

# University of Southern California

Department of Electrical Engineering - Electrophysics

EE 326Lx Essentials of Electrical Engineering

Lab #1

This lab concerns voltage, current, and resistance measurements using the HP (now Agilent) 34401A digital multimeter (DMM). Although you may have experience with these measurements, you are probably unfamiliar with several sources of error.

Before you begin, take a moment to review the protoboard organization shown in Fig. 1. The individual holes in each of the horizontal sets of five are electrically connected and typically provide access to circuit components. The long vertical columns of holes are also electrically connected and typically support commonly used voltage levels such as the supply voltage and ground.

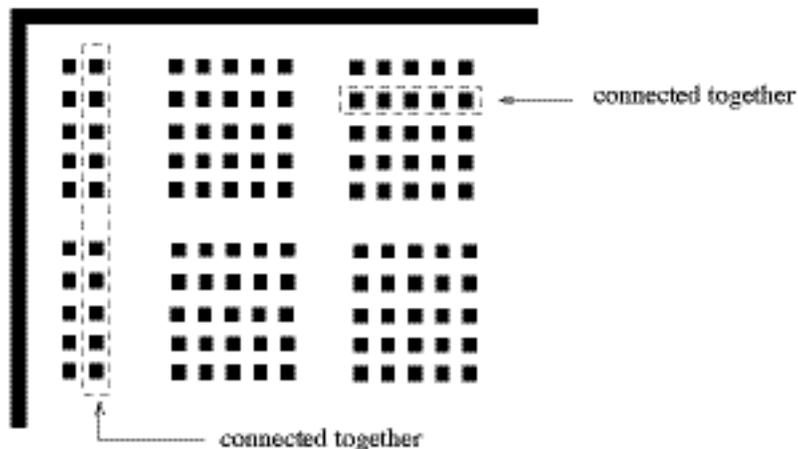


Figure 1: A small section of the protoboard.

## Part A

1. Connect two test leads to the HI and LO holes on the right side of the DMM front panel, then configure the instrument to test electrical continuity (resistance less than a small preset value) by pressing the “Cont” button. The instrument should beep when the leads are connected together.

Note: You can view the preset threshold for electrical continuity by pressing Shift then On/Off from the MENU CHOICES buttons. The menu tree has three levels: Menus, Commands, and Parameters. Move down ( $\nabla$ ) or up ( $\wedge$ ) the tree to get from one level to the next, and view the horizontal choices by moving left ( $<$ ) or right ( $>$ ). The preset threshold is located in Menu A, Command 2, Parameter level. Please do not change the setting.

2. Use the continuity checker to confirm the organization of your protoboard.
3. Now consider the green “GND” terminal on the power supply.

Is it connected to the metal case of the power supply?

Is it connected to the “COMMON” terminal on the power supply?

In your write-up . . . What are the electrical motives for your results?

## Part B

1. Obtain a  $10\text{-}\Omega$  resistor from a TA, then construct the circuit of Fig. 2. Use the + and - terminals of the 6-V supply, and set it to 1.000 V.

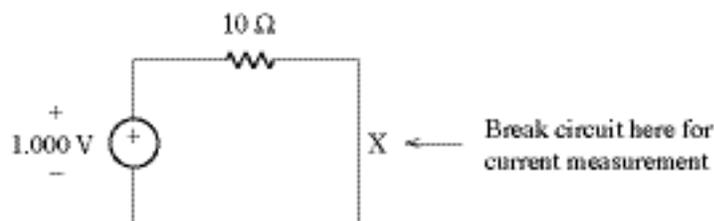


Figure 2: Circuit for Part B.

2. Use the DMM front-panel test-lead connections of §A1, but configure the instrument as a voltmeter by pressing “DC V.” Connect a lead at each end of the resistor, and measure the voltage across it. How does your measurement compare with the voltage indicated on the power-supply panel? Explain.
3. Adjust the the voltage measurement scale downwards ( $\vee$ ) or upwards ( $\wedge$ ) by pressing the appropriate button. Find the most sensitive scale that does not indicate OVLD (overload), then determine the power-supply voltage that produces OVLD on this scale. Return the power supply to a 1.000-V setting.
4. The DMM normally displays a digital voltage at short and regular intervals following precise analog-to-digital conversions (ADCs). Fluctuations in the voltage display often reflect the corrupting influence of electrical noise.

To view the result following a *single* ADC, press the “TRIG” button. Press the button again to clear and view another instantaneous result. Press “Shift” then “TRIG” to return to autotriggering.

The DMM can average over several samples to suppress fluctuations. Go to Menu C, Command 3, Parameter level to see the preset value for the number of samples per trigger. Use the  $\vee$  and  $\wedge$  keys to set a new value at 10, then press “ENTER.” How does this affect your measurement, particularly in terms of speed? Please restore the preset number of samples when finished.

5. Break the resistor circuit at the point indicated by the “X” in Fig. 2. Use another DMM: Connect a test lead between the front-panel hole marked “I” and the resistor end at the break, and connect a test lead between the front-panel hole marked LO and the negative (-) supply end at the break. Configure the instrument as an ammeter by pressing “SHIFT” then “DC I.” Does the current reading meet expectations?

Note: ALWAYS break a circuit before inserting an ammeter. In the event that a protocol-challenged student from another class has failed to do this, the ammeter may have a blown fuse and no indication. Have a TA check the DMM and provide a new 2-A fuse, if necessary.

6. The DMM measures current by looking at the voltage across a very small internal resistance and calculating the consistent current through Ohm’s law.

What is the measured current when the ammeter indicates the largest number of significant digits for a scale in amperes (A)? What is the measured current when the ammeter has the smallest number of significant digits for a scale in milliamperes (mA)? Explain your results by measuring the voltage across the ammeter for each condition. (This will allow you to determine the internal resistance of the ammeter.)

In your writeup . . . A dc-to-dc converter (found in most laptop computers) has an input terminal pair that is connected to a battery and an output terminal pair that is connected to an unknown bounded load resistance. The converter is called a boost converter if the output voltage is larger than the input voltage. It is called a buck converter under opposite conditions. Either way, one hopes for a high-efficiency conversion process in which the ratio of output to input power is not far below unity. An inefficient converter would quickly drain the battery. In view of your results from Part B, show how you would connect two voltmeters and two ammeters to measure the converter efficiency with minimal error over several decades of load current.

### **Part C**

1. Connect two test leads to a DMM as in § A1, but configure the instrument as an ohmmeter by pressing “ $\Omega$  2W.” Measure:

The resistance of the resistor of Part B (for write-up calculations).

The through-body resistance from one hand to the other for both you and your lab partner.

The internal resistance of a DMM set in voltage mode.

The resistance from one end to the other of a five-hole protoboard set.

2. The last of the preceding resistance measurements should be very small. As such, it can be corrupted by parasitic contributions such as the series resistance of the leads and the series contact resistance between each lead and its point of connection with the device under test (DUT). You can nearly eliminate these contributions in one of two ways:

Disconnect the DUT, connect the leads at their ends, and press “Null.” Then repeat the measurement with the DUT (five-hole protoboard set). What is the resistance? The null function subtracts lead resistance.

Perform a four-wire “Kelvin” measurement. Connect the test leads as before, but include two other leads—one from the high side of the DUT and the other from the low side of the DUT to the left-side HI and LO front-panel holes, respectively. Press Shift then “ $\Omega$  4W” to measure. What is the resistance? Explain your result in terms of the equivalent circuit of Fig. 3. Hint: What is the current through  $R_b$  and  $R_b'$ ?

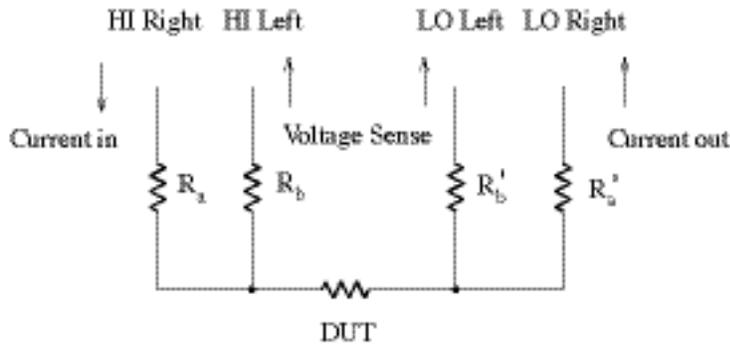


Figure 3: Circuit for a Kelvin 4-wire resistance measurement.

## Part D

1. Ask the TA to give you a MAX874 voltage reference IC, which provides constant-voltage output over a range of temperature and load conditions. (This will be used in Lab 2.) Find the data sheet at [www.maxim-ic.com](http://www.maxim-ic.com). Provide a 5-V input at pin 2 in relation to ground (Pin 4). Measure the output voltage at pin 6.
2. Devise a means for measuring the output voltage vs. source load current, then plot your results for  $10 \mu\text{A} < i_{source} < 10 \text{ mA}$ . (Excel will be helpful.) You can change the load current with the help of a 100-k $\Omega$  potentiometer. Stop the measurement when the output voltage changes by more than 50 mV from its zero-load value. Compare your results with the Typical Operating Characteristic (TOC) shown in the data sheet.

3. Devise a means for measuring the output voltage vs. sink load current—this is current pushed back into the voltage reference from a higher potential. Plot your results for  $10 \mu\text{A} < i_{\text{sink}} < 10 \text{ mA}$ . Stop the measurement when the output voltage changes by more than 50 mV from its zero-load value.

Note: The TA will give you a 10-k $\Omega$  variable resistor (potentiometer) to facilitate the preceding measurements. If necessary, have the TA explain the function of the potentiometer terminals.