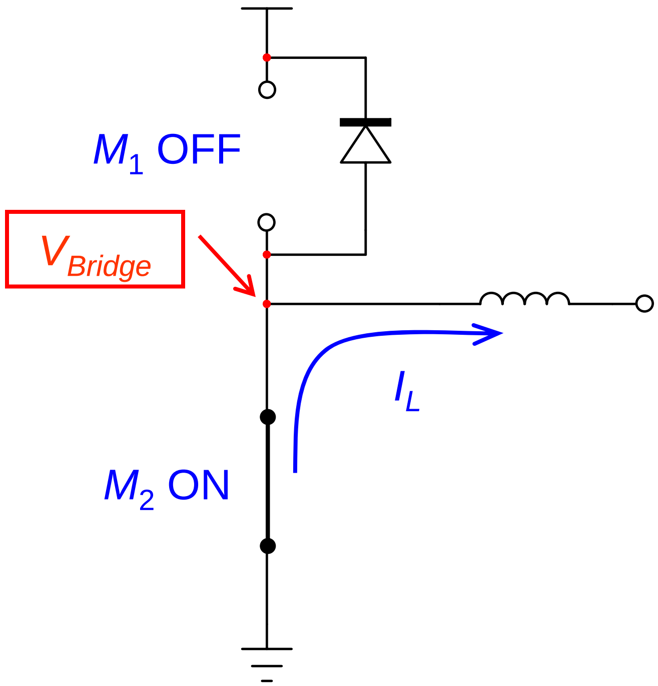
Step 2:

M_1关闭 OFF

M_2关闭 OFF

理论：降压转换器工作
Theory: Buck Converter Operation

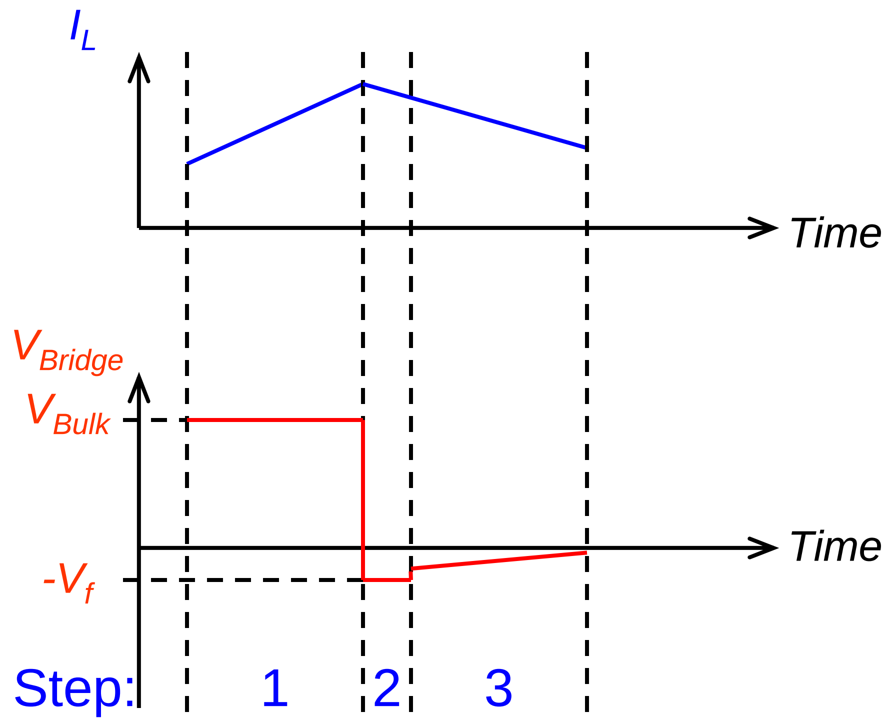
- 降压转换器第三阶 3rd step of the buck converter:



Step 3:

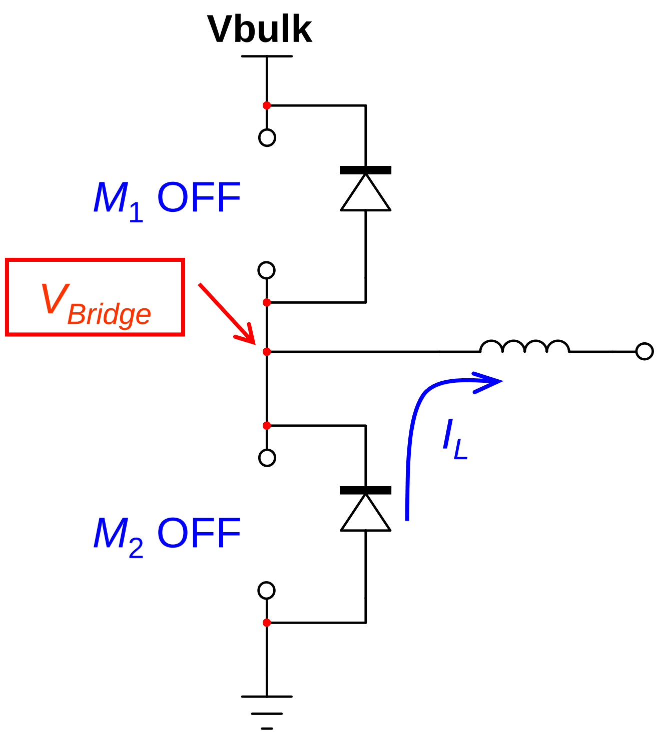
M_1关闭 OFF

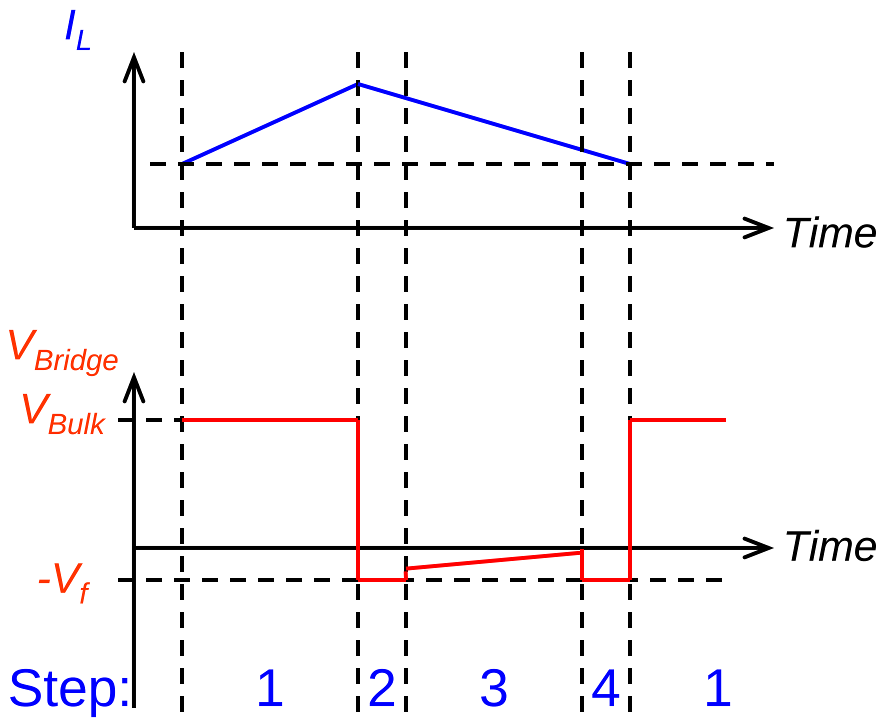
M_2导通 ON



理论：降压转换器工作
Theory: Buck Converter Operation

- 降压转换器工作第四阶 4th step of the buck converter:





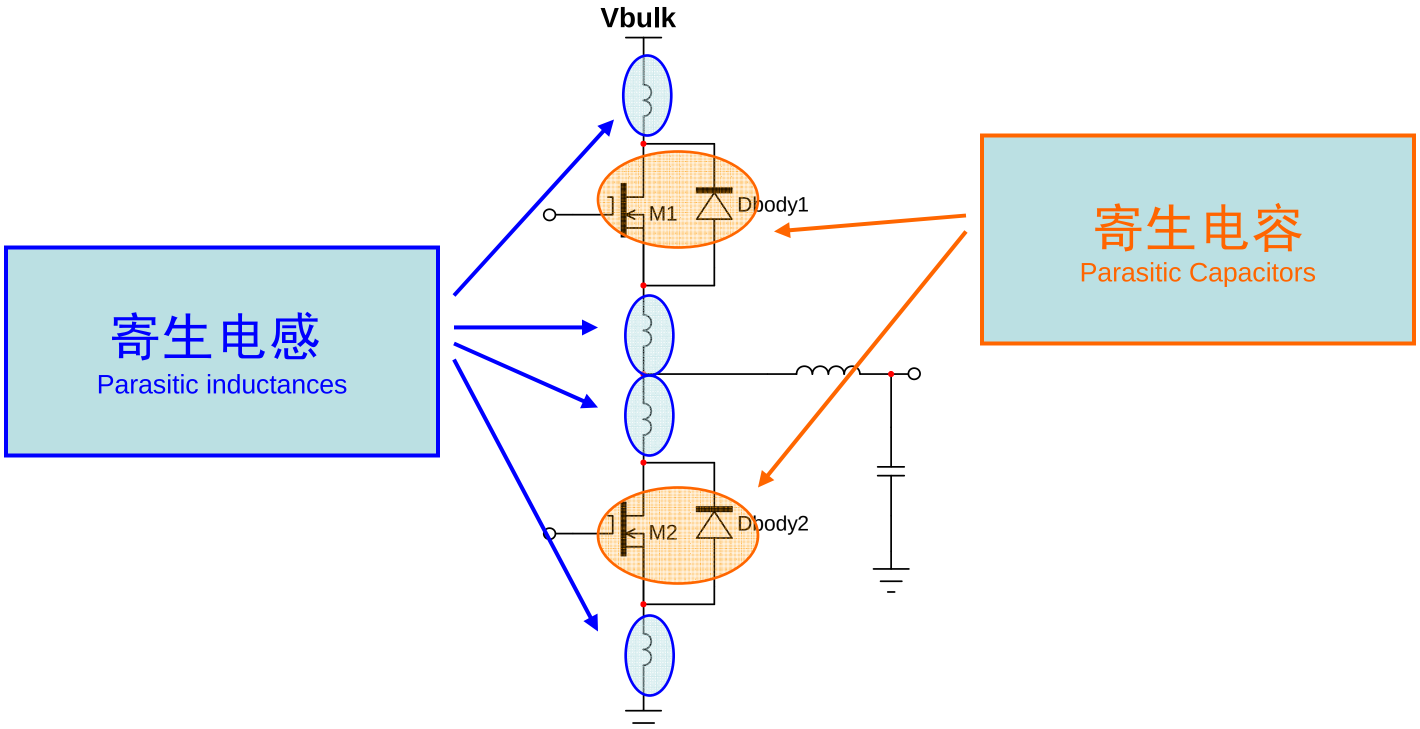
Step 4:

M_1关闭 OFF

M_2关闭 OFF

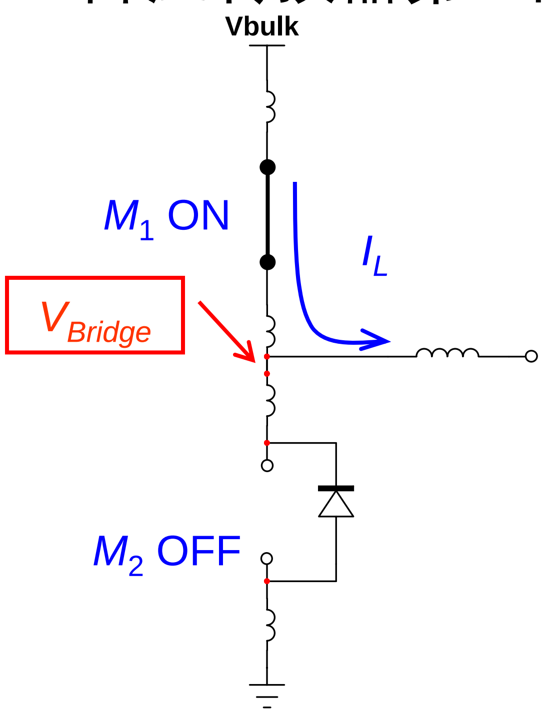
实际：降压转换器工作
Bench: Buck Converter Operation

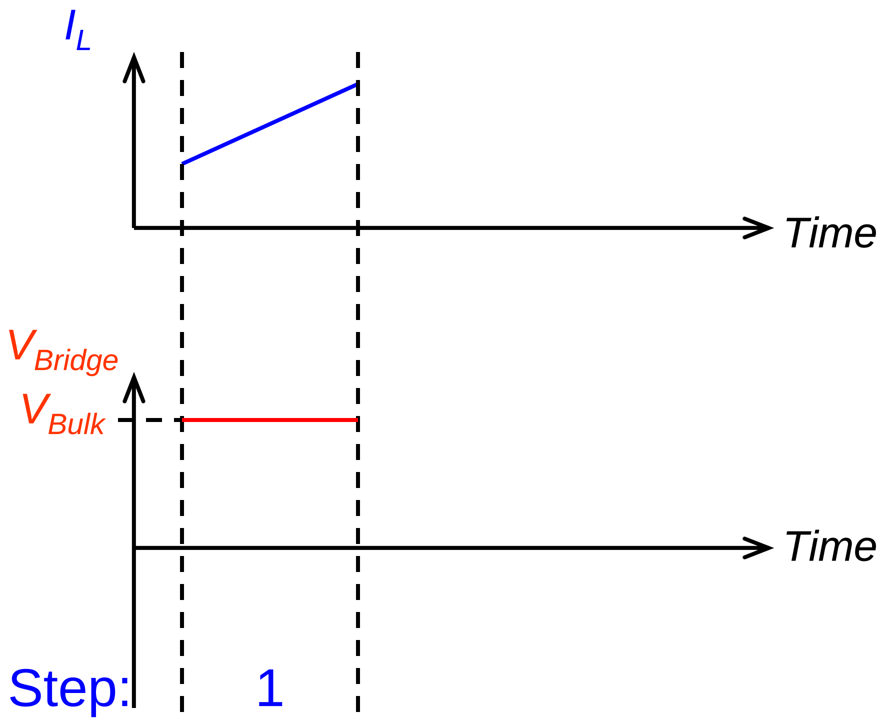
- 寄生参数随处可见 Anywhere but in a ppt file there are parasitic elements:
  - 真正的降压转换器 True buck converter:



实际：降压转换器工作
Bench: Buck Converter Operation

- 降压转换器第一阶 1st step of the buck converter:





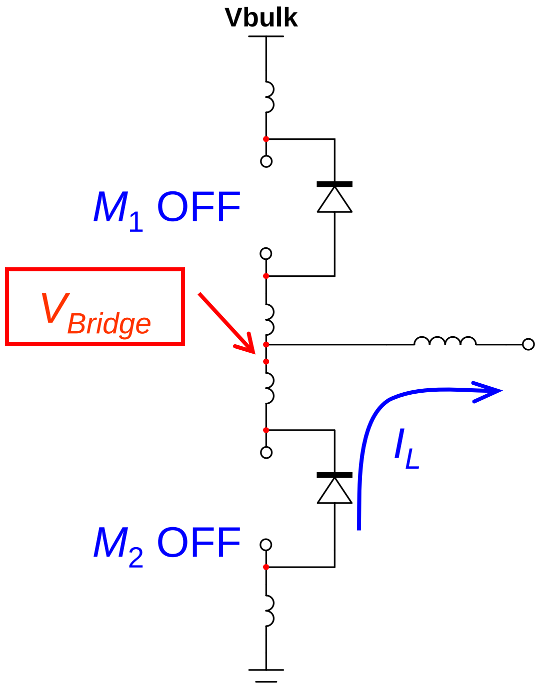
Step 1:

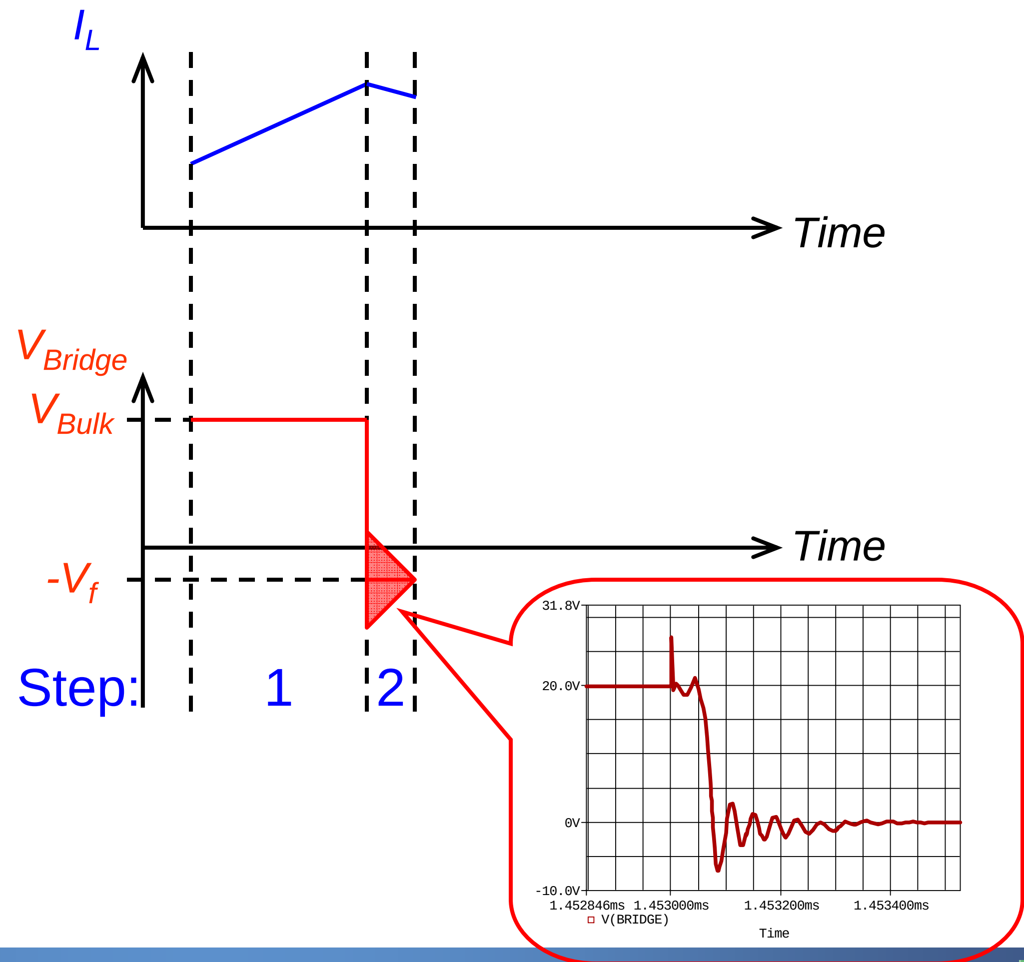
M_1导通 ON

M_2关闭 OFF

实际：降压转换器工作
Bench: Buck Converter Operation

- 降压转换器第二阶 2nd step of the buck converter:





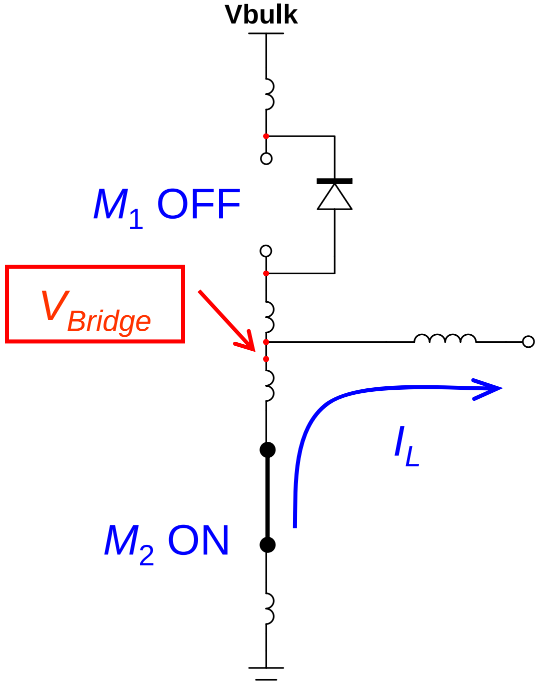
Step 2:

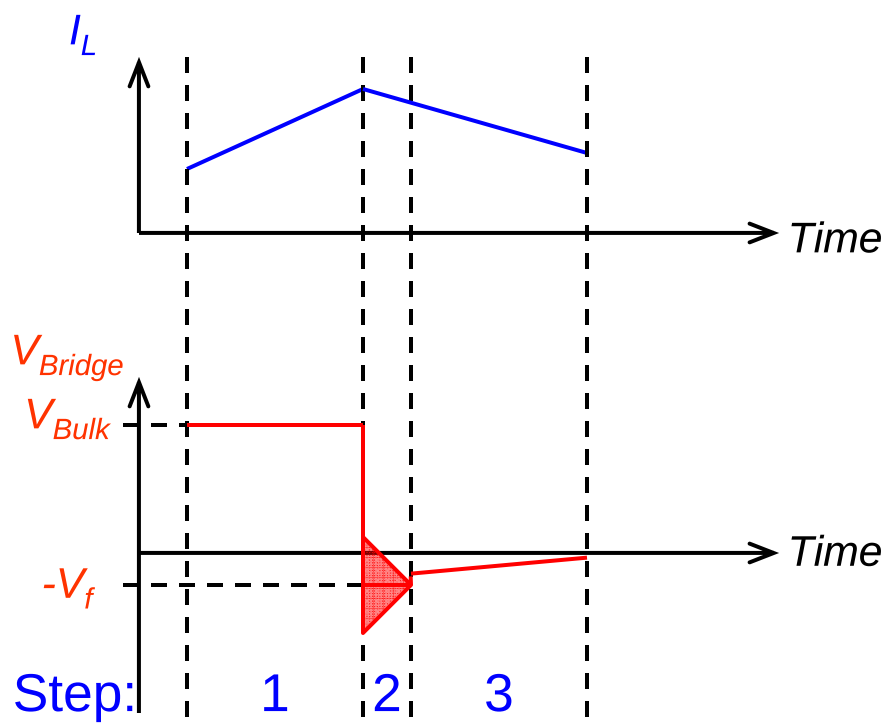
M_1关闭 OFF

M_2关闭 OFF

实际：降压转换器工作
Bench: Buck Converter Operation

- 降压转换器第三阶 3rd step of the buck converter:





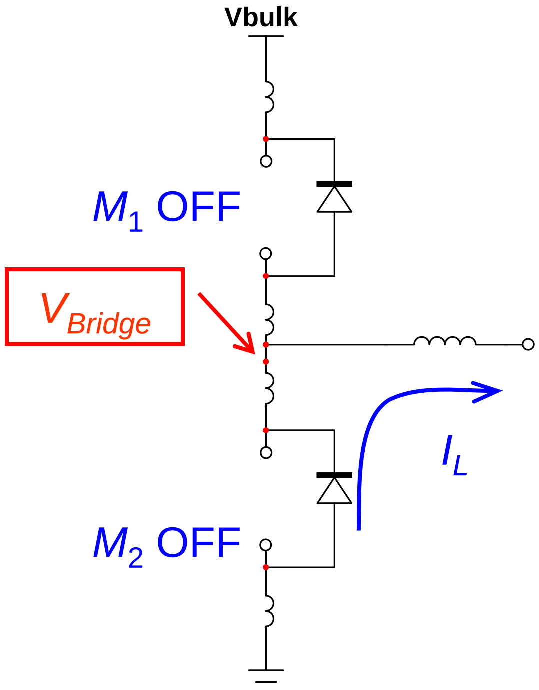
Step 3:

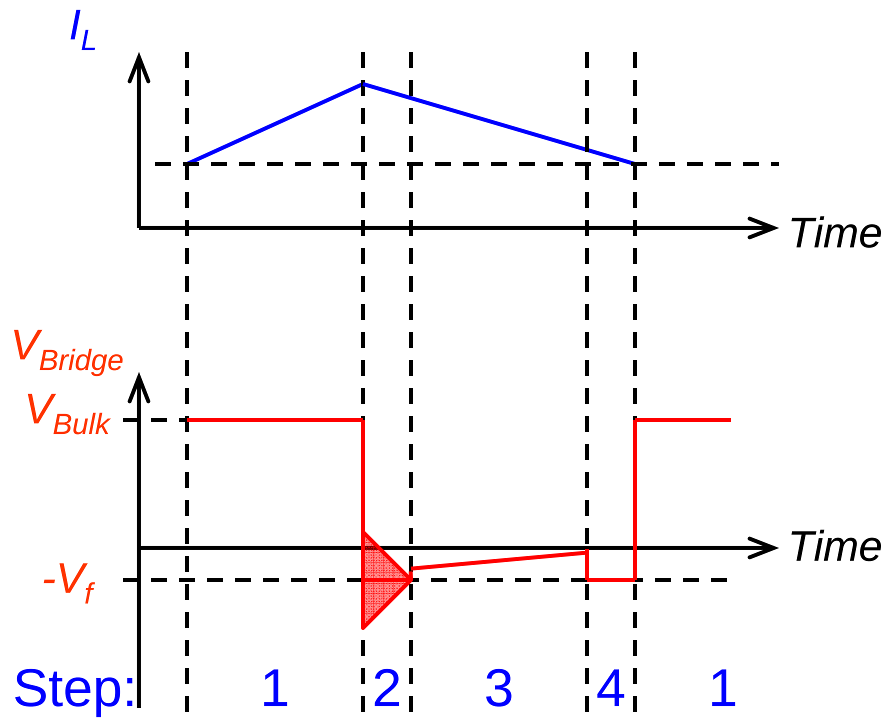
M_1关闭 OFF

M_2导通 ON

实际：降压转换器工作
Bench: Buck Converter Operation

- 降压转换器第四阶 4th step of the buck converter:





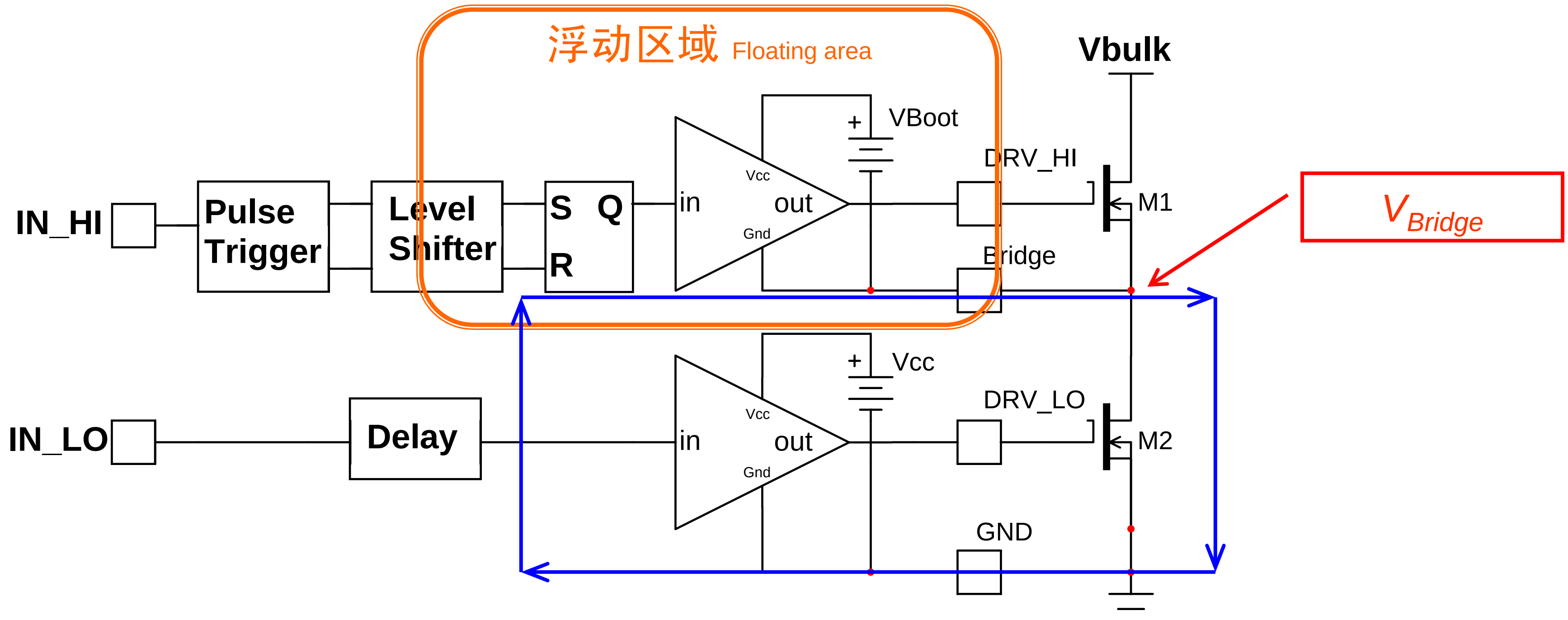
Step 4:

M_1关闭 OFF

M_2关闭 OFF

实际：降压转换器工作
Bench: Buck Converter Operation

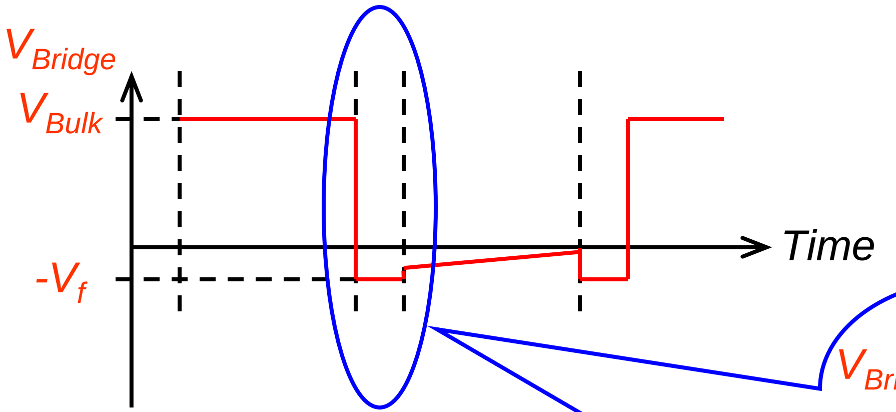
- 桥引脚上的负电压将会在驱动器IC内部产生负电流 Negative voltage on bridge pin will create negative current injection inside the IC driver.

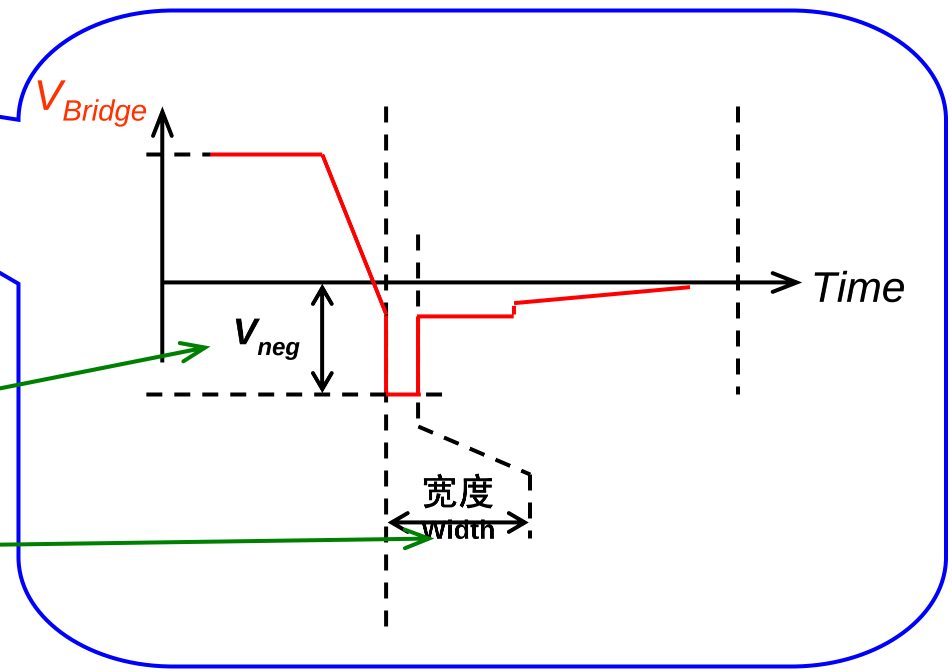


$V_{Bridge} < 0$ V时的泄漏通道 Leaky path when $V_{Bridge} < 0$ V

这泄漏通道可能在驱动器IC内部造成一些麻烦
This leakage path could create some trouble inside the driver IC.

如何理解负电压？
How to Characterize the Negative Voltage?





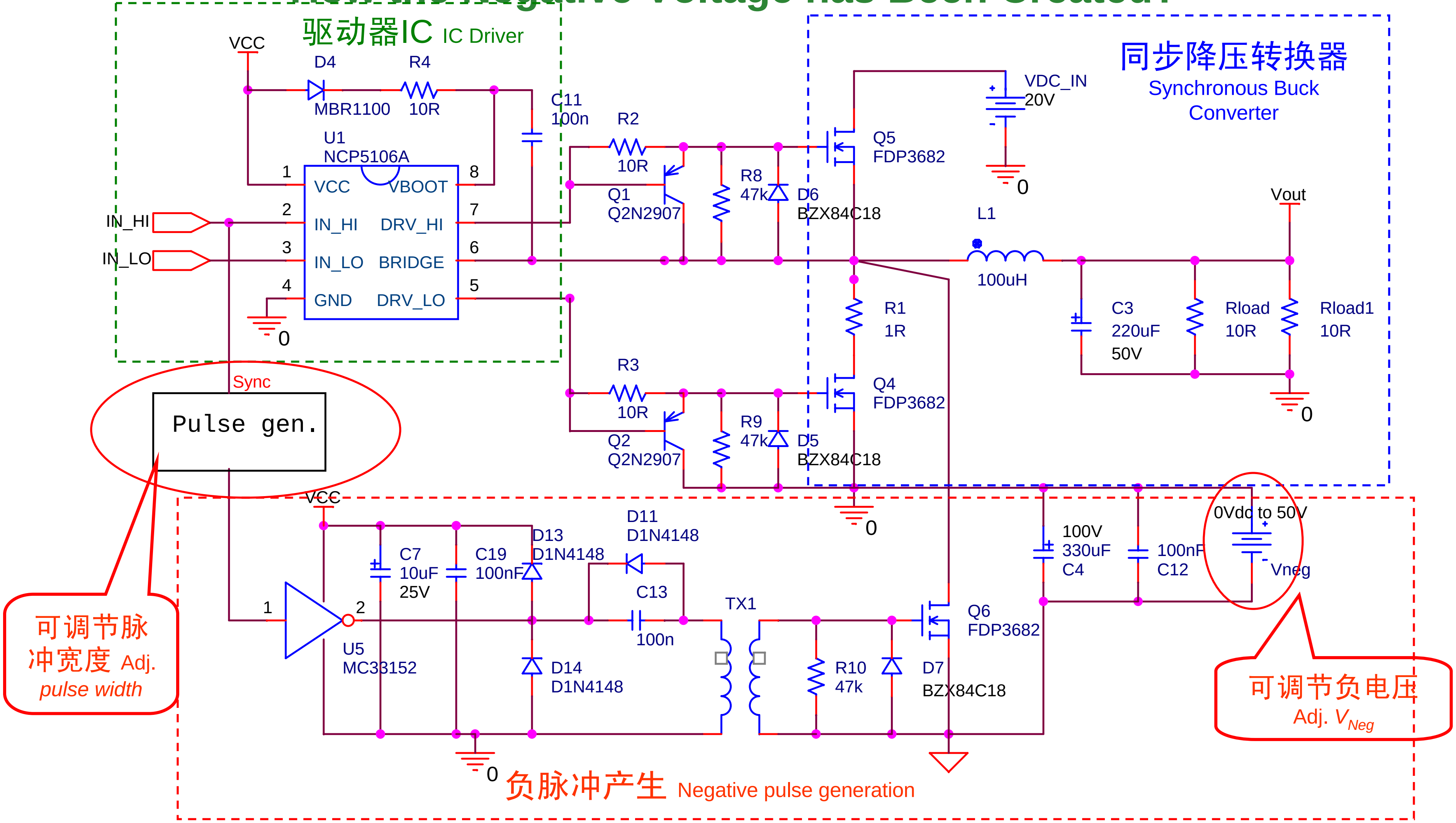
原理 Principle:

- 桥引脚上增加负脉冲Negative pulse is added on bridge pin:
  - 带可调节负电压 With adjustable Negative voltage
  - 及可调节宽度 And adjustable Width

负电压在每个脉冲宽度增大，直至驱动器IC失效 At each pulse width the neg. voltage is increased until the driver IC fails.

如何产生负电压？

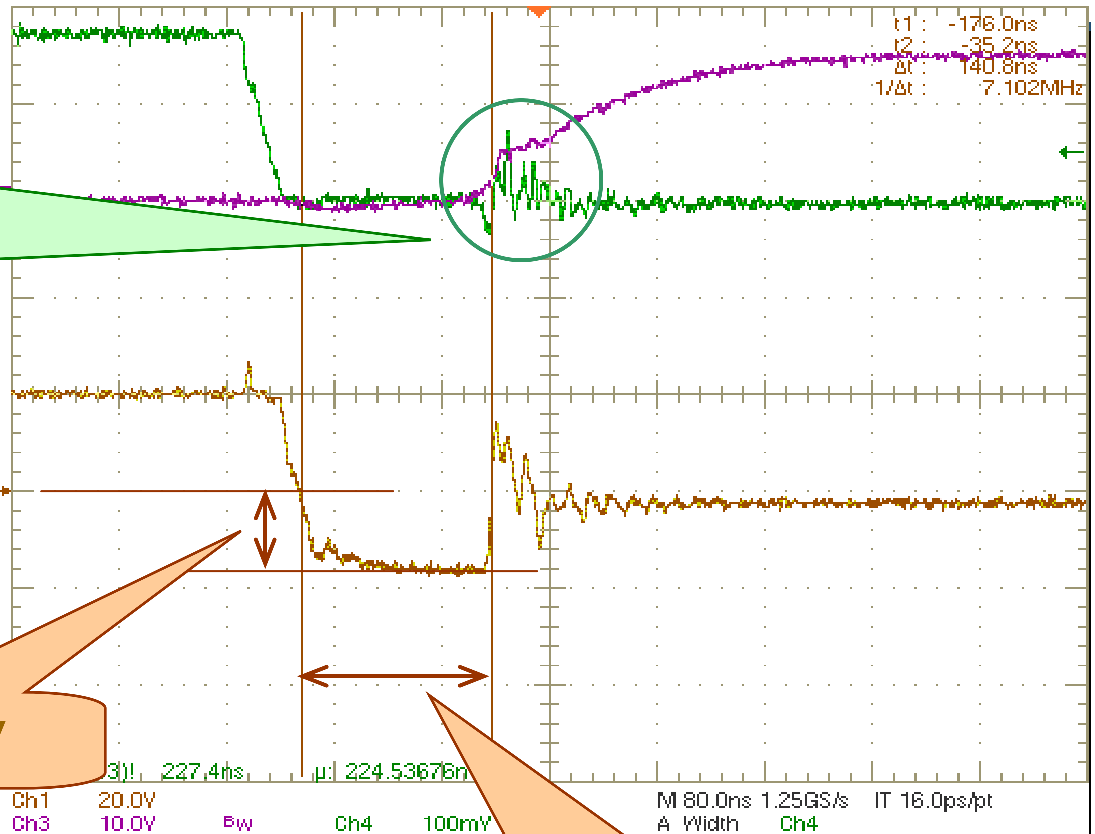
How the Negative Voltage has Been Created?



负电压测量示例

Example of Negative Voltage Measurement

桥引脚释放时，它在高端驱动器上产生一些噪声 When the bridge pin is released, it generates some noise on the hi- side driver.



VG_LO

(10 V/div)

VG_HI

(10 V/div)

桥电压引脚
Vbridge pin

(20 V/div)

V_{neg} = -18 V

宽度 Width = 150 ns

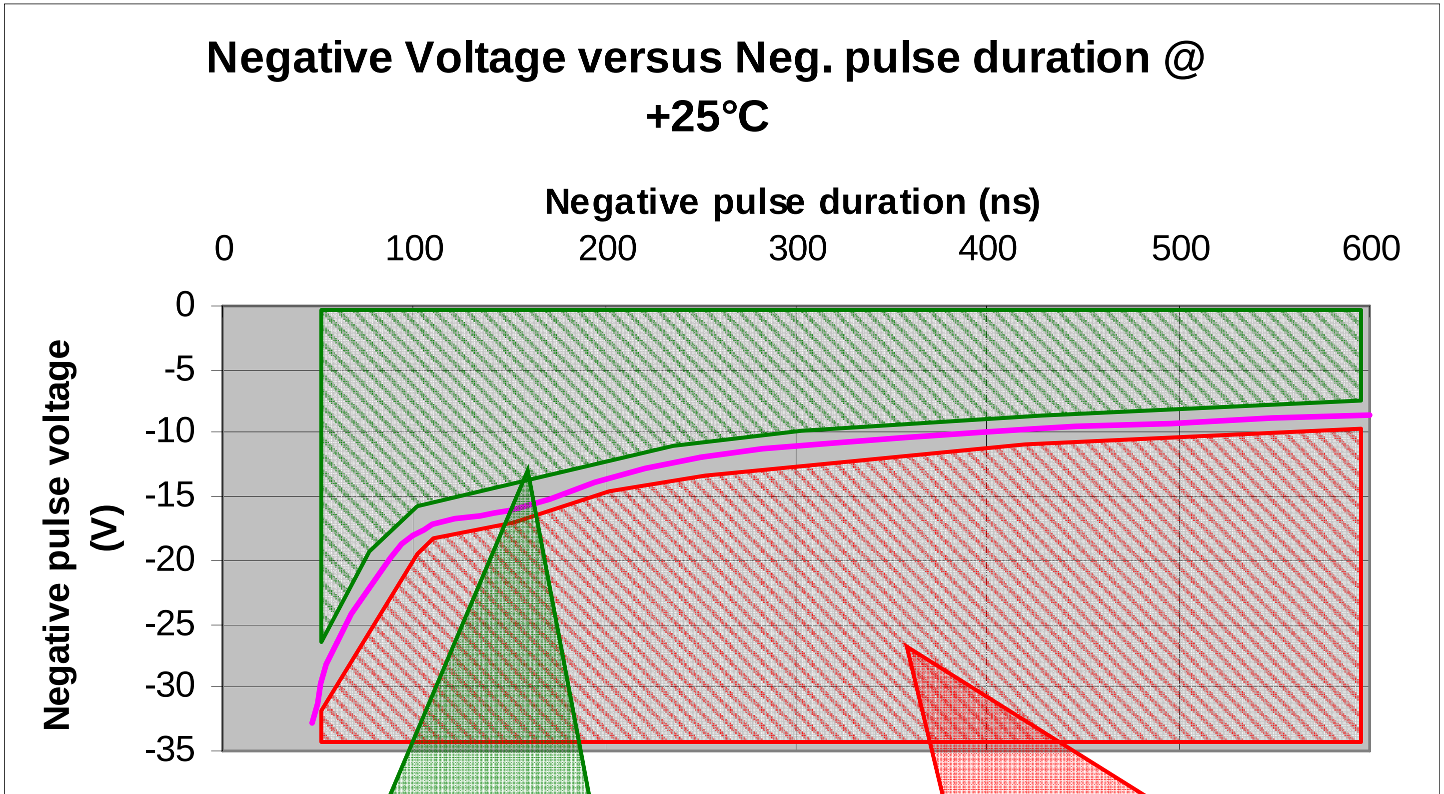
时间 Time

(80 ns/div)

注：桥引脚电压接近零时施加负电压

Note: Negative voltage pulse is applied when the bridge pin voltage is reaching zero.

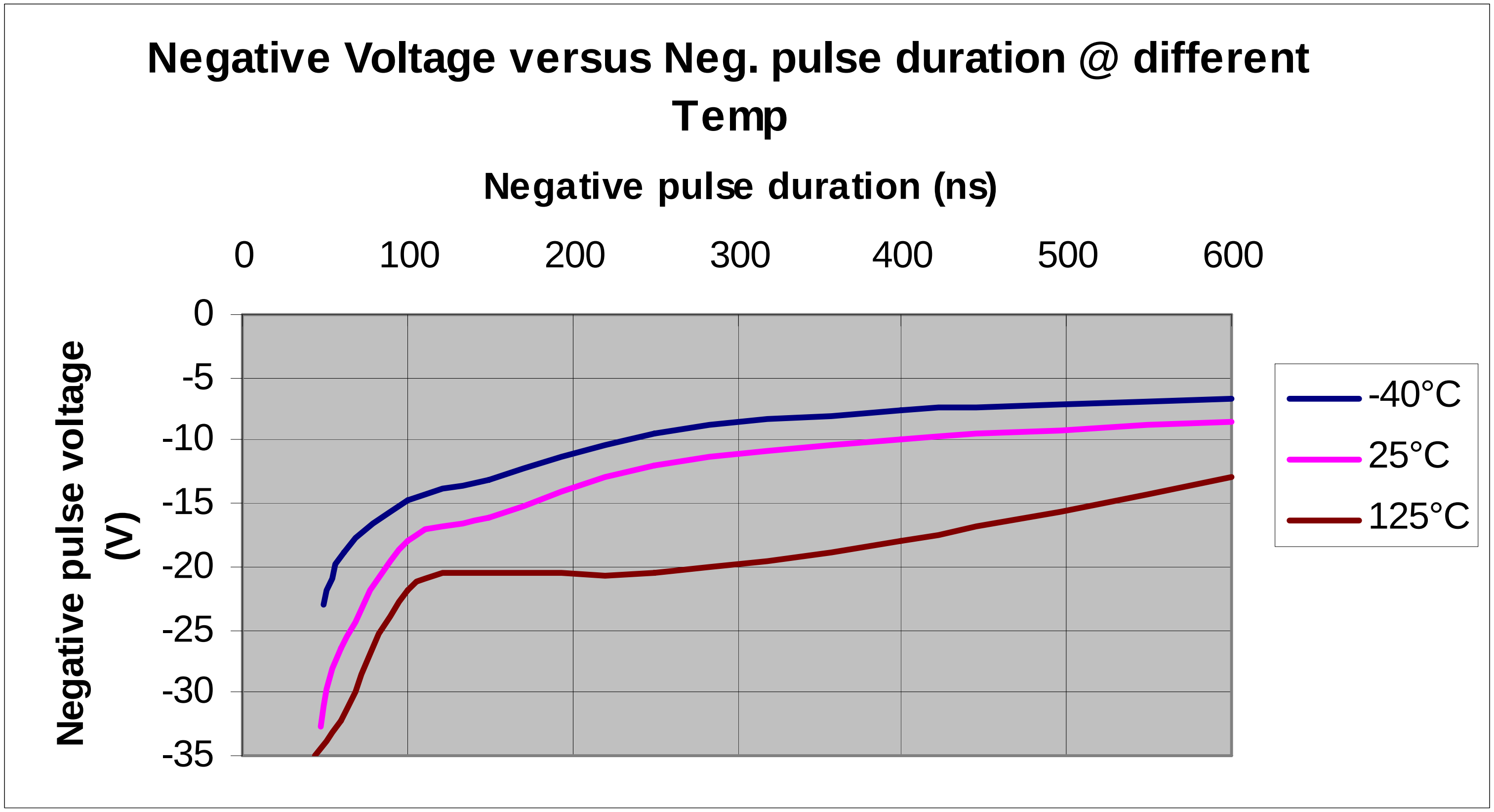
负电压特征表述
Negative Voltage Characterization



如果负脉冲在这个区域内，驱动器将正常工作 If the negative pulse is inside this area, the driver will work properly.

如果负脉冲在这个区域内，驱动器将不会正常工作或者可能损坏 If the negative pulse is inside this area, the driver will not work properly or can be damaged.

负电压温度特征表述
Negative Voltage Characterization in Temperature



- 注：各颗驱动器IC的数据表中将提供这些特征表述

Note: These characterizations will be available in each IC driver datasheet

驱动器IC评测 Driver IC Remarks

- 安森美半导体在完整温度范围内(即-40℃< T_j < +125℃)去定义电气参数。参见电气参数表或特征曲线。 ON Semiconductor defines electrical parameters on overall temperature range (here -40 ° C < T_j < +125 ° C). See electrical table & characterization curves.

- 很多竞争对手仅在特定环境温度下(T_{amb} = +25 ℃)去定义电气参数。并不总是提供温度特征描绘 Competitors define the electrical parameters only at T_{amb} = +25 ° C. Temp characterization is not always available

  ➔ 扩展温度范围中最低及最高温度分别是多少？ what about min & max over extended temperature range?

- 很多竞争对手从特征曲线中析取的电气参数值很可能未顾及工艺变化问题 The competitors values extracted from the curves probably do not take into account the lot to lot process variations

  ➔ 变化范围可能较大 the range variation is probably wider.

安森美半导体驱动器IC相互参照

ON Semiconductor IC Driver Cross Reference

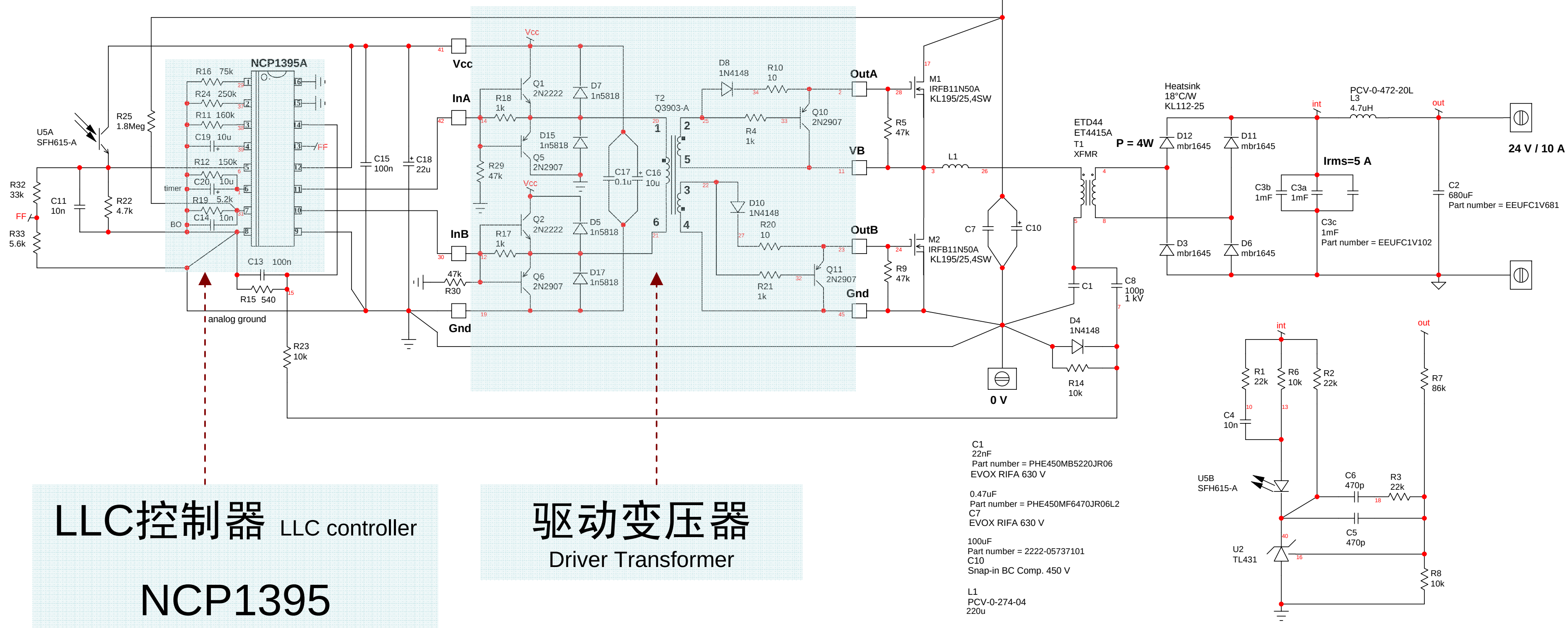
	Drive trise / tfall typ. (C_L=1 nF)	Propag. Delay typ. t_{ON} / t_{OFF}	Matching Delay Typ / Max	Cross Conduction Protection	Pin-Out Compati-bility	Remarks
NCP5181	40 ns / 20 ns	100 ns / 100 ns	20 ns / 35 ns	-	IR2181 – IRS2181	•3.3 V CMOS/TTL inputs
NCP5106A	85 ns / 35 ns	100 ns / 100 ns	20 ns / 35 ns	-	IR2106 – IRS2106, FAN7382	•3.3 V CMOS/TTL inputs
NCP5106B	85 ns / 35 ns	100 ns / 100 ns	20 ns / 35 ns	✓	IR2106 – IRS2106, FAN7382	•3.3 V CMOS/TTL inputs •Internal fixed dead time 100 ns
NCP5304	85 ns / 35 ns	100 ns / 100 ns	20 ns / 35 ns	✓	IR2304 - IRS2304, L6388/84 FAN7380	•3.3 V CMOS/TTL inputs •Internal fixed dead time 100 ns
NCP5111	85 ns / 35 ns	750 ns / 100 ns	30 ns / 60 ns	**NA**	IR2111 – IRS2111,	•3.3 V CMOS/TTL input •Internal fixed dead time 650 ns •One pin for creepage
NCP5104	85 ns / 35 ns	620 ns / 100 ns	10 ns /45 ns	**NA**	IR2104 – IRS2104	•3.3 V CMOS/TTL input •Internal fixed dead time 520 ns

议程 Agenda

- 使用半桥配置的拓扑结构 Topologies using a half-bridge configuration
- 软开关与硬开关的区别 The difference between soft and hard-switching
- 门驱动变压器 The gate-drive transformer
- 全硅方案 The all-silicon-solution
- 比较 Comparison
- 总结 Summary

采用驱动器变压器的LLC半桥电路图

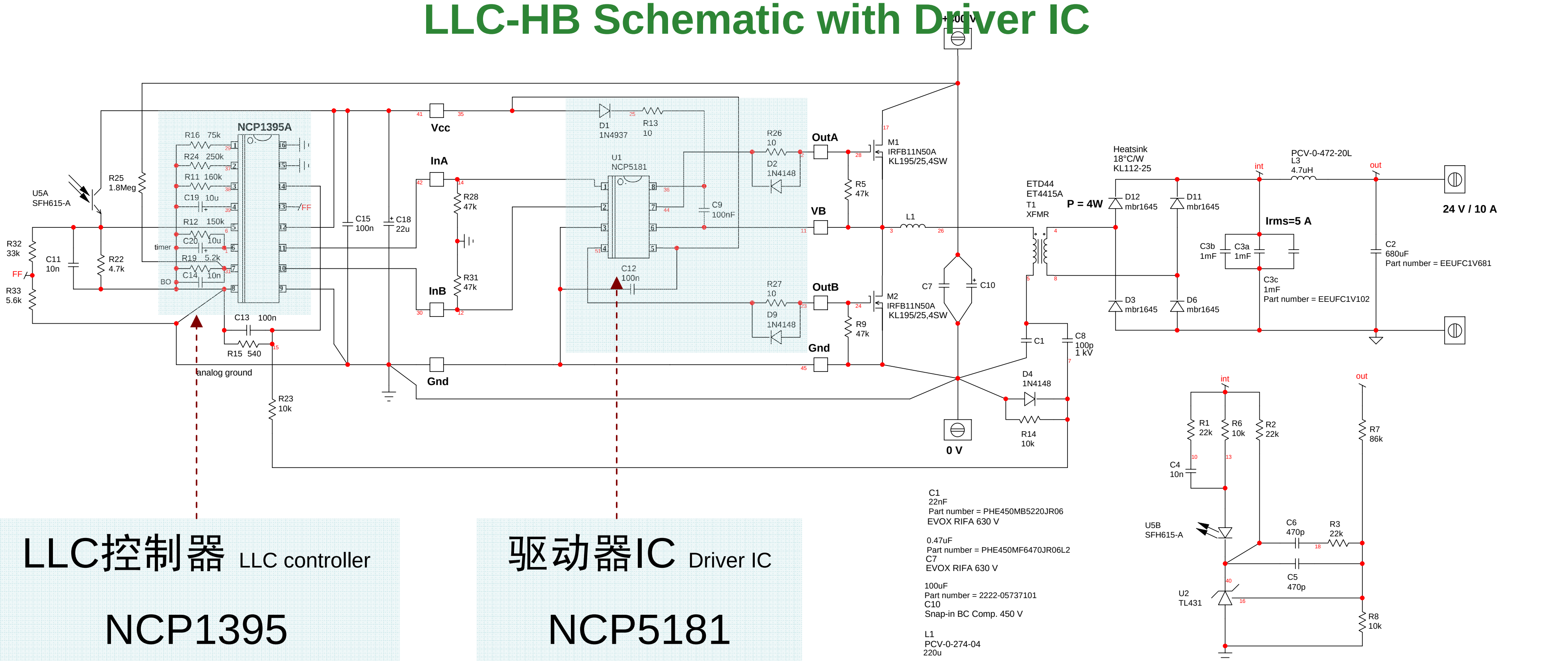
LLC-HB Schematic with Driver Transformer



- 规格为24 V @ 10 A的LLC半桥 LLC-HB with 24 V @ 10 A
- NCP1395, 带双DRV输出的LLC控制器 the LLC controller with dual DRV outputs.
- 变压器驱动LLC转换器的MOSFET Transformer drivers the MOSFETs of LLC converter.

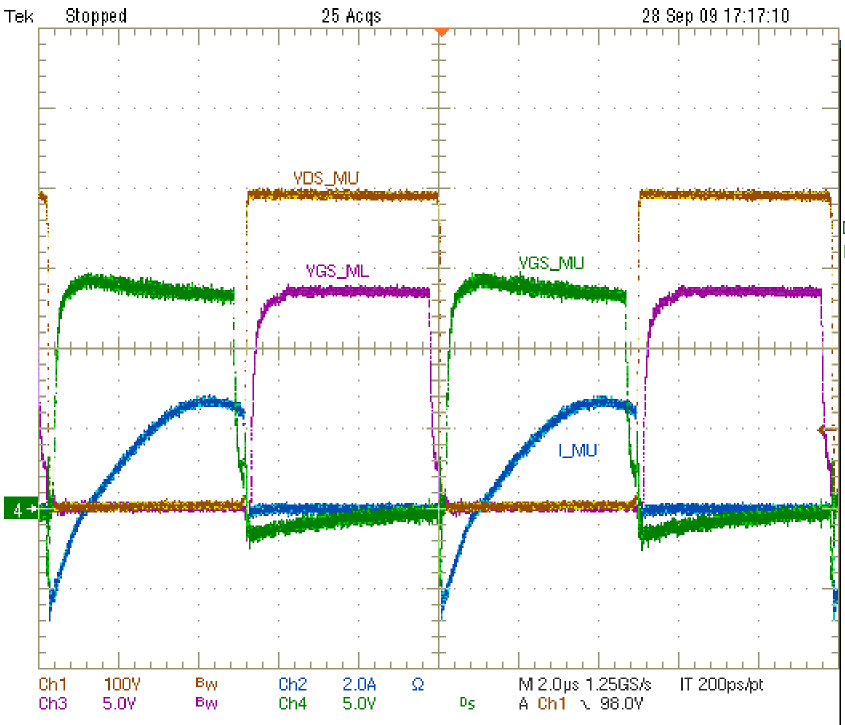
采用驱动器IC的LLC半桥电路图

LLC-HB Schematic with Driver IC

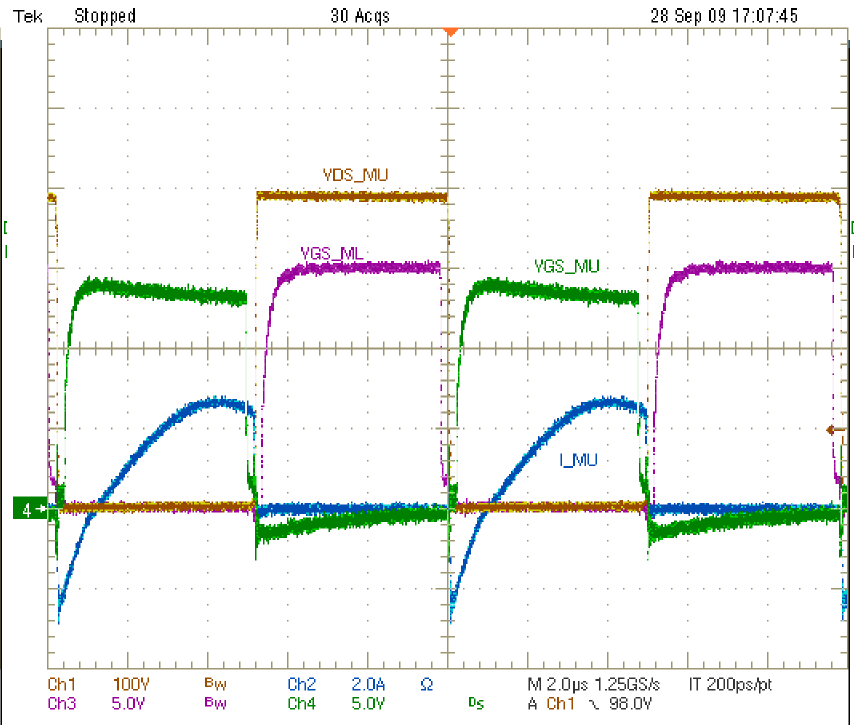


- 规格为24 V @ 10 A的LLC半桥 LLC-HB with 24 V @ 10 A
- NCP1395, 带双DRV输出的LLC控制器 the LLC controller with dual DRV outputs.
- NCP5181, 驱动器IC驱动LLC转换器的MOSFET driver IC drives the MOSFETs of LLC converter.

V_{GS}波形 V_{GS} Waveform



驱动变压器 Driver transformer



驱动器IC Driver IC (NCP5181)

2 μs / div

V_{GS_ML} (5 V/div)

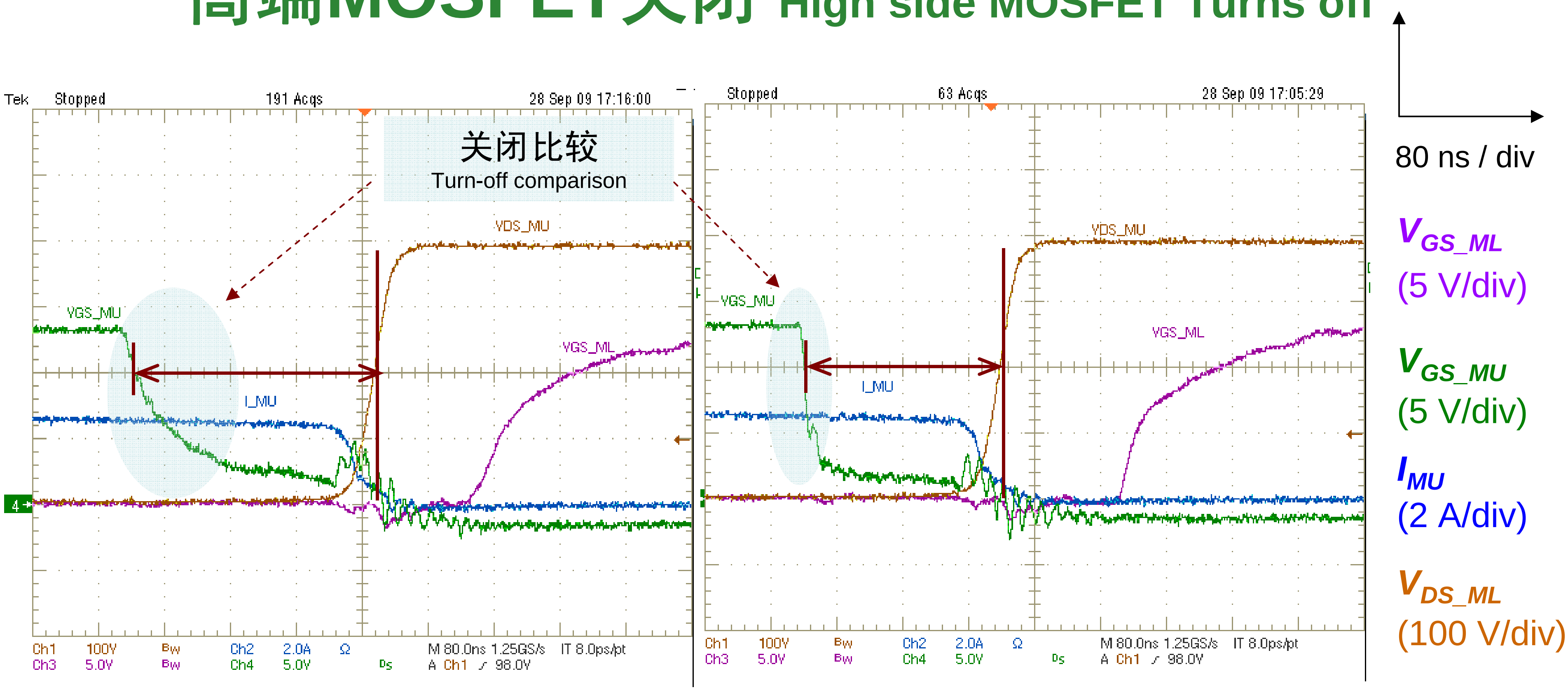
V_{GS_MU} (5 V/div)

I_{MU} (2 A/div)

V_{DS_ML} (100 V/div)

- 波形看上去类似 The waveforms seem similar.

高端MOSFET关闭 High side MOSFET Turns off

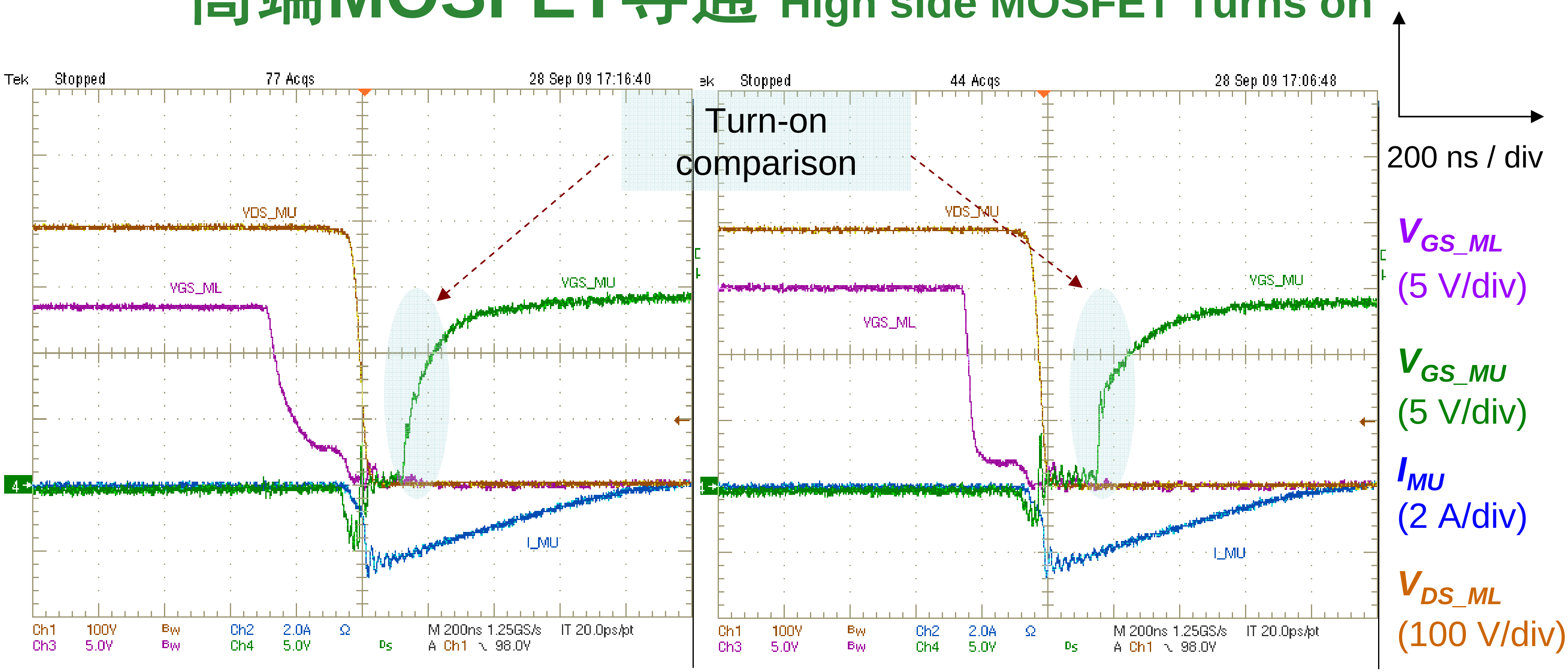


驱动变压器 Driver transformer

驱动器IC Driver IC (NCP5181)

- 驱动器IC更有力地关闭MOSFET The driver IC turns off the MOSFETs more vigorously.
- 驱动器IC关闭MOSFET时快70 ns，降低开关损耗 IC turn-off is 70 ns faster, lowering the switching losses

高端MOSFET导通 High side MOSFET Turns on



驱动变压器 Driver transformer   驱动器IC Driver IC (NCP5181)

- 驱动器IC在高端与低端MOSFET之间保持安全及足够的死区时间 The driver IC keeps safe and enough dead time between high and low side MOSFETs.

能效比较
The Efficiency Comparison

	输入功率 Input power (W)	输出功率 Output power (W)	输出电压 *Vout* (V)	输出电流 *Iout* (A)	能效 η
驱动器IC Driver IC	128.33	119.72	23.96	5.00	93.29%
	257.2	235.46	23.57	9.99	91.55%
驱动变压器 Driver Transformer	128.34	119.72	23.96	5.00	93.29%
	258.5	236.46	23.67	9.99	91.48%

- IC驱动器与变压器方案的能效没有显著区别 There is no efficiency difference between the IC driver and transformer solutions.

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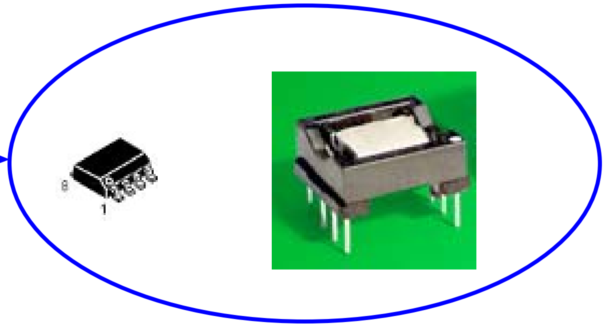
总结：变压器还是IC？
Summary: Transformer or IC?

- 如果精心设计，两种方案都可以 Both solutions work if well-trimmed.
- 我们建议采用驱动器IC的理由 We recommend the IC solution because:
  - 我们不卖变压器 We don't sell the transformer.
  - 变压器需要手动插入 Manual insertion for the transformer.
  - 简化布线 Ease the layout
  - 简化设计 Ease the design
  - 免除诸多变压器问题，如 Free of transformer problems, e.g.:
    - 隔离被破坏 isolation is destroyed,
    - 磁通走散 flux walking away,
    - 关闭后未预料到的振铃 unexpected ringing after turn off,
    - 低高度电源中变压器的高度是个问题 Height of the transformer in low profile PSU



For More Information

- View the extensive portfolio of power management products from ON Semiconductor at www.onsemi.com
- View reference designs, design notes, and other material supporting the design of highly efficient power supplies at www.onsemi.com/powersupplies