Lab 11 & 12: Measure Trace Resistance and Blow-up traces.

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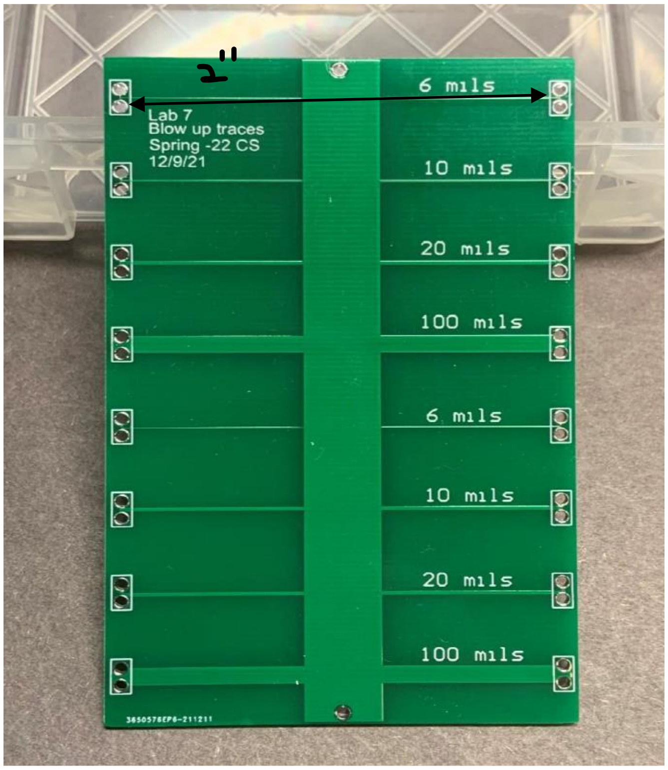
Purpose: This lab experiment is to learn basic measurement practices of traces using 2-wire and 4-wire methods. To understand the maximum current that can be passed through the narrow traces, the traces are set to blow up.

Understanding the Test Board:

The test board has four traces, 6 mils, 10 mils, 20 mils and 100 mils. The length to the center is 1 inch long and the total length of trace from one end to other is 2 mils.



Resistance Measurement:

1. **Estimating the resistance of each trace**:

As per the manual, the copper is 1oz copper, the trace widths are 6, 10, 20 and 100 mils and trace length is 1 inch.

According to the formula of resistance, r,

r = resistivity *(length/ Area) = resistivity/thickness) * number of squares

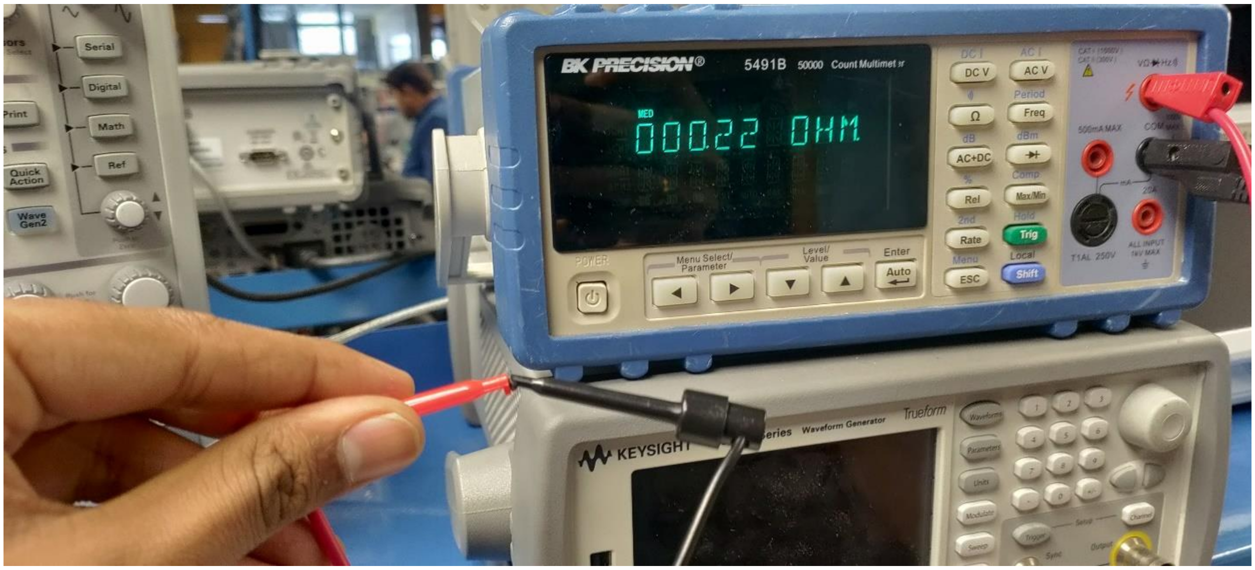
= sheet resistance * number of squares

Since, its 1oz Cu, the sheet resistance for 1 oz Cu = (1.7*e-8 / 34*e-6) = 0.5mOhm/square

Therefore, the estimated resistance values for 6, 10, 20 and 100 mils are 83.3, 50, 25, 5 mOhms.

2. **2-wire Method**:

Using a bench DMM, the values of resistance obtained are 260,230,200 and 180 mOhms. These values are nowhere related to the estimated resistance. This might be caused due to loop resistance. When measured just the loop resistance, it is around 220 mOhm.



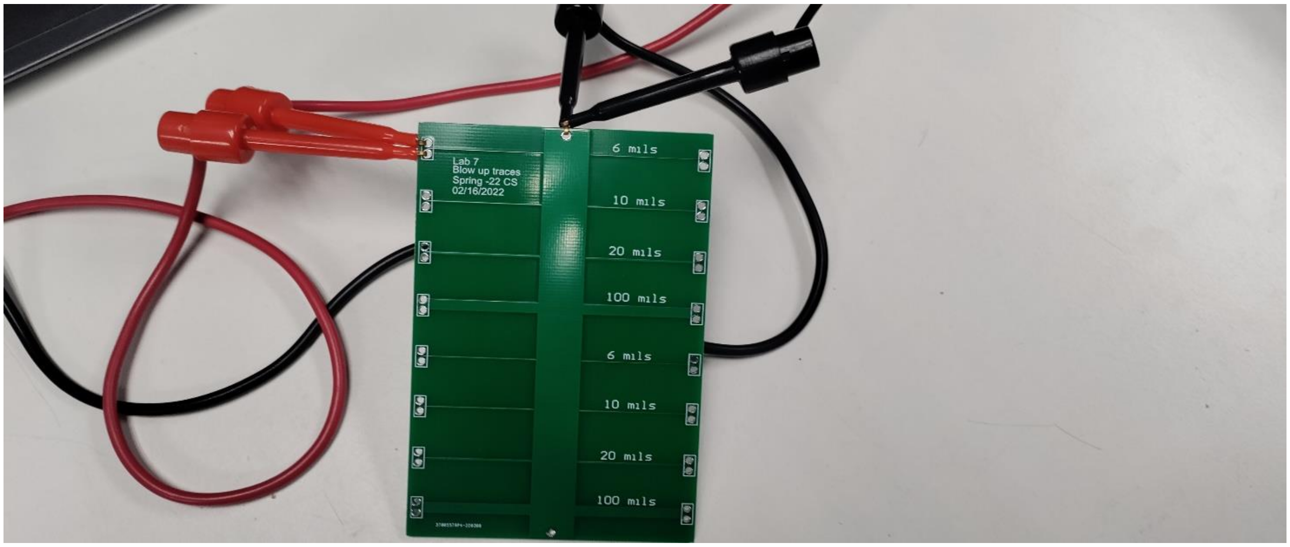
There might be chances due to the wire we used and internal error of the bench setup for the measurement in mOhms.

3. **4 -wire method**:

By setting the input in constant Current mode, with 1A current, the voltage drop is measured across the trace using the DMM. This gives the voltage and as it is constant current, the resistance of the trace path can be calculated.

For this experiment, the current is set for 1A for easy calculation purposes and this current would not break any of the traces. The voltage is set to 4V so that there will be no issue while staying in constant current mode.

The following is the screenshot for measurement setup of 4 wire method. Since we are calculating it on the 1-inch trace, the constant current source is connected to one end of trace and the other end to the ground. For measuring the voltage drop, the probes of DMM are connected to the source pin and ground as shown below.



After getting the voltage drop and calculating the resistances, the following table is created.

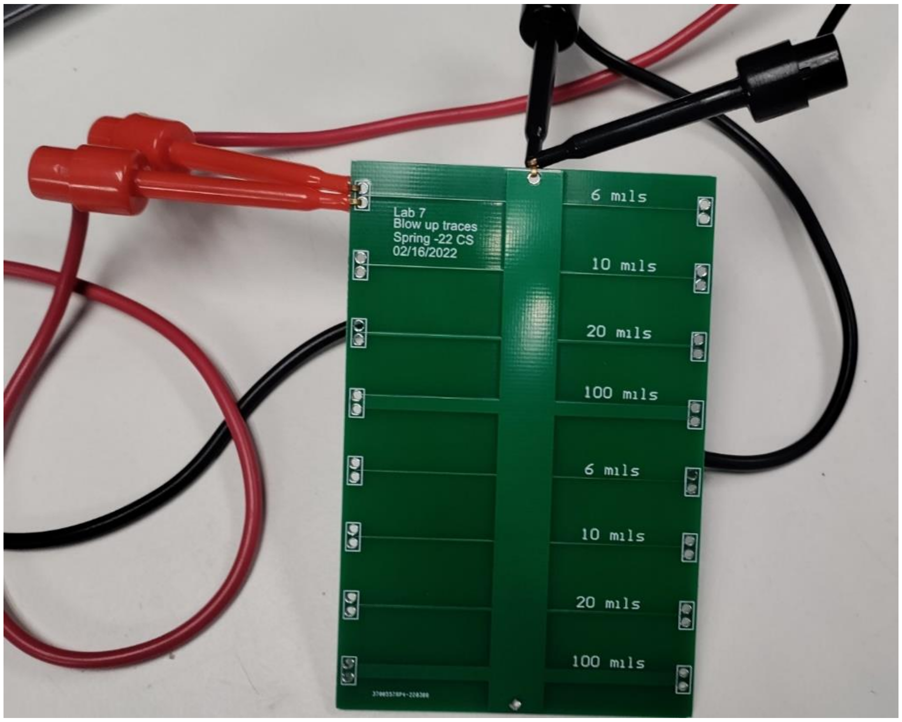
Line Width	Estimate by Formula	2 wire method	4 wire method		
			I/P Voltage, I/P current	Reading on DMM	Resistance
6 mils	83.3 mOhm	260mOhm	4V, 1A	92.17 mV	92.17mOhm
10 mils	50 mOhm	230mOhm	4V, 1A	50.42 mV	50.42mOhm
20 mils	25 mOhm	200mOhm	4V, 1A	24.57 mV	24.57mOhm
100 mils	5 mOhm	180mOhm	4V, 1A	7.47 mV	7.47 mOhm

The 4 wire method is more accurate than the 2 wire method of measurement since the values obtained are closer to the estimated resistance values. Even in 4 wire method there is a little inaccuracy, up to 10% difference in obtained values. This might be due to the probes used to measure the resistance values, the trace path, since it is a longer path for 100 mils whereas for a 6 mils trace from source to ground connection. There are pretty good chances we might go wrong for the 2 inch measurement and calculating it for 1 inch. Hence in my opinion, the 4 wire method is more accurate than 2 wire method.

Trace Blow Up:

From the Saturn PCB tool, we get the estimate of maximum current that can be passed through the different width traces. This gives us a basic idea of how much current we should initiate the experiment with before blowing up the traces. The rise of temperature is considered 40 deg C as it is considered warm. The safe current through 6, 10, 20 and 100 mils traces before they get warm are, 1.15, 1.76, 2.86 and 7.89 A, respectively.

The following are the screenshots of initial input from power source and experiment setup.



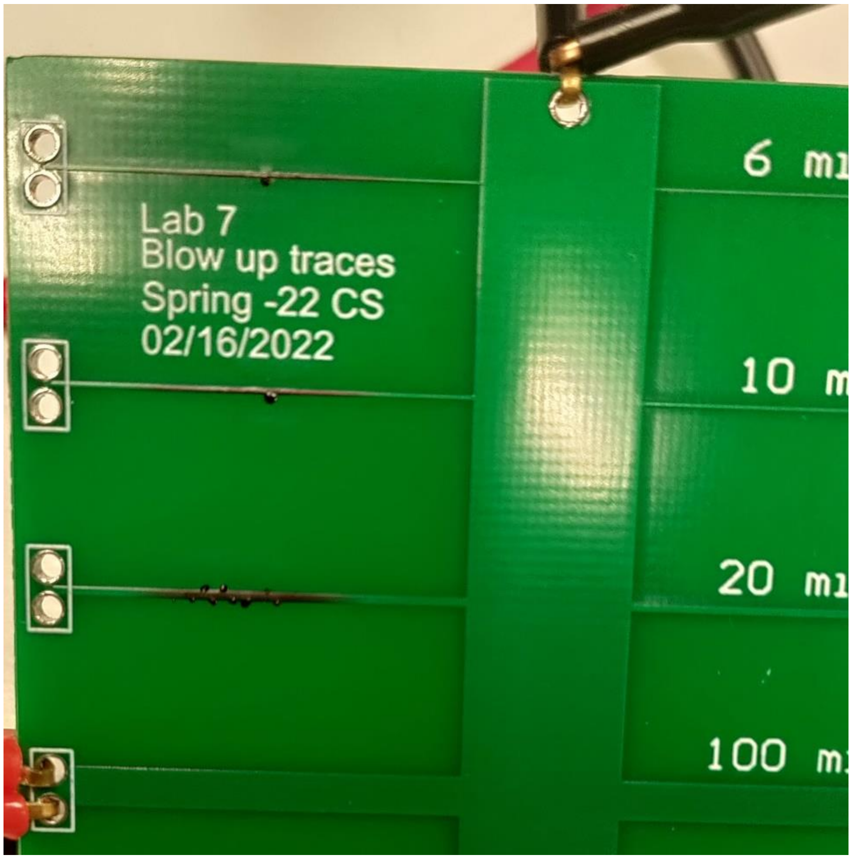
The current is passed through the traces for the 1-inch trace. The resistance is measured for understanding the heating of the trace. If there is a rapid rise in resistance, the trace is heated up and ready to burn.

The initial settings for the 6-mil trace blow up are 3V and 1A.

The following is the table for the different values obtained in the experiment.

Line Width	Voltage/ Current init	V/ I warmup	V/ I Hot	V/I Burn	Saturn PCB tool
6 mils	3V/ 1A	3V/ 2.5A	3V/ 3.3 A	3V / 3.908A	1.15 A
10 mils	3V/ 1A	3V/ 3.5A	3V/ 4.8A	3V/ 5.829A	1.76A
20 mils	3V/2.5A	3V/ 5.5A	3V/ 6.5A	3V/ 9.469A	2.86A
100 mils	5V/ 4A	Slightly warm at 5V/ 10A	Not hot	No Burn	7.89A

The final board after the traces are blown up is as the following screenshot,



Conclusion: For the resistance measurement the 4-wire method is better than the 2-wire measurement. The 6-mil trace could handle 2.5 mA at 3V but burns off at approximately 4A at 3V. The 10 mils trace could handle 3.5A at 3V but burns off at approximately 5.8A at 3V. The 20 mils trace could handle 5.5A at 3V but burns off at approximately 9.5A at 3V. The 100 mils trace has a very low resistance and would require a higher amount of heat to burn off which requires a lot of current through the source. The trace could just warmup at 10A (maximum possible current from power source at lab) at 5V.