

功率器件

开关波形的监测方法

对于开关电源和电机驱动电路等、通过功率元件观测开关位置的时候，一般使用示波器和电压探头。开关波形为方波，因而功率电路其中包含高功率的高频波。若探测波形的探头的使用方法不正确就没办法观测到准确的波形。本应用笔记对开关波形的正确监测方法予以说明。

开关位置

例如，即使开关电源电路的输出电压为正确的数值、也必须确认开关动作是否为误动作、开关波形是否超过元件的定格电压。由于开关波形为方波，其中包含的高次谐波成分频率可能达到数 GHz，重要的是由于功率电路中的功率很大，即使较小的寄生参数（特别是电感成分）的影响也可能产生较高的电压。

使用电压探头观测波形

理想情况下，开关位置的监测使用的是差动探头。由于价格太高，一般 300V 以下的低压电路多使用无源型电压探头。Figure 1 是使用电压探头来监测开关位置的照片。探头的尖端连接到开关位置，GND 侧与附属的鳄鱼夹接地引线相连接。Figure 2 是观测波形。上侧是开关波形，下侧是 DC/DC 转换器的输出波形。这里观测的是开关信号急速变化时的振铃现象。

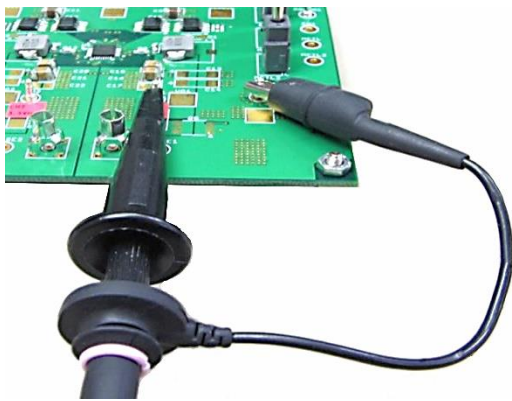


Figure 1. 电压探头监测开关位置，GND 侧与附属的鳄鱼夹的接地引线相连接

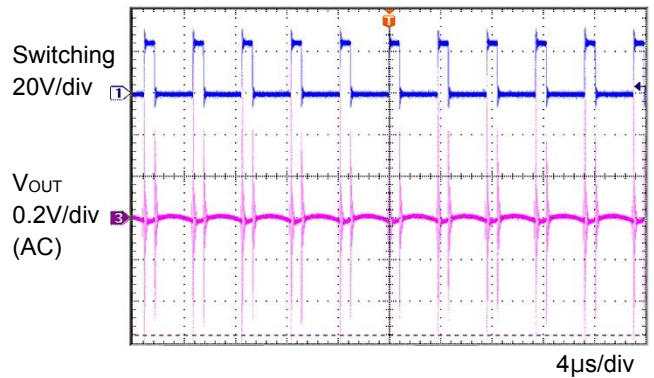


Figure 2. 鳄鱼夹的接地引线所连接的探头观测的波形

关于该振铃，探头的接地引线上有电感附加，与探头的输入电容发生串联谐振。因此，该方法无法观测到正确的波形。

探头的等价电路例如 Figure 3 所示。谐振式根据算式(1)求出。接地引线的长度为 160mm 时，估算每 1mm 的电感值 1nH，总电感值为 160nH。于是算式(1)的谐振频率约为 200MHz。

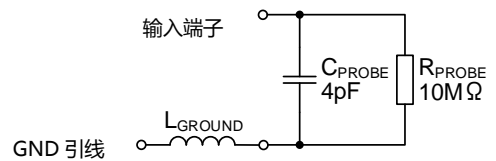


Figure 3. 探头的等价电路举例

$$f_r = \frac{1}{2\pi\sqrt{L_{GROUND} \times C_{PROBE}}} \text{ [Hz]} \quad (1)$$

为了得到准确的波形，需要防止谐振的影响，有必要减小接地引线的附加电感。而缩短接地引线的长度即可减小电感、提高谐振频率，这可以使谐振频率进入到机器的测定频带之外。

如 Figure 4、5 所示为短接地引线的例子。Figure 4 是 PCB 实装类型、Figure 5 是 PCB 接触类型。探头适配器的 GND 引线的长度缩短到了数 mm，使电感降到数 nH。

这些附件与电压探头是一同销售的。



Figure 4 探头尖端适配器
(Tektronix 社生产)



Figure 5. 接地弹簧
(Tektronix 社生产)



Figure 6. 使用探头尖端适配器来监测开关位置的状态

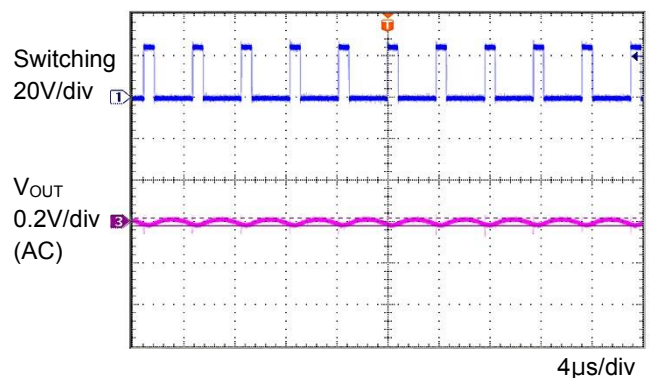


Figure 7. 使用探头尖端适配器所观测到的波形

Figure 6 所示的是使用探头适配器来监测开关位置的状态，其测定结果如 Figure 7 所示。与前面所述的与鳄鱼夹的接地引线相连接的探头所观测的波形 (Figure 2) 相比，可以看到探头造成的振铃基本没有发生，得到的是更接近于原始波形的波形。

以上手段仅适用于电路的动作电压较低的情况，在动作电压较高的情况下无法得到准确的波形。这种情况下请使用高压差动探头，或者光隔离型差动探头。

简易的探头尖端适配器

前面所述的探头尖端适配器的效果很显著，手头若没有，可以用简易的替代品来代替。下面是制作方法介绍。

1. 将引线电阻或 0.5mm 的镀锡线卷在探头的接地部位，作为适配器的接地支持部分 (Figure 8)。
2. 将引线电阻或 0.5mm 镀锡线卷在镊子的尖端，作为适配器的尖端支持部分 (Figure 9)。
3. Figure 10 为作成的适配器和所使用的探头。
4. 焊接在基板上上使用 (Figure 11)。



Figure 8. 制作适配器的接地支持部分



Figure 9. 制作适配器的尖端支持部分



Figure 10. 作成的简易探头尖端适配器

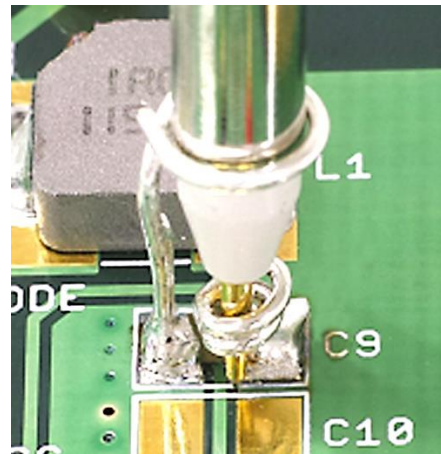


Figure 11. 实装在基板上的状态

仿真中的探头的影响

仿真结果有可能与实测波形不一致，其中一个重要原因是测定系统的不同。仿真的测定探头是理想探头，输入阻抗无限大。此外在实测时，监测点与测定机器相连接时会附加有各种寄生阻抗。前面所述的探头的接地引线也是其中之一，在仿真波形与实际不一致的时候，需要在仿真电路中追加测定设备的等价电路。

Figure 12 是使用 MOSFET 来仿真开关的电路图，Figure 13 是仿真结果。结果是可观测到基本没有振铃的波形。

接下来是设想用探头来监测，追加 Figure 3 的等价电路。Figure 14 是仿真的电路图，Figure 15 是仿真结果。接地引线的长度是 160mm，因此假定寄生电感值为 160nH。可看见波形中发生了较大的振铃，与原始波形差异较大。

以上为其中一个范例，可以明确测定系统中附加的等价电路对观测波形造成了影响。

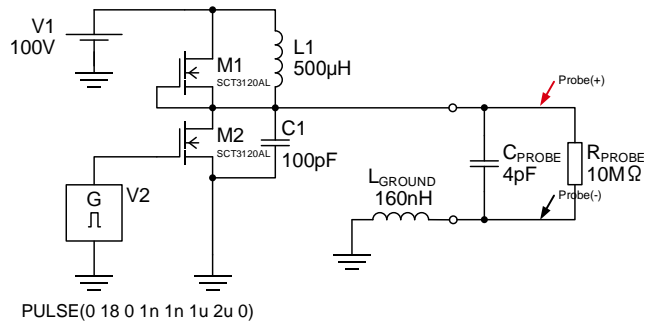


Figure 14. 附加了探头等价电路的仿真电路

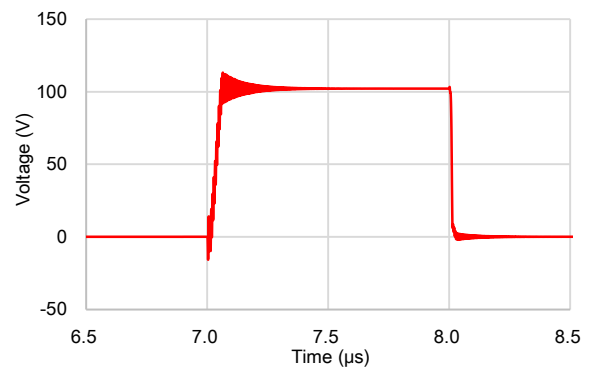


Figure15. Figure 13 的仿真结果波形

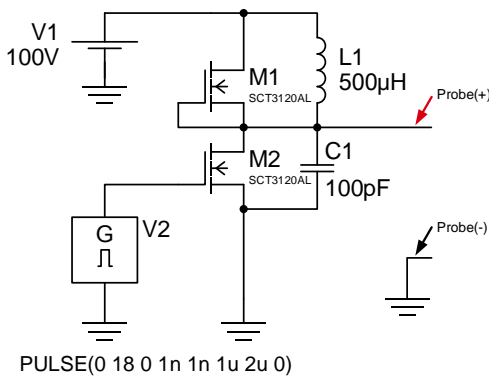


Figure 12. 使用 MOSFET 来仿真开关的电路

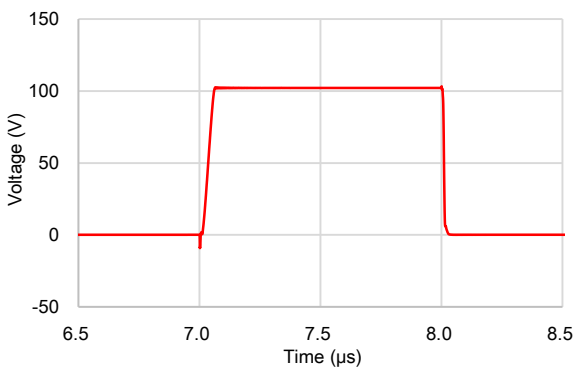


Figure 13. Figure 11 的仿真结果波形

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