University of Colorado Boulder

Electrical and Computer Engineering

ECEN3730 Practical PCB Design Manufacture

LABORATORY REPORT

Labs 11 and 12: Trace Resistance & Trace Blow up

Student Name: Mathias Labuszewski

Lecturer in charge:

Arielle Blum

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1 Introduction

This combined lab report discusses the experiments conducted in Labs 11 and 12. Lab 11 focused on measuring trace resistance using both the 2-wire and 4-wire methods, while Lab 12 concentrated on determining the maximum current-carrying capacity of narrow traces and observing their behavior under high current conditions. The integration of these two labs allowed us to gain a comprehensive understanding of resistance measurement techniques and the practical limitations of trace conductors.

2 Objectives

1. Contribute to the overall understanding of the relationship between trace geometry, resistance, and current-carrying capacity.
2. Learn the principles and practical application of both the 2-wire and 4-wire methods for measuring resistance.
3. Gain proficiency in estimating the resistance of traces based on their dimensions and the concept of sheet resistance.
4. Apply theoretical knowledge to measure the resistance of traces using the 2-wire and 4-wire methods.
5. Learn to estimate the maximum current-carrying capacity of narrow traces based on trace width and temperature rise considerations.
6. Apply knowledge of electrical principles, such as resistance, current, and temperature coefficients, to real-world experiments.

3 Test Board

In this lab, we used a test board with various trace patterns to perform reverse engineering and deduce a model of the trace connections. We measured the resistance of 1-inch long test lines on the board using both the 2-wire and 4-wire methods. The goal was to understand the practical applications of these measurement techniques.

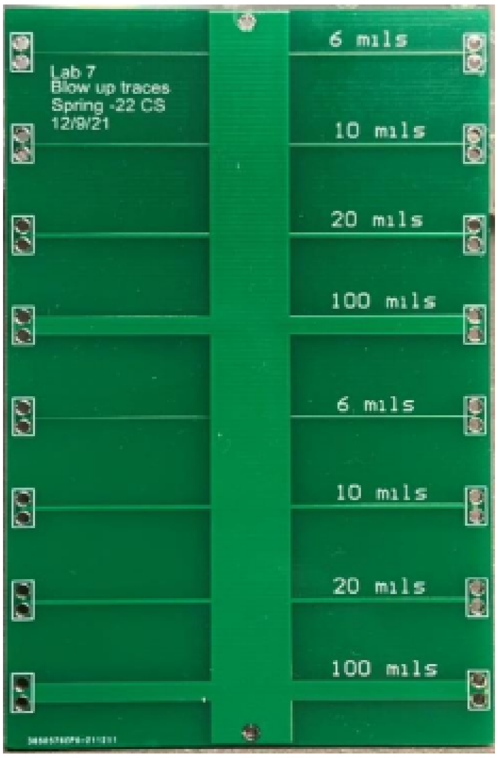

Figure 1: Picture of Board 1

The board has one big center conductor and smaller traces branching off it. There is two probe points at the end of each of trace.

4 Methodology

4.1 Estimating Trace resistance

- Before we take measurements, we should anticipate what we expect to see.
- Assumptions: 1oz copper, 1 inch trace, center trace negligible.
- Resistance (R) = $p(\frac{L}{A})$
  - $= p(\frac{L}{wt})$
  - $= \frac{p}{t}\frac{L}{w}$
  - $= \frac{p}{t} = SheetResistance = \frac{1.7*10^-8m\Omega}{35*10-6m}$
  - $= 0.5m\Omega\frac{L}{w}$
- Resistance (R) = $0.5m\Omega\frac{1}{w}$ (1 inch trace)

Line With(mils)	R Estimate($m\Omega$)
6	83.3
10	50
20	25
100	5

4.2 Measuring Trace resistance

To measure resistance, we have the conventional two-wire method, and the 4 wire method. The 2-wire resistance measurement method is the simplest and most commonly used approach for measuring resistance in various electronic circuits and components. This method involves the use of a Digital Multi meter (DMM) or an Ohmmeter to measure resistance between two points on a component or circuit. This is prone to error, as the connection resistance of the lead, as well as the resistance of the wires.

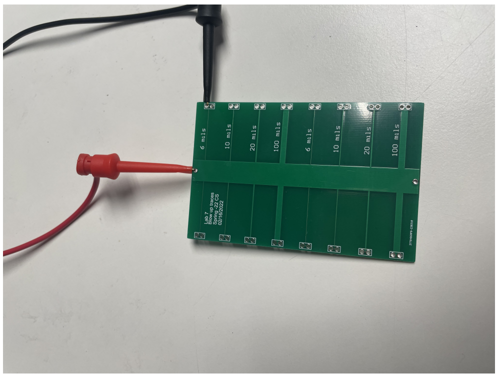

Figure 2: 2 wire method used

The 4-wire resistance measurement method, also known as the Kelvin or 4-point probe method, is a more advanced technique that addresses the limitations of the 2-wire method, especially in scenarios where high measurement accuracy is crucial. In the 4-wire method, two sets of leads are used: one set for sourcing the current and another set for measuring the voltage. A known current is passed through the component or trace using the current source leads. The voltage drop is measured directly at the component or trace, but this measurement is isolated from the current source. It is taken using the sense leads. The resistance is calculated based on the measured voltage and current, eliminating the impact of lead and connection resistance.

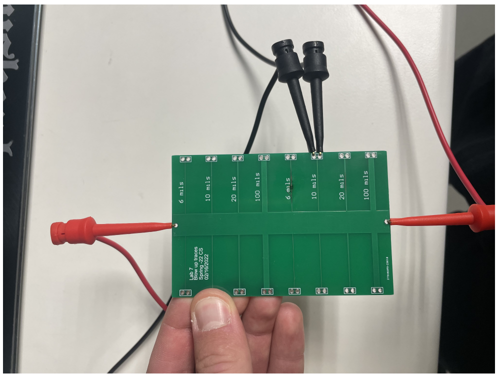

Figure 3: 4 wire method used

4.2.1 2 Wire measurements

- Using the lab bench multi-meter, we calculated the resistance of the traces, making sure to negate the probe resistance.

Line With(mils)	R Measured($m\Omega$)
6	112
10	100
20	90
100	89

4.2.2 4 Wire measurements

- Using the lab bench power supply and the lab bench multimeter, we used the Kelvin method. We used a current of 1A for easy calculations.

Line With(mils)	R Measured($m\Omega$)
6	99.2
10	58
20	33
100	8

4.2.3 Observations

Line With(mils)	R Calculated($m\Omega$)	R Measured 2 wire($m\Omega$)	R Measured 4 wire($m\Omega$)
6	83.3	112	99.2
10	50	100	58
20	25	90	33
100	5	89	8

Calculated values and measured values are very close. The 2 wire method was very inaccurate. With very small resistances the 2 wire method does not produce accurate results. However, the 4 wire method produced very accurate results. The difference was most likely due to tolerances in the cables, power supply, and multimeter.

4.3 Max Current of Traces

4.3.1 Estimating Trace resistance

Before subjecting any traces to high currents, we used a calculator to estimate the maximum current that 6 mil and 20 mil wide traces could handle without exceeding a 40°C temperature rise over ambient. These estimates served as a reference point for our experiments.

Figure 4: Saturn PCB Tool: Conductor current as 1A for 6 mil trace.

4.3.2 Measuring Trace resistance

We applied a controlled current to the traces and observed their response. We monitored the traces for noticeable warmth, hotness, and the onset of smoking. These observations allowed us to determine the maximum current capacity for 6 mil and 20 mil wide traces.

The setup was identical to the 4 wire method.

Line With(mils)	Amps Calculated(A)	Amps when trace got warm(A)	Amps when trace got hot(A)	Amps when trace started smoking(A)
6	1	2.2	3.1	4.0
20	2.2	3.6	6.5	10

4.3.3 Observations

We see the traces blew much higher over the recommended limit Saturn PCB tool gave us. You never want to be pushing that much current through a small trace in a PCB. The other big factor was the heat-sinking capacity of the PCB. During the trace blow-up, the hotter the trace got the resistance rose. This in turn led to it getting hotter and so forth. In the Saturn PCB Tool, changing the thermal characteristics of the PCB affects the recommended current by a lot. If we could get a PCB that would be able to sink all the heat generated, we would be able to run a much greater current the the same size trace.

4.4 Outcomes

- Select the Appropriate Method: Choose between the 2-wire and 4-wire methods based on the specific requirements of the measurement task, balancing simplicity and accuracy.
- Minimize Measurement Errors: Be mindful of lead resistance effects, especially when using the 2-wire method, and take steps to mitigate their impact.
- Achieve Precision: Opt for the 4-wire method when conducting high-precision measurements, ensuring accurate results in critical applications.
- Material Characterization: Use proper trace width based on the nominal current.
- Enhance Troubleshooting: Use the appropriate resistance measurement method to troubleshoot circuits effectively and identify faulty components.

4.5 Conclusion

In conclusion, the 2-wire and 4-wire resistance measurement methods are invaluable tools in the field of electronics and electrical engineering. Understanding their principles, applications, and differences allows professionals to make informed choices when measuring resistance in various circuits and components. The 2-wire method, while simple and versatile, is prone to lead resistance effects, making it less suitable for high-precision measurements of low-resistance components. In contrast, the 4-wire method excels in scenarios where accuracy is paramount, effectively eliminating lead resistance and providing highly accurate resistance measurements.