~~H62PEP~~EEEE2046: Energy Project: Using Differential Voltage Probes

1.0 Introduction

This document considers the use of Differential Voltage probes. You should (will!) use these frequently during the Energy project. The aim of the document is to clarify why they are used when looking at electronic and electrical circuits.

2.0 Oscilloscope probes

Figure 1: Standard "Passive" Probe

Figure 2: Differential Voltage Probe

Figure 1 shows a "standard" voltage probe. You will no doubt have used these in various labs during your course. It should be noted that when these are plugged in to the Oscilloscope, the crocodile clip is connect to Earth (ground) of the oscilloscope. This connection is common to all probes that are plugged into the oscilloscope. This can cause difficulties when wanting to probe multiple parts of the circuit which are "floating" or not connected to this commonly shared ground. Under these circumstances, it is much better to use a Differential Voltage Probe.

A Differential Probe is basically a differential amplifier circuit (and in some cases a full instrumentation amplifier)- you may have come across these circuits in your studies of operational amplifiers. The differential probe circuit is very well designed in order to achieve all of the desirable characteristics of a good differential amplifier (wide bandwidth, good noise rejection etc.)- as a result they generally cost a lot more than a passive probe- treat them with care!

Because of their non-passive nature, the internal circuits of a differential probe must be powered. On the probes in the lab (similar to figure 2) you will find a power supply connection on the side- note, there is also an on/off switch…. Make sure your turn the probe on when using it! If powered using batteries- also remember to turn it off when not in use.

These probes are used frequently in the testing and debugging of power electronics circuits. The examples in section 3 should clarify why this is the case.

~~5.0~~3.0 Examples of why Differential probes are useful

Figure 2 shows a basic circuit which can easily be used to show one of the common pitfalls when using passive probes in a circuit.

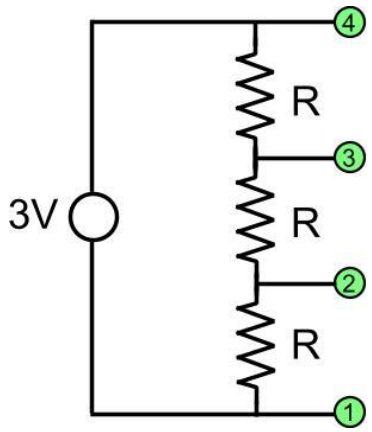

Figure 3: Test circuit for probe example

Measuring a "floating voltage" in a circuit

In figure two there is a 3V voltage source across three series connected resistors (all of a common value, R). By "floating voltage" we mean a voltage which is not referred directly to the 0V part of the circuit (this is a loose definition, but will do for now).

If we take a passive probe and connect the clip to point 1 and the probe tip to point 2, we will see a voltage of 1V on our oscilloscope. Let's now say that we wanted to take another probe and measure the voltage across the middle resistor, between points 2 and 3. For this, we connect the probe clip to point 2 and the probe tip to point 3. We expect to also see 1V, but instead we 1.5V. Why is this?

Remember, from above, that the clips of the probes are connected together inside the scope and bonded to earth (ground). This means that when we probe the second resistor we have a clip from the first probe connected to point 1 and the clip from the second probe connected to point 2. Since these two clips are connected together inside the scope- this short circuits the bottom resistor, leaving only the middle and top resistors in circuit. Since they have the same resistance, at point 3 we will see half of the input voltage rather than a third of it- i.e. we get a voltage of 1.5V instead of 1V.

A differential probe does not have one of its probes connected directly to earth through the internal circuit of the scope. As a result the two leads effectively "float" and can be connected anywhere in the circuit, without affecting its operation.

Measuring differentially with two passive probes

Another way of measuring the voltage across the middle resistor would be to connect one probe between point 1 and 2, and another probe between 1 and 3- note that there is now a common connection between the 2 clips (i.e. they are both connected at 1) and therefore none of the resistors are short circuited. We can now use the Maths functions on the scope to subtract one from the other in order to gain the voltage across the middle resistor. This method works but can result in a lot of noise on the final signal on the Maths channel.

Differential probes are very good at blocking "Common Mode" noise (see your Op-Amp notes and the term "Common Mode Rejection Ratio"). As a result, if it is placed directly across points 2 and 3, accurate, low noise measurements of the voltage across this middle resistor can be taken.

Non-isolated Power Supplies

As you may have learned from you lectures on Power Electronics- not all power supplies have isolation. As a result, some of them will already have a connection of their output voltage to earth. Care must be taken when probing such systems with passive probes as clipping the probe (not the tip, the clip) anywhere above this potential may result in a short circuit through the oscilloscope causing damage.

This is a reason why it is safer to use a differential voltage probe since this is not directly connected to the earth of the oscilloscope. You must, however, always respect the voltage ratings of the probe which are usually clearly printed on the device. You should also make use of the range select switch on the probe to get the most accurate voltage measurement.

~~6.0~~4.0 Uses of differential probes in the Energy Project

In the Energy project, there are many cases where differential voltage probes are useful. These include:

- Looking at the isolated outputs of the gate drive circuit
- Probing the voltage in the main power circuit when a passive probe is making measurements on the non-power (i.e. logic, PWM) circuits
- Looking at the voltage across the output filter inductor
- Looking at the voltage across the two MOSFETs in the forward converter (note they don't have a common connection)
- Etc. (speak to us in the lab)

As a result, you should get used to using these probes in the lab. Remember, they come with a power supply and must be powered (there is an internal circuit that needs powering).

Confused?

There are two very good videos (amongst others) on YouTube that may help with your understanding of the above. Failing that, speak to the staff in the lab.

https://www.youtube.com/watch?v=OZDijMDHmtI

https://www.youtube.com/watch?v=a28lVMsWFEY

Al Watson, November 2018