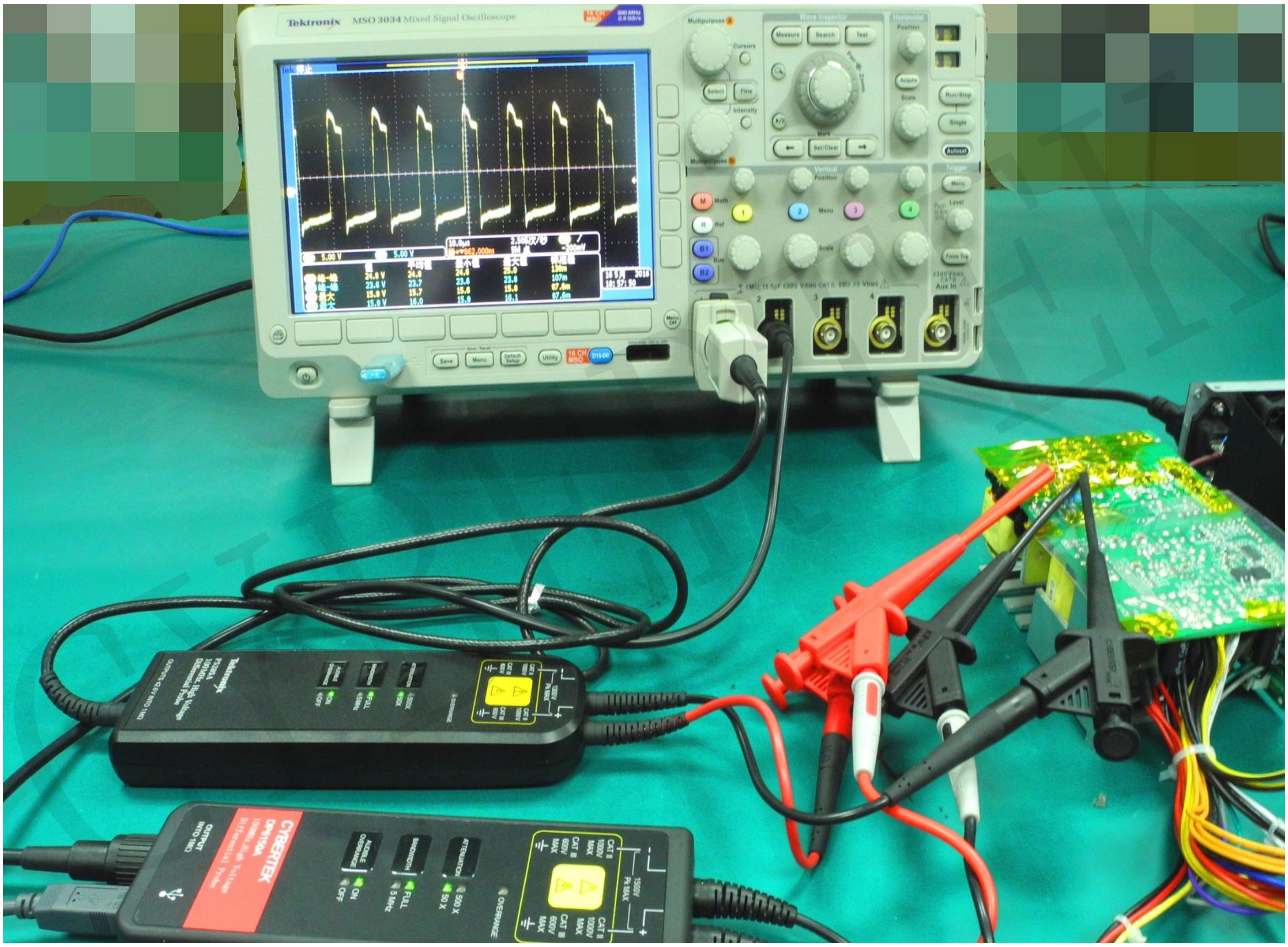
Explore the High Voltage Differential Probe CMRR Index

Shenzhen Zhiyong Electronics Co., Ltd



Summary

There're many types of oscilloscope probe, and the high voltage differential probe is one of those, widely used in the application of switch power supply. This article will mainly talk about what is the differential signal, the way to measure differential signal, the theory of high voltage differential probe and important index of it, and case analysis focusing on main index CMRR.

What is differential signal

Before talk about differential probe, let's talk about differential signal first. Differential signal is the signal referring each other rather than referring grounding. For example, figure 1 represents the voltage signal on the up and down switch MOSFET (Q1, Q2) of switch power supply half bridge. Figure 2 represents voltage signal of the multi-phase power supply system. All the signals above is essentially floating above the ground.

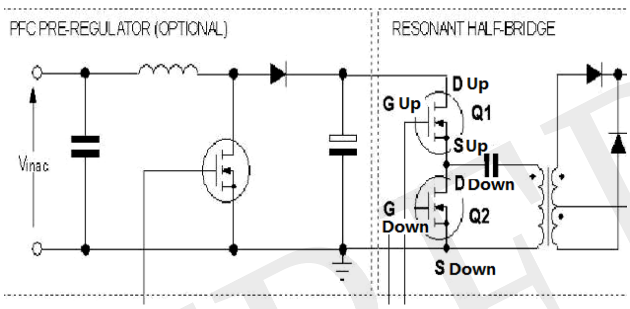


Figure 1 differential signal on the switch MOSFET of the switch power supply

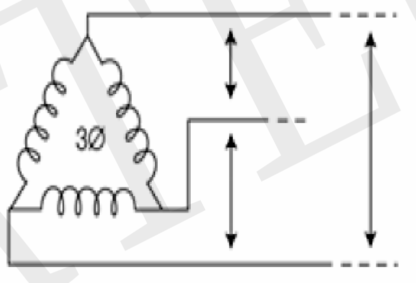


Figure 2 differential signal of the Multi-phase power supply system

Measuring Method of Differential Signal

The common measuring methods for differential signal is shown below:

- ✧ **Measuring by two probes and calculating using the Mathematical operation function of the oscilloscope. Refer to Figure 3**
- ✧

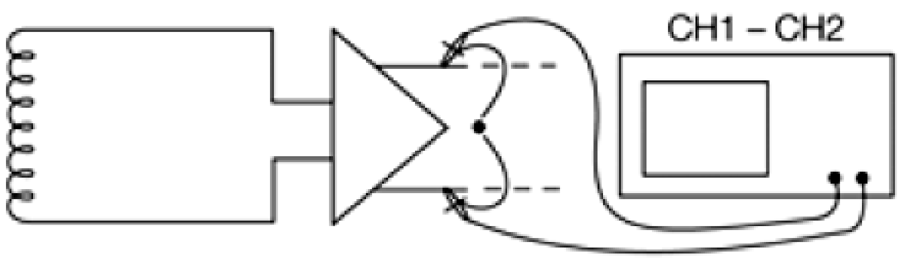


Figure 3 Measuring by two probes and calculating using the Mathematical operation function of the oscilloscope

It's a common method using two probes to do two single-port measurement, and it's also the least expected method for differential measurement. By measuring grounding signal and using Mathematical operation function of the oscilloscope (Signal A minus Signal B), users can measure differential signal. When the signal is low frequency signal, the signal amplitude is large enough and can surpass any noise, this method can be applied. Combining two single-port measurement can cause several potential problems. One of the problems is that every probe has a separated continuous signal path to the oscilloscope, and any delay difference in these two paths can cause time drift for two signals. For high speed signal, this drift will cause the differential signal's amplitude and timing errors. Another problem is that they can't provide enough CM noise suppression. In the actual circuit, there're many sources of CM noises such as the noise caused by the two signal line of the clock line nearby, noise caused by external resources like fluorescence. By the increase of the frequency, single-port CMRR's performance will worsen quickly. If CM interference is reserved, this can cause enlarged signal noise than the real noise.

✧ Float measurement of the oscilloscope

The currently common wrong way to do float measurement is done by cutting off the ground line of standard three head AC socket or using an alternative isolation transformer to cut off the connection between neutral and grounding line. Thus, the oscilloscope is floating from the protective grounding line as Figure 4, to reduce the grounding circuit's influence. This method is actually infeasible, because in the circuit of the building the neutral may have connected with grounding, and it is not a safe measuring method. Moreover, it violated the industrial health and safety rules and it provide bad result. At the same time there will be a large parasitic capacitance when the oscilloscope is ground floating, and the float measurement will be destroyed by the oscillation, the wave form measured will serious distorted. In a few words, the oscilloscope floating measurement will easily destroy the DUT, damage the oscilloscope, potentially harm the human body and get inaccurate result with lots of errors.

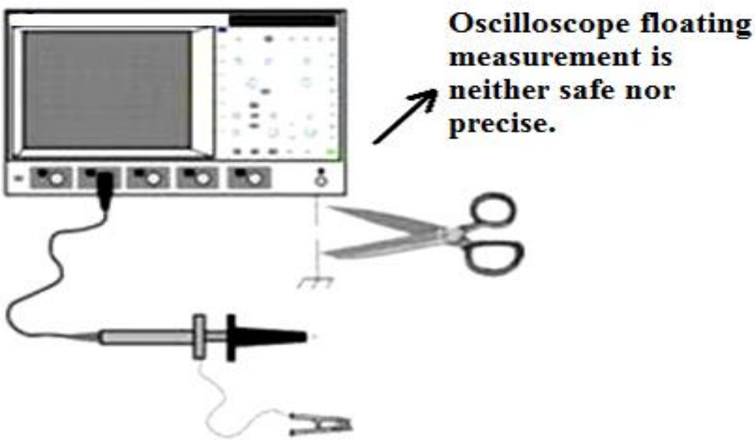


Figure 4 Oscilloscope Floating Measurement diagram

✧ **Differential Measurement**

The best solution for float measurement is using differential probe with high CMRR, because both input ports don't have a grounding problem, the differential calculation of the input signal of both path is done in the front probe already, and thus the signal transmitted to the oscilloscope channel is differential voltage already. As a result, the oscilloscope can realize safe float measurement without cutting of the grounding of the three head socket as shown in Figure 5

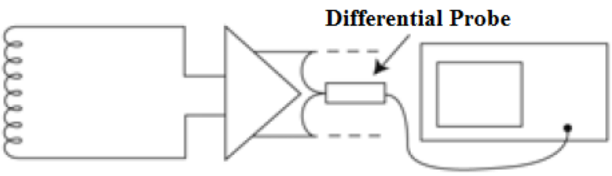


Figure 5 differential probe measurement diagram

Differential probe

✧ **Theory of differential probe**

The main theory diagram of the differential probe is shown below:

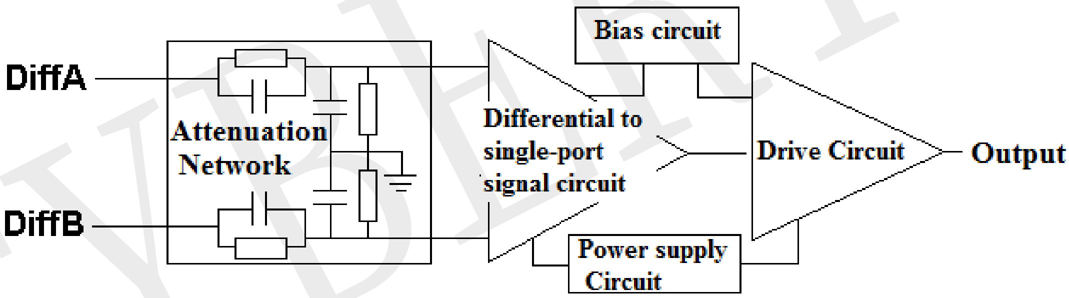


Figure 6 Common theory diagram of differential probe

Differential probe is consisted of the attenuation network, Differential signal to single end signal output, power circuit, biasing circuit and drive circuit.

✧ **Type of Differential Probe**

There're commonly two types of differential probe: one type is for low voltage signal which is relatively common in high speed digital circuit. This type of differential probe's test voltage amplitude is usually ±8V with bandwidth normally above 1GHz. The second type is for high voltage measurement. Its test voltage is about KV and it is commonly found in the measurement of switch power supply. This type of differential probe is called high voltage differential probe and its bandwidth is usually within 20MHz~100MHz.

✧ The application of high voltage differential probe

The high voltage differential probe is focusing on the measurement of float system. In the power supply system test, measurement of the relative voltage difference of the line and line or the line and neutral in three phase power supply is always required. Many users always directly use single-port probe to measure two point voltage and destroy their probe. The reason is that the signal common line terminal of most oscilloscope is connected with protective grounding system, which is normally called "grounding." What happened when doing so is, all the signals in and out of the oscilloscope share a common connecting point. This common connecting point is usually the shell of the oscilloscope using the third grounding line of the AC power supply equipment, connect the probe grounding to a test spot. If single-port probe is used in this case, the grounding of it will connect with the power supply line and make a short cut. So, we need differential probe to do float measurement

✧ Three important index for the differential probe

Bandwidth (Common): All probes have bandwidth. The bandwidth of probe is defined as the frequency when the probe response causes the output amplitude reduced to 70.7% (-3 dB), as shown in Figure 6. When selecting oscilloscope and probe, users need to know that bandwidth influences measurement accuracy in many aspects. In amplitude measurement, when sine wave frequency is closed to the limit of bandwidth, amplitude of the sine wave will reduce. At the limit of bandwidth, the amplitude of the sine wave will be measured as the 70.7% of the actual amplitude. Thus, to realize maximum amplitude measuring precision, users must select the oscilloscope and probe which have the bandwidth several times higher than the maximum frequency range planned. This conclusion is also suitable for measuring rise time and fall time. Wave form transform edge (such as pulse and square wave edge) is consisted of high frequency component. Bandwidth limit makes these high frequency attenuates, thus the conversion displayed is slower than the actual conversion speed. To precisely measure rise time and fall time, the measuring system used must have enough bandwidth to keep the high frequency component forming the rise time and fall time. In the common situation, when using the rise time of the measuring system, the rise time of the system should be two times of that of the measurement. Normally in the field of switch power supply, bandwidth of 50MHz is enough.

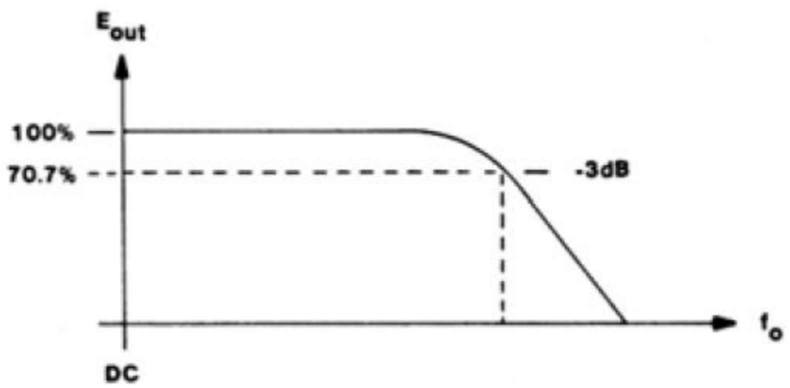


Figure 7 Frequency when bandwidth is 70.7% (-3dB) of the amplitude of the sine wave

CMRR: CMRR is defined as the differential probe's ability of suppressing CM signal of two test point in the differential measurement. This is the key index of the differential probe, its function is: CMRR=|Ad/Ac|. In this case, Ad means the voltage gain of the differential signal. Ac = voltage gain of the CM signal. In the ideal situation, Ad should be large and Ac should be zero, thus CMRR is infinite. But in the real test, 10000:1 is good enough for CMRR. This means that 5V CM input signal will be suppressed and its output will be 0.5mV. CMRR decreases when the frequency increases, as a result specifying the frequency of CMRR is the same importance as CMRR value. When measuring the upper FET drive wave form of whole bridge or half bridge circuit, CMRR is especially important. This is also the difficulty for the high voltage differential probe measuring this type of signals. As shown in Figure 1, Upper FET GS drive voltage is relatively small, but the CM voltage is high. So, measuring wave form of this point requires high CMRR for differential probe, and there will be example later.

Distortion: Distortion is defined as any amplitude error of the expected input signal response or ideal response. In the practice, distortion will usually occur during high-speed wave form transformation, represented by so called "Damped oscillation." The two differential input lines of the differential probe is very long, normally 30cm. As a result, if this index of the differential probe is designed badly, the signal measured will easily distort. Different manufacturers' differential probe can give different result, and some of them diverge largely, and this index is one of the reasons.

Of course, differential probe has other indexes like input impedance, input capacity, precision, attenuation, which are not quite different for different manufacturers and won't be mentioned one by one.

● Case Analysis for High Voltage Differential probe CMRR index

The case analysis below will give the users basic understanding about how to easily measure the CMRR index of the differential probe.

Test Platform:

Oscilloscope: TEK MSO3034

Probe: TEK P5205A (1300V/100MHz); Zhiyong DP6150A (1500V/100MHz) for contrast.

Switch power supply: common 200W switch power supply

✧ The easy method to verify CMRR

Shorting the red and black clamp of the differential probe and connect the G pole of the upper bridge drive FET. Theoretically the output of differential probe is zero, but it's not possibly in the real practice, because the point under test has large CM voltage to ground, and the power supply used is about 400V, meanwhile the differential probe has limited CMRR, there will be output. Larger output means worse CMRR of the differential probe.

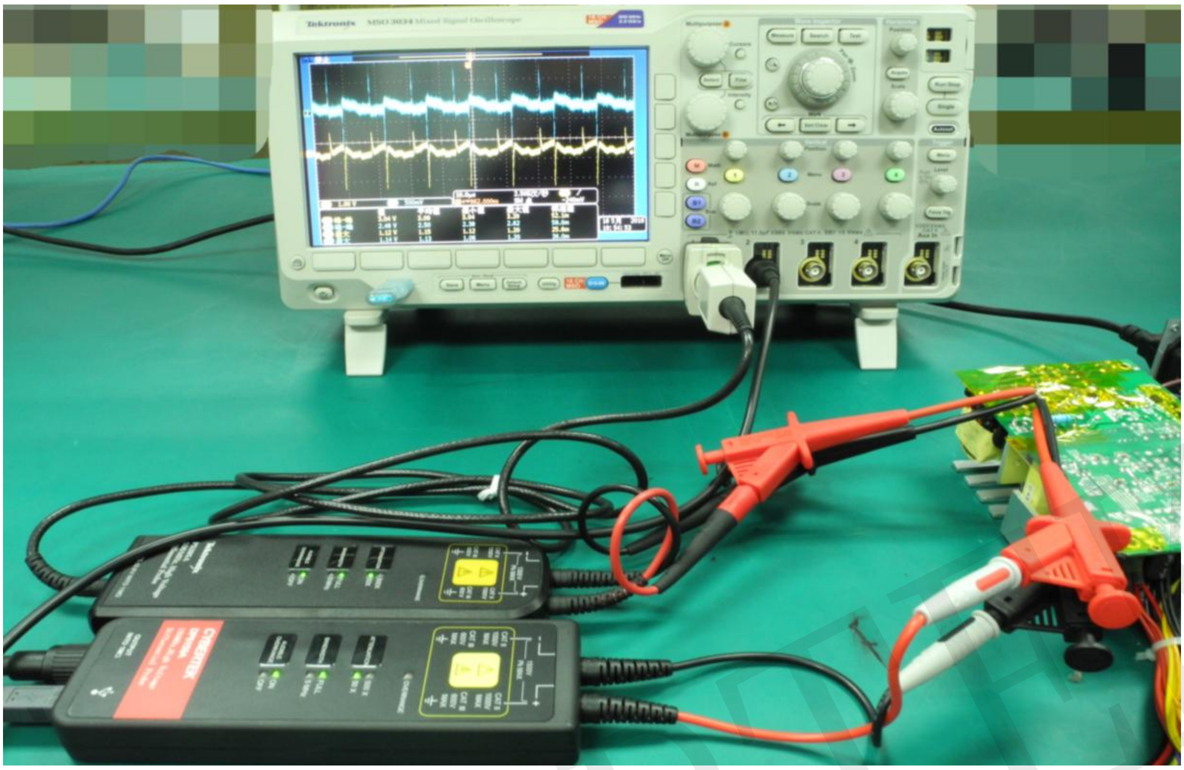


Figure 8 demo system for CM test. (Black and Red clamps are connect to G or S at same time)

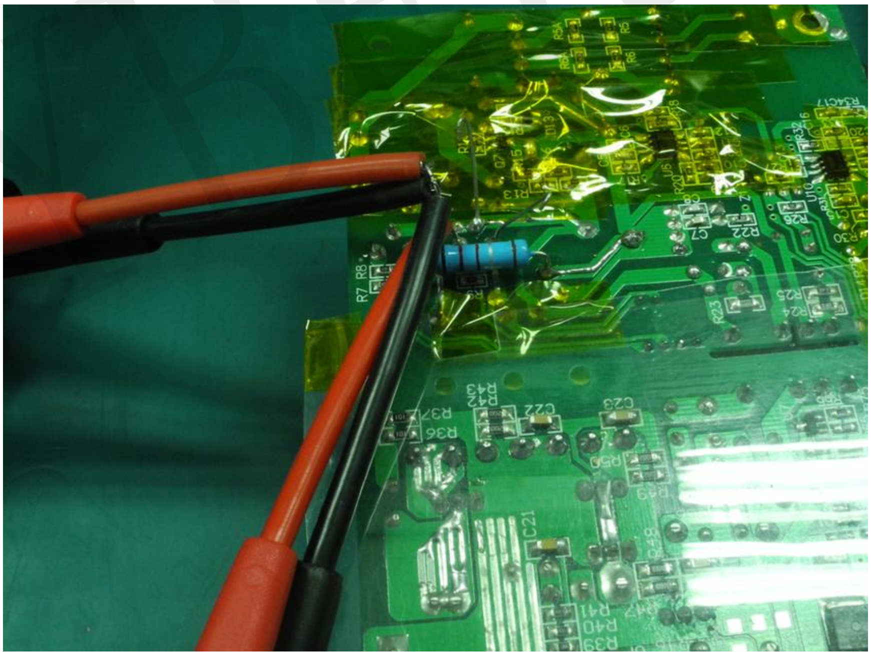


Figure 9 Close up for CM test point.

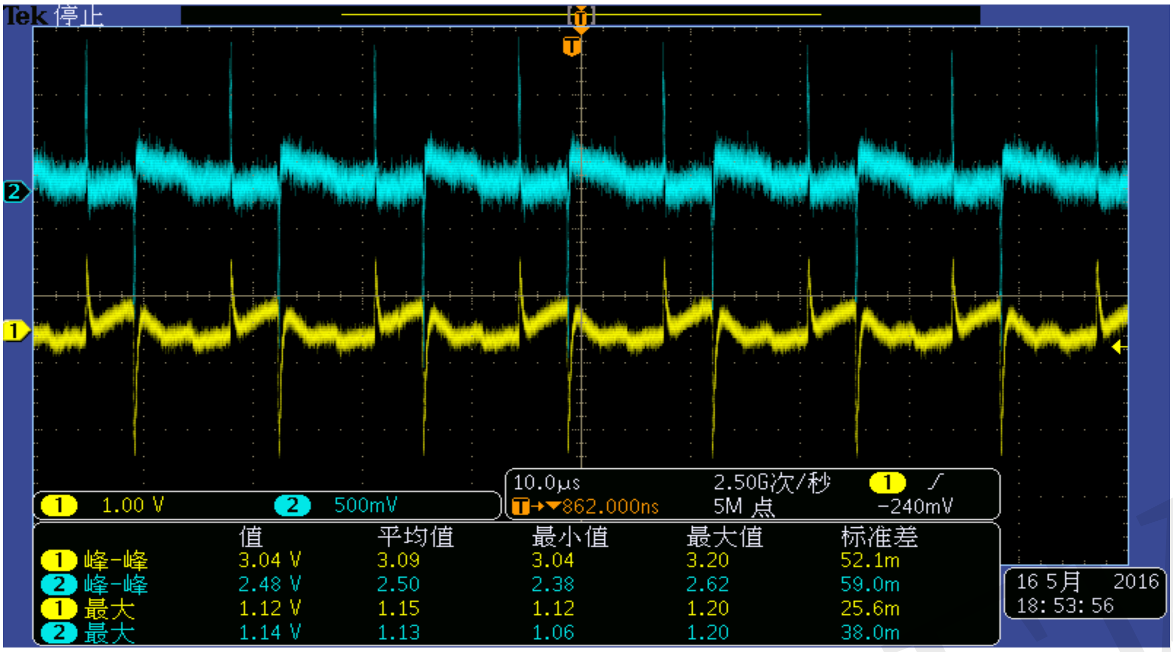


Figure 10 Upper FET CM output wave form

Shown in the figure above, because the differential probe doesn’t have enough CM ability, the output peak of the CM signal for TEK in Channel 1 is 3.04V and for Zhiyong in Channel 2 is 2.48V. Comparing these two machines, the CM of Zhiyong’s probe is better than TEK’s. The CM signal will influence the actual drive wave form measurement. The peak in the figure influences high-frequency part and the test influences low-frequency part.

✧ Actual test of drive wave form

The experiment below is the GS wave form tested in the actual measurement with reference below

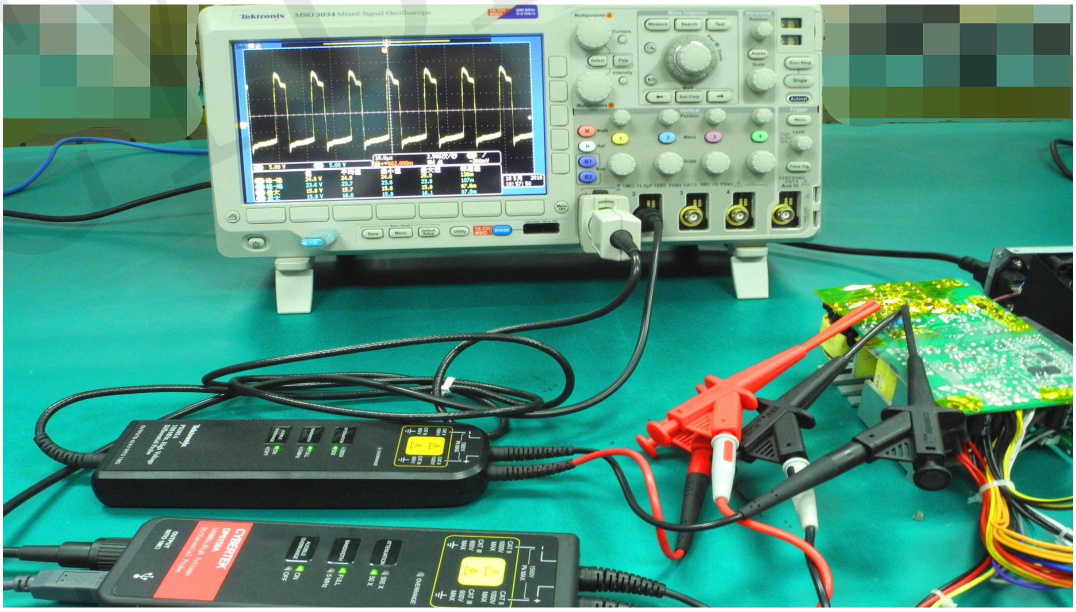


Figure 11 upper FET GS drive measurement system diagram

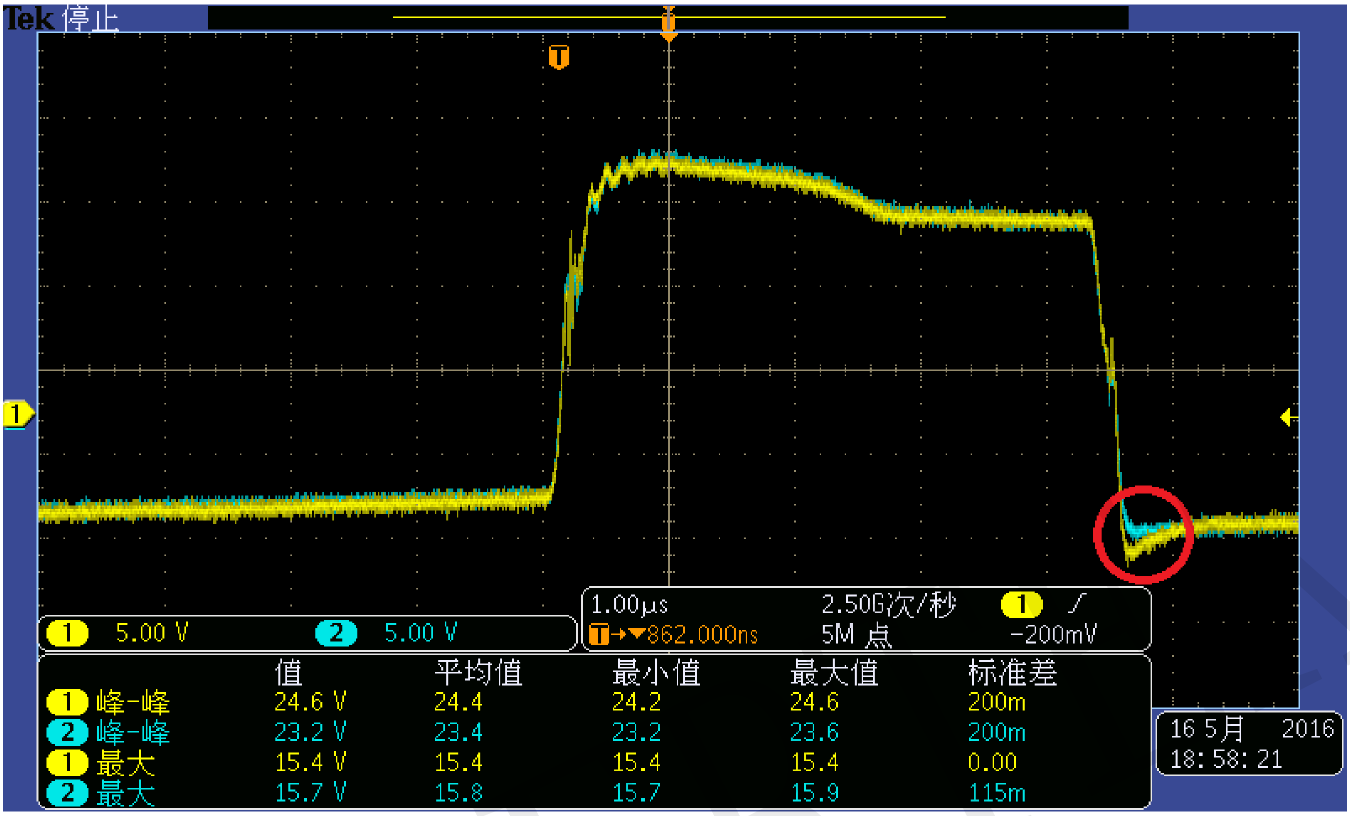


Figure 12 upper FET drive wave form analysis

Shown in the figure above, there's difference between the two probe measurements in the red circle, which is caused mainly by common mode. According to the CM experiment before, the distortion here is caused by the peak of CM, and DP6150A is closer to the actual value. The CMRR of different manufacturers is different, so users can use this method to test the CMRR of the probes and know if the drive wave form gained is close to the actual value.

Conclusion: Differential probe is the most commonly used tool in the field of switch power supply satisfying the requirements of float measurement and isolation. When measuring small signal, users should choose the manufacturer that makes probe with good CMRR and pay attention to the measuring method such as twisted pair to make precise measurement. The **CYBERTEK** DP6000 series can basically fulfill most measuring requirement in any situation.