Lab 11 & 12: 4-wire vs. 2-wire measurements & blowing up traces

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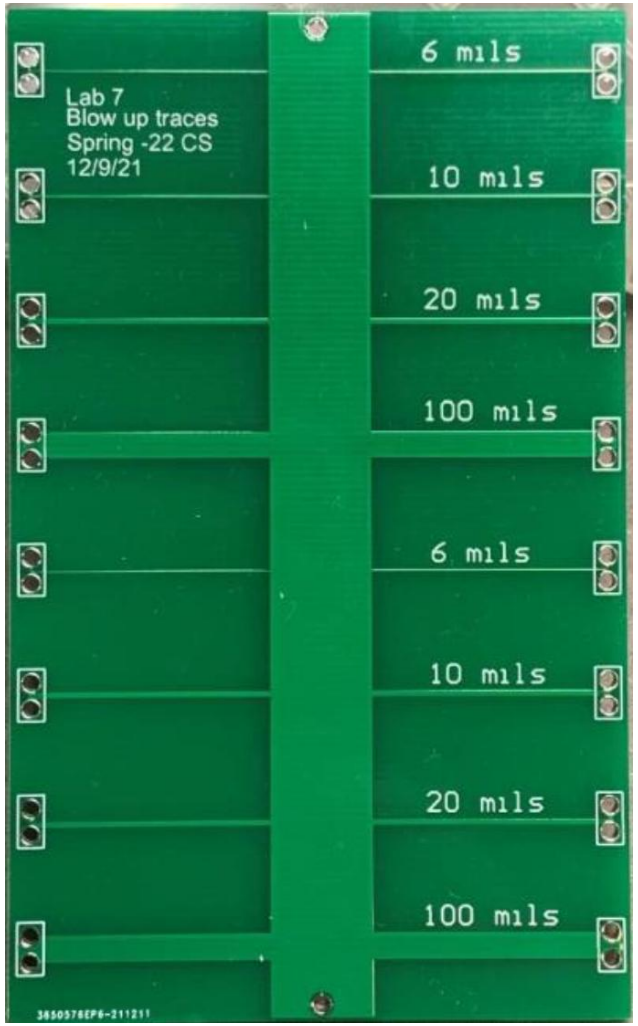
Overview

- These labs focus on developing our understanding of trace widths on printed circuit boards.
  - Lab 11 focuses on measuring the resistance of traces using the 2-wire and 4-wire methods.
  - Lab 12 demonstrates how much current a trace can handle, by testing its limits until failure.



DUT: PCB with varying trace widths

Lab 11: 4-wire vs. 2-wire measurements

- Typically, the 2-wire method for measuring resistance of a DUT gives an accurate measurement. However, when the expected resistance measurement is <1 Ohm, the 2-wire method can introduce extra resistance from the series resistance of the contact leads, contact resistance, or internal offset voltage of the DMM. This was demonstrated by shorting wires from the DMM, with the short leads (left) and standard clip leads (right). To avoid this extra resistance in our measurements, the 4-wire method is developed.

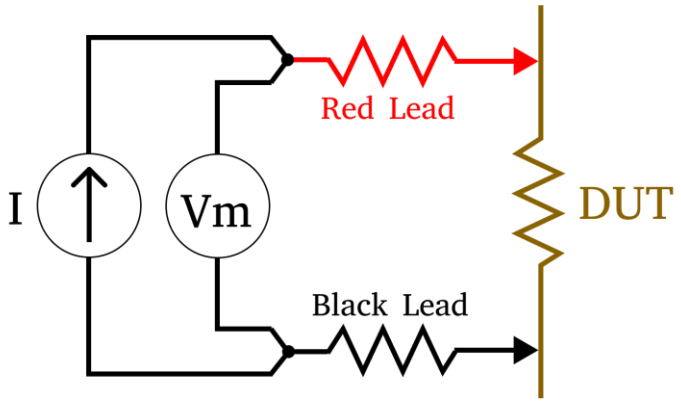
Short leads resistance

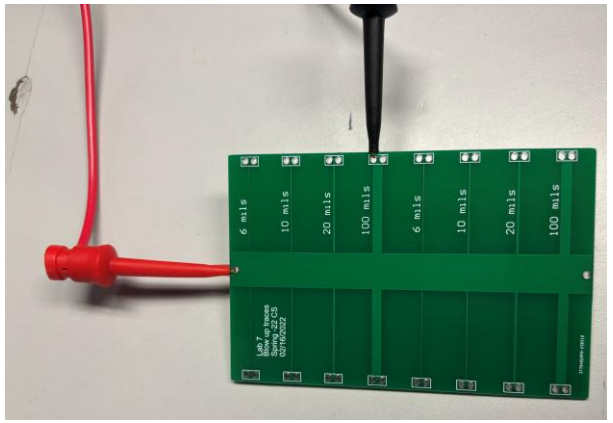
Standard clip leads resistance

Lab 11: 4-wire vs. 2-wire measurements (cont.)

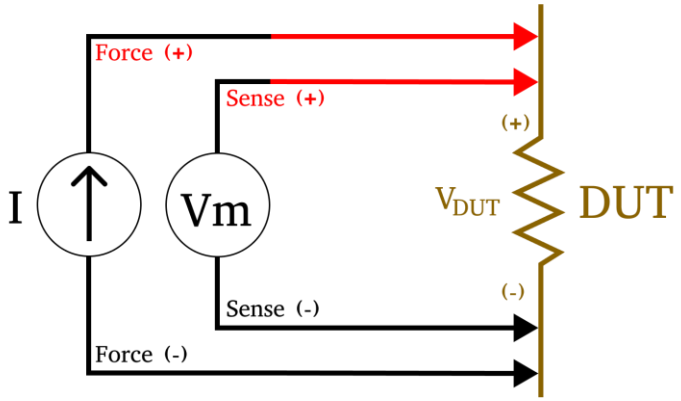
- Why they differ:
  - The 2-wire method uses two connections across the DUT, with a current flowing through the voltmeter. This method includes the resistance of the wires, which can be comparable to the DUT resistance if it is less than 1 Ohm, causing an inaccurate value for the DUT.
  - The 4-wire method uses four connections across the DUT, with the voltage measurement leads being separated from the where the current is flowing. This allows for the voltage measured to be only across the DUT, without the wires being taken into account.

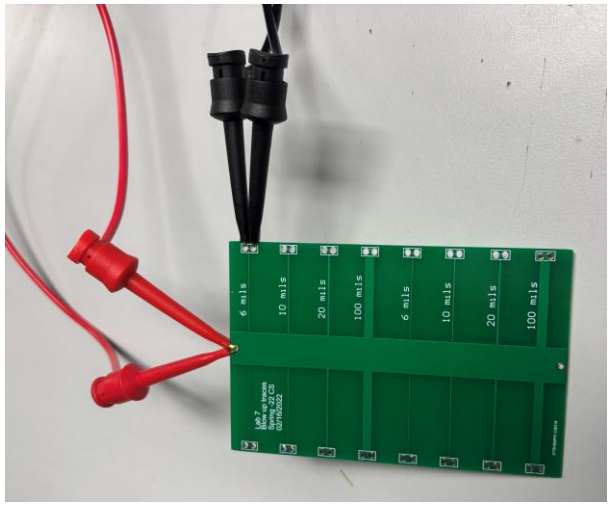
Lab 11: 4-wire vs. 2-wire measurements (cont.)





2-wire method





4-wire method

Image credit: PowerSystemsDesign.com

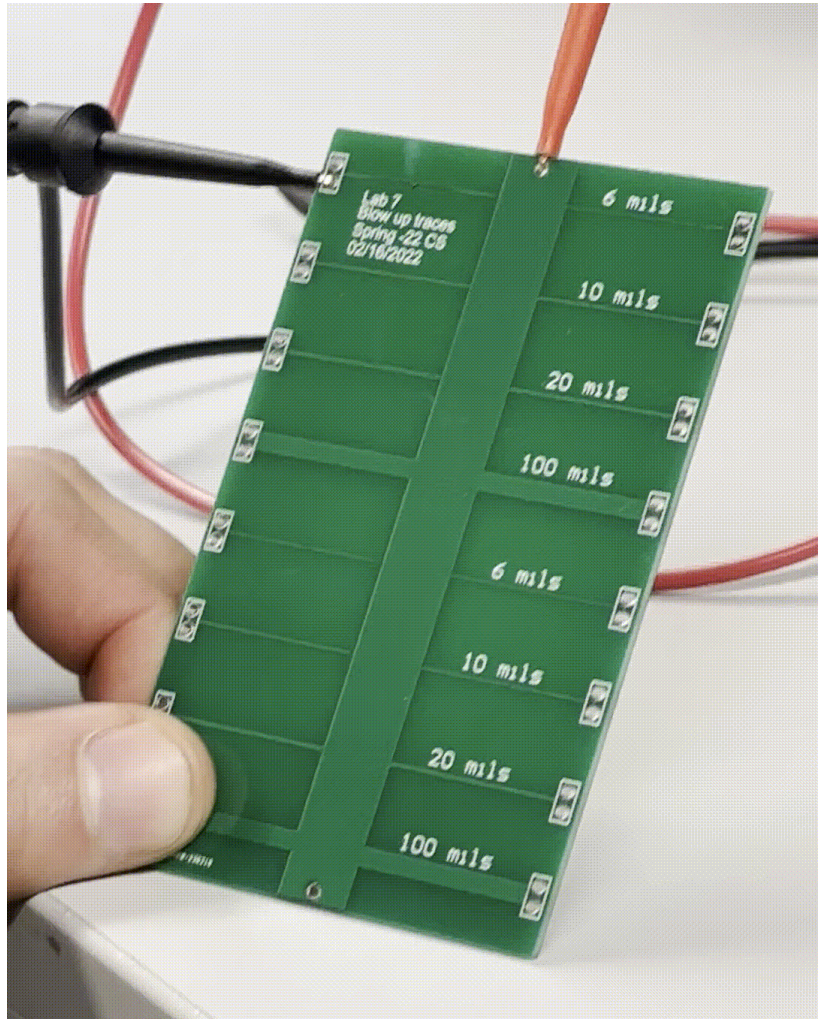
Results

- Rule-of-thumb: For 1 oz copper, th eseries resistance of a 6 mil trace is 83 mOhms/inch and for a 20 mil tace, it is 25 mOhms/inch. The 400 mil trace in the middle was approximately 1.25 mOhm/inch which added a small amount of resistance, as reflected in the total rule of thumb value.
- These measured values were not exact to the rule of thumb measurement, but it shows how much closer the 4-wire measurement was to the 2-wire.

	Rule of thumb	2-wire	4-wire
6 mil	84	193	75
10 mil	52	156	38.8
20 mil	28	137	18.4
100 mil	9	121	3.8

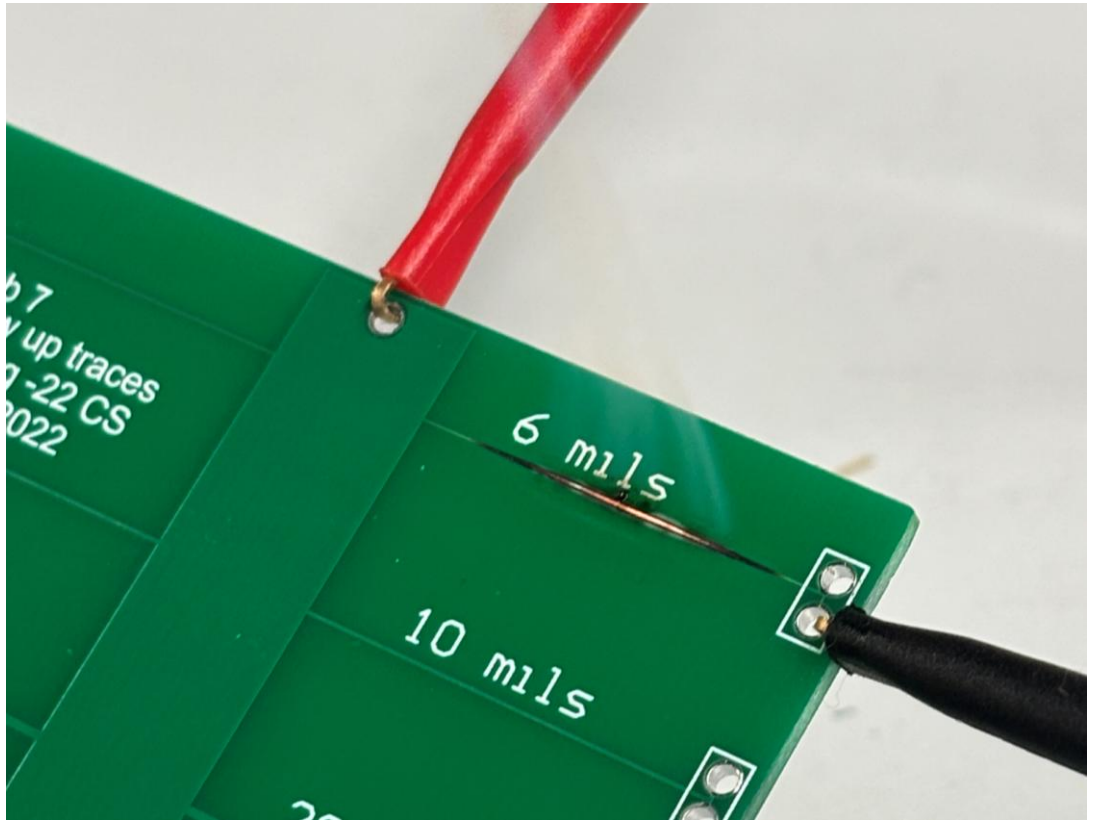
Lab 12: Burning traces

- In this lab, we wanted to test the upper limits of the amount of current we could send through a 6 mil PCB trace before fatigue and eventually failure. We also noted when it began to get warm and hot to the touch.
- To accomplish this, the short wires were connected to a DC power supply with 1 A and the voltage was ramping by 0.5 V until the trace turned red hot and eventually started smoking.



Results

- Trace fatigue & failure
  - Warm: 1.5 A
  - Got hot: 2.5 A
  - Failed: 4.5 A



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Summary

- In this lab, I learned about measuring trace resistance based on its width and copper pour thickness, and how the 2-wire and 4-wire methods can affect the accuracy of measurements of devices with a resistance less than 1 Ohm. For this case, the 4-wire method should be used to the wire resistance of the DMM is not taken into account. I then learned that even small trace widths can handle much more current than expected until they fail, but it is generally not recommended to put more than 1.5 A through a 6 mil trace and 3.6 A for a 20 mil trace with a 40ºC temp rise over ambient.