TECH NOTE

LDT-5940C Temperature Controller
Voltage Measurement Techniques

OVERVIEW

This technical note presents results of voltage measurements made across a resistive load with the LDT-5940C Thermoelectric Temperature Controller using 2- and 4-wire methods.

BACKGROUND

Accurate voltage measurements made across two current carrying wires are complicated by the internal resistance of the wire used. In applications where measurement accuracy is crucial, such as laser diode or TEC characterization, standard 2-wire measurements may not be sufficient. Alternate measurement techniques offer improved accuracy.

In 2-wire adjusted measurements, the resistance of the wiring used in the setup is entered into the instrument. The instrument then uses this resistance value to calculate the voltage drop in the wiring and displays only the voltage across the load. This method is subject to error arising from inaccuracies in the resistance value entered.

True 4-wire measurement setups (Figure 1) involve two fully independent connections to the load. In addition to a current source, a high-impedance voltmeter is connected across a second set of wires. Since negligible current flows in the voltage sensing wires, voltage drop across these wires is insignificant and measurements are accurate. If the voltage sensing wires are not connected, no useful voltage measurements can be made.

Pseudo 4-wire measurements (Figure 2) offer flexibility. In this method the voltmeter is internally connected to the current source through large resistances, R_{PSEUDO}, in order to measure a voltage at the output terminals, but can also be connected through independent wires to the input terminals of the load for greater accuracy. This allows for a meaningful voltage and resistance measurement even if a second connection is not present. The internal connection between the voltmeter and current source causes some inaccuracy due to current flow through the R_{PSEUDO} resistors when four connecting wires are present.

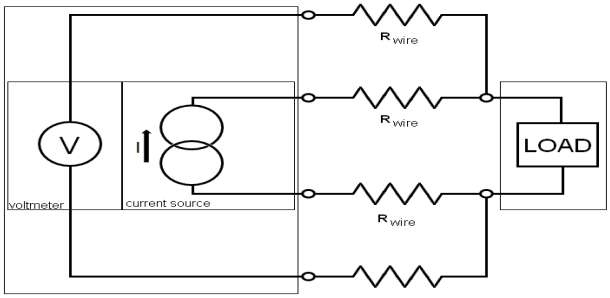

Figure 1: True four-wire measurement diagram

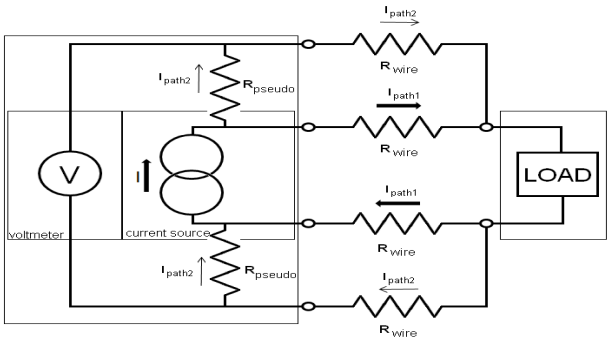

Figure 2: Pseudo 4-wire measurement diagram, note that I_{path2} is kept small relative to I_{path1} by high resistance R_{pseudo} connections

MEASUREMENT SETUP

A 2 Ω resistive load was connected to the TEC current source of the LDT-5940C via 4 strands of 22 gauge wire and driven at 0.50 A, 1.00 A, 1.50 A, 2.00 A, 2.50 A and 3.00 A. An Agilent 34410A 6 ½ digit multimeter was used to measure voltage across the load at each current level. The results were compared to corresponding measurements made by the LDT-5940C using 2-wire, adjusted 2-wire, and pseudo 4-wire methods.

For the adjusted 2-wire measurement, the resistance of 12 feet of four 22 gauge copper wires connected in parallel was calculated. Contact

resistance was measured at 0.004 Ω. The sum of these, 0.052 Ω, was entered into the LDT-5940C.

RESULTS

The results of the measurements are shown below. The average error as compared to the true 4-wire measurement was 3.38% for the 2-wire, 0.89% for the adjusted 2-wire, and 1.37% for the pseudo 4-wire measurements. At higher current the measurements became less accurate for 2-wire and pseudo 4-wire measurements.

Current (A)	Voltage at Load (V)[1]	2-wire measurement (V)[2]	% error
0.50	1.04	1.07	2.88%
1.00	2.05	2.12	3.41%
1.50	3.06	3.16	3.27%
2.00	4.04	4.18	3.47%
2.50	5.04	5.22	3.57%
3.00	6.03	6.25	3.65%
Average magnitude of error:			3.38%

Table 1: Standard 2-wire measurements

Current (A)	Voltage at Load (V)[1]	2-wire adjusted measurement (V)[2]	% error
0.50	1.04	1.05	0.96%
1.00	2.05	2.07	0.98%
1.50	3.06	3.08	0.65%
2.00	4.04	4.07	0.74%
2.50	5.04	5.09	0.99%
3.00	6.03	6.09	1.00%
Average magnitude of error:			0.89%

Table 2: Adjusted 2-wire measurements

Current (A)	Voltage at Load (V)[1]	Pseudo 4-wire measurement (V)[2]	% error
0.50	1.04	1.05	0.96%
1.00	2.05	2.08	1.46%
1.50	3.06	3.10	1.31%
2.00	4.04	4.09	1.24%
2.50	5.04	5.12	1.59%
3.00	6.03	6.13	1.66%
Average magnitude of error:			1.37%

Table 3: Pseudo 4-wire measurements

1. Measurements taken using Agilent Multimeter
2. Measurements taken using LDT-5940C

CONCLUSION

These results demonstrate the usefulness of adjusted 2-wire and pseudo 4-wire methods in increasing accuracy of voltage measurements. This can translate into better temperature accuracy and more reliable data on laser diode characteristics.

Pseudo 4-wire measurement provides better accuracy than 2-wire measurement. However, a second connection must be made to the load. The effort in making this connection is minimized by using connection cables which contain independent voltage sense wires. For example, all ILX connection cables have independent voltage sense wires for pseudo 4-wire measurements.

The further increase in accuracy seen with adjusted 2-wire measurements requires accurate measurement or calculation of wire resistance. The overall accuracy of these measurements is dependent on the accuracy of the wire resistance entered. Theoretically, percentage error can be made arbitrarily low if data on wire resistance is perfectly accurate. Obtaining wire resistance data requires extra effort. However, if accurate measurements are vital, adjusted 2-wire measurements can offer the best performance when careful calculations and/or measurements of wire resistance are performed.