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APPLICATION NOTE
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有源米勒钳位技术 Active Miller Clamp Technology

AN-5073/D

在IGBT的驱动设计中，特别是对中小功率的IGBT驱动，工程师们更倾向于简单的板级布局和简单的解决方案，于是去掉驱动负电源成了很有吸引力的解决方案，但是同时这个方案也带来了一定的问题。

如图1所示的驱动，上桥和下桥的IGBT都使用单电源供电。如图2黑色波形所示，正常情况下，两个IGBT不会同时导通，栅极电压不会同时为高。但是由于dv/dt的存在，IGBT关闭之后栅极会出现毛刺电压，如图2红色波形所示。如图3所示，让我们以Q2为例做更详细的说明。Q2关闭之后，Q1开启，Q2的CE电压将会升高，由于dv/dt很高，电流通过Q2的Cgc流过限流电阻Rg和驱动的输出阻抗，这个电流我们称为米勒电流。米勒电流的大小可以通过如下公式(1)计算。

$$I_{gc} = C_{gc} \times \frac{dv}{dt} \quad \text{(eq. 1)}$$

如果对速度的要求很高，dv/dt也会随之增大，那么米勒电流造成VGE2就会升高到Q2的阈值电压，造成Q1和Q2同时导通，这对于Q1和Q2都是非常危险的，当然也会造成功耗的浪费。

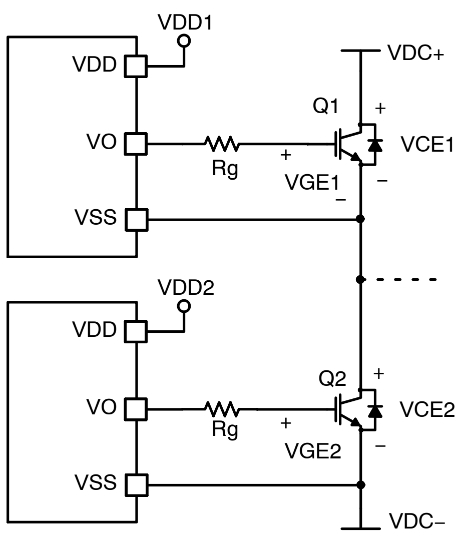

图1. 一个桥臂去掉负电源的应用电路

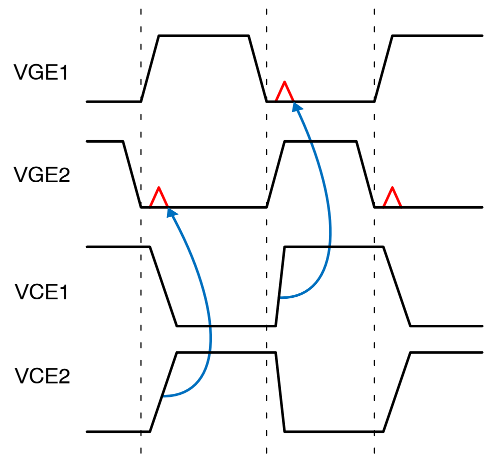

图2. VGE和VCE波形图

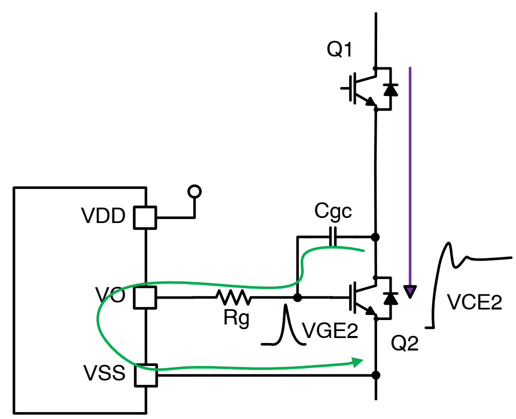

图3. Q2米勒电流和串通电流的产生示意图

为了避免这个问题，IGBT关闭之后必须能够有效的控制IGBT的栅极电压，从而降低米勒电流的影响。下边是通用的解决方案，如图4、图5所示，其中绿色电流代表关闭电流，红色电流代表开启电流。图4中，IGBT开启和关闭使用了不同的电阻，这样保证在IGBT关闭之后，米勒电流流过的电阻值更小，就可以降低栅极上的电压毛刺。但是关闭阻抗又不能太小，太小会造成IGBT关闭过快，造成过高的di/dt。图5中所示的方法使用了PNP，在IGBT关闭的过程中，PNP被打开，米勒电流更多的被PNP旁路掉。

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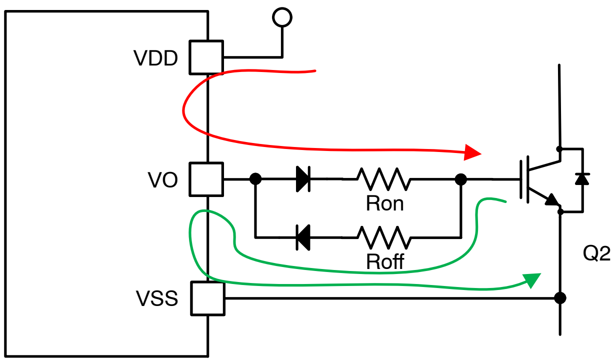

图4. 降低米勒电流的影响方法, 降低IGBT关闭阻抗

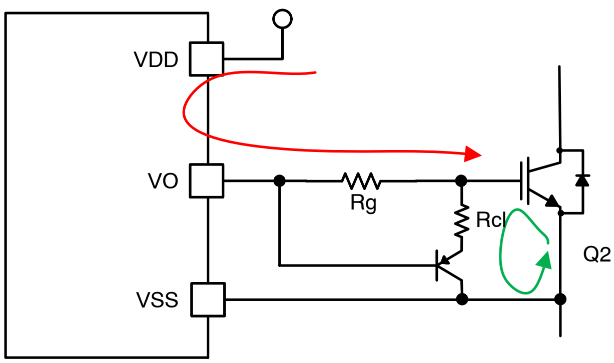

图5. 降低米勒电流的影响方法, 用PNP做旁路电流

安森美(**onsemi**)结合市场和应用对高压环境的需求推出了具有米勒钳位功能的智能光耦驱动产品，如FOD8318和FOD8332*。如图6所示，这些产品集成了MOSFET开关来旁路米勒电流。在IGBT关闭的过程中，当栅极电压下降到2 V的时候，电压Vgcl变高，启动米勒钳位开关，钳位电压是2.5 V的时候钳位电流典型值是1.1 A，这样IGBT的栅极电压被很好的钳位在IGBT的开启电压以下。IGBT开启的时候，Vgcl变低，米勒钳位开关关闭，米勒钳位功能失效。所以，米勒钳位功能只在IGBT关闭的时候有效，而且不会影响IGBT的开启。

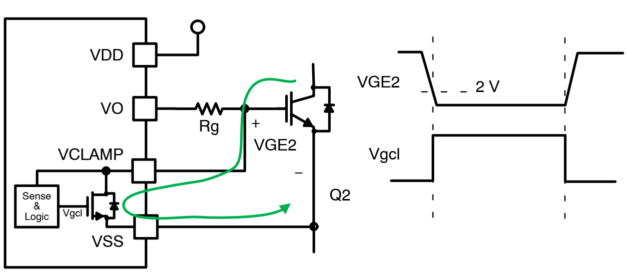

图6. 有源米勒钳位技术智能光耦驱动

IGBT允许的dv/dt和IGBT自身的开关特性有关，和驱动电路如驱动阻抗也有关系。如图7所示,用安森美的FOD8318驱动IGBT − FGH60N60SMD (600 V/60 A)做评价测试，驱动电阻为20欧姆，当dv/dt是2.3 kV/μs的时候，IGBT栅极上的电压会达到5.12 V。如图8所示，应用了有源米勒钳位技术之后，在同样的dv/dt和同样的测试条件下，IGBT栅极上的电压只有1.68 V。这说明米勒钳位技术能够有效的降低dv/dt造成的影响。

图7. 没有用米勒钳位技术VGE和VCE波形图

图8. 使用米勒钳位技术VGE和VCE波形图

如何知道安森美的产品是否适合驱动所用的IGBT呢？需要比较一下安森美产品中的ICLAMP参数和所用IGBT的米勒电流Igc。我们用Cres参数来等效IGBT的Cgc，从FGH60N60SMD规格书上，我们看到Cres是85 pF。

利用公式 (1)，$I_{gc} = C_{gc} \times \frac{dv}{dt}$

算出 Igc = 85 pF x 2.3 kV/μs = 0.20 A.

安森美的规格书中ICLAMP最小值是0.35 A，大于0.20 A，所以安森美的FOD8318是可以用于单电源驱动 IGBT，FGH60N60SMD的。

另外，我们观察到，毛刺电压达到阈值电压IGBT就会开启，所以我们可以用阈值电压VGE(th)max)来计算。

$$Igc < \frac{VGE(th)max}{Rg + Rdrv} = \frac{6\ V}{20 + 1} = 0.29\ A \qquad \text{(eq. 2)}$$

利用公式(2)计算出来Igc的最大值再和ICLAMP比较来判断也是一种简便的方法，特别适合不知道dv/dt的情况下的判断。如果所用的驱动电阻是10欧姆，利用公式(2)，Igc会增大到0.55 A，这种情况下，钳位电流至少会旁路掉0.35 A，多余的0.2 A会流过11欧姆，产生的VGE电压是2.2 V，也不会开启IGBT。当然ICLAMP也有限制，规格书中要求不能超过1.7 A，否则会损坏驱动芯片。

总结：由于有源米勒钳位技术的应用，安森美的智能光耦驱动产品FOD8318和FOD8332等，能够有效的帮助工程师去掉驱动的负电源，以减少板级布线的繁琐，同时提高了驱动的可靠性。更多的产品信息,请登录www.onsemi.cn了解。

Related Resources

FOD8318 − IGBT 驱动光电耦合器，2.5 A 输出电流，具有有源米勒钳位、检测和隔离故障感测功能。
FOD8332 − IGBT 驱动光电耦合器，2.5 A 输出电流，具有有源米勒钳位、检测和隔离故障感测功能。

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