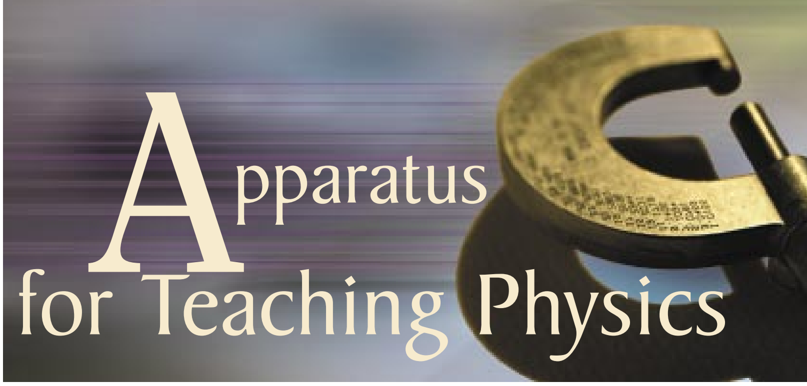

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Using the Vernier LabPro as an Ohmmeter and Multimeter

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Vernier Software and Technology's LabPro® data acquisition device[1] has the cursorily documented[2] ability to measure resistance. Here we describe how to build a resistance probe and how to configure Vernier's Logger Pro® data acquisition software to automatically detect and understand the probe. We discuss the range, accuracy, and limitations of this ohmmeter. When this probe is used with voltage and current probes already available from Vernier, the LabPro may be used as a digital multimeter.

Until recently, we used LabPros in tandem with ordinary digital multimeters in our general physics laboratories. The LabPro was used to measure voltage and current while a multimeter was required to measure resistance. Since our multimeters were approaching the end of their service life and also tend to be permanently "borrowed" by faculty and graduate students, we wondered if we could use the LabPro to measure resistance. We learned that the LabPro contains a built-in ohmmeter that needs only a simple probe to be used. Although this ohmmeter is not currently marketed *or supported* by Vernier, the LabPro uses this function to automatically detect probes that contain specific resistors. The LabPro technical manual[2] briefly describes how to build a resistance probe and suggests that it would have a usable range of 1 kΩ to 100 kΩ. We have found that the ohmmeter has the respectable range of about 100 Ω to 1 MΩ.

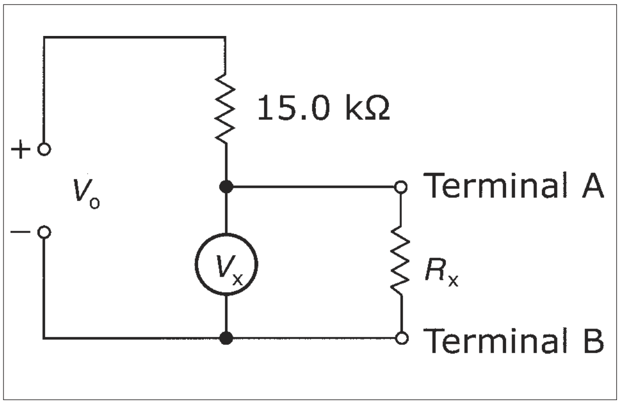

Fig.1. The ohmmeter voltage divider circuit.

The LabPro's built-in ohmmeter is a simple voltage divider circuit (see Fig. 1). The unknown resistor R_x is placed in series with a known resistor R_o, which is 15.0 kΩ. The LabPro measures the voltage V_x across R_x. This voltage is related to the reference voltage V_o by

$$V_x = \frac{R_x}{R_x + R_o} V_o .$$

The unknown resistance may be calculated from this equation by solving for R_x:

$$R_x = \frac{V_x}{V_o - V_x} R_o .$$

The LabPro reference voltage V_o is nearly 5.0 V. It is important to realize that the accuracy of V_o has a substantial effect on the accuracy of the upper range of the ohmmeter. Consider that if the unknown resistance R_x is much greater than R_o, then V_x will be close to V_o.

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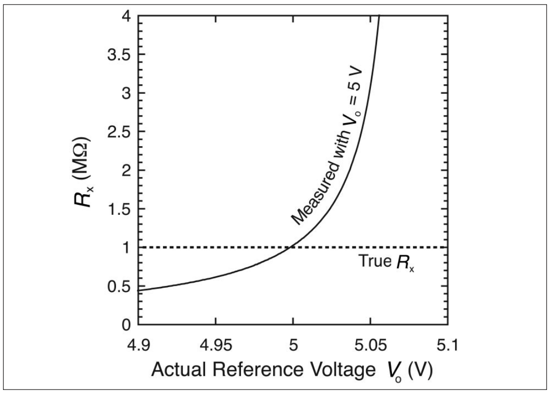

Fig. 2. The resistance of a 1-MΩ resistor measured with a LabPro using a reference voltage V_o that is incorrectly assumed to be exactly 5 V.

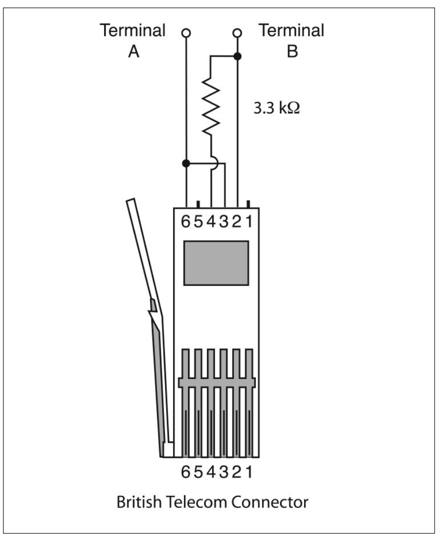

Fig. 3. Design of a resistance probe that includes an auto-identification resistor.

Therefore, a small error in V_o can lead to a nearly vanishing denominator and a diverging R_x. This effect of an inaccurately known V_o on the value of R_x measured by the ohmmeter is illustrated in Fig. 2. Calibration of the ohmmeter (through software) is therefore an exercise in improving the accuracy of V_o.

```
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<Calibration Units="" PrettyUnits="Volts " IDName="RP" UserName="Ohmmeter" IDValue="4"
        DDSIndex="0" RangeDesc="" ColumnName="Potential" ShortColumnName="Pot"
        ExperimentType="1" DecimalPlaces="-1" Trace="0">
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    <DisplayRange YMin="0" YMax="5"/>
<CalcColumn0 Name="Resistance" ShortName="R" Units="kOhms"
        Equation="%sID*15/(5-%sID)"
        YMin="0" YMax="1000" DecimalPlaces="3" Trace="2"/>
    </Calibration>
    </CalibrationList>
</Sensor>
```

Fig. 4. Ohmmeter configuration text entry for the file "Sensormap.xml."

Design of the Resistance Probe and Configuration of Logger Pro

Probes are connected to the LabPro using British-Telecom-type connectors. To construct a resistance probe, solder a 3.3-kΩ resistor between the AutoID line (Pin 4 of the BT connector) and the ground line (Pin 2). Solder an alligator-type clip to the ground line. For the second terminal, connect both the Vres (Pin 3) and the Vin-low (Pin 6) lines together to an alligator-type clip. Refer to the circuit diagram shown in Fig 3.

Logger Pro 3.2[3] uses the file "Sensormap.xml" to interpret AutoID codes. In Mac OS X, this file can be accessed by control-clicking on Logger Pro and choosing "Show Package Contents" in the contextual menu, and then navigating through the folders "Contents" and "Resources." In Windows, this file is located in the folder "Support" in the "Logger Pro 3" folder. Make a backup copy of this file. Then either replace it with the modified version available on our website (http://www.physics.pdx. edu/~bodegom/ohmmeter) or modify it yourself. To do this, open the file with a text editor. Scroll to the bottom of the page and insert the text shown in Fig. 4 before the line that contains </SensorMap>. It is probably easier to duplicate a similar entry in this file and make the necessary changes to match the text in the figure.

The equation Logger Pro uses to calculate resistance, Equation= "%sID*15/(5-%sID)", is located near the end of the block of text in "Sensormap.xml." This is the equa-

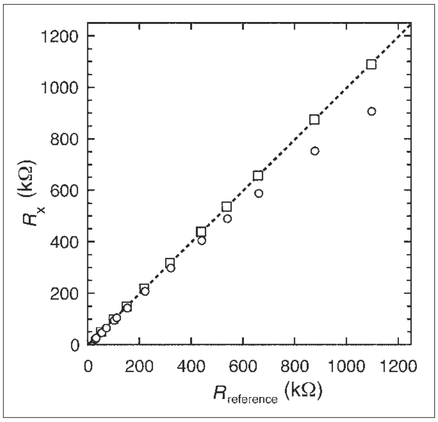

Fig. 5. Difference between the resistance measured by a particular LabPro before and after calibration of the reference voltage. The dashed line represents perfect agreement with an ordinary digital multimeter.

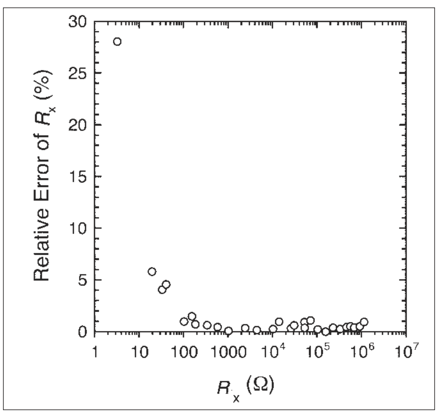

Fig. 6. Relative error of a particular LabPro ohmmeter. Note that the relative error increases below 100 Ω.

tion given above for R_x. V_x is "%sID, R_o is 15, and V_o is 5. To calibrate the ohmmeter, connect an independently measured high-value resistor (e.g., 1.000 MΩ) to the resistance probe. Adjust V_o, by 1 mV or smaller steps, until R_x measured by the LabPro agrees with the known value within a percent or two. This will require repeated trials of adjusting V_o, saving the file, loading Logger Pro, measuring R_x, and quitting Logger Pro to readjust V_o. As long as the LabPro remains matched to the computer, this calibration should not be required again.

To use the LabPro as a digital multimeter, simply connect resistance, voltage, and current probes. Logger Pro 3.2 automatically detects and configures itself for any combination of probes.[4]

Discussion

To determine the accuracy of the ohmmeter, we measured the resistance of resistors having values from a few ohms to more than 1 MΩ with a LabPro operated by uncalibrated and calibrated software. In Fig. 5 the resistances measured by the LabPro are plotted against the values read by an ordinary digital multimeter. In this plot, a slope of one indicates complete agreement between the two instruments. For R_x less than about 200 kΩ, the LabPro ohmmeter agrees with the multimeter even when Logger Pro is not calibrated. For larger resistances, the calibrated LabPro ohmmeter and digital multimeter agree up to 1 MΩ (higher-value resistors were not tested).

The precision of the LabPro suffers when R_x is less than about 100 Ω. In this range, readings can fluctuate by 10% or more, especially when R_x is less than 20 Ω. The relative error of the LabPro ohmmeter is plotted in Fig. 6. The error was determined by considering the fluctuation in individual readings and the disagreement between the LabPro and a digital multimeter. We found that within the range of 100 Ω to 1 MΩ, the LabPro has a relative error about 1 or 2%.

To test the variability of reference voltages from LabPro to LabPro, we determined V_o for 24 LabPros. We found that 21 LabPros had V_o's between 4.9910 and 5.0015 V. Three LabPros had reference voltages from 5.0700 to 5.0708 V. Based on this small sample size, V_o will usually need only slight adjustment in Logger Pro to achieve reasonable accuracy up to 1 MΩ. Because of the variability of reference voltages that we observed, we recommend that each LabPro be identified in some way so that it can be paired permanently with the computer that stores the LabPro's unique reference voltage.

Vernier's LabPro can be used as an ohmmeter that has an accuracy of ± 1 or 2% within a range of 100 Ω to 1 MΩ. This range and accuracy should be sufficient for educational use. Vernier's Logger Pro data acquisition software can be altered to automatically identify resistance probes that contain an AutoID resistor. This means that the resistance probe is as easy to use as other commercially available probes. When the resistance probe is combined with the voltage and current probes currently sold by Vernier, the LabPro can be used as a digital multimeter.

References

1. Vernier Software & Technology, Beaverton, OR 97005; http://www.vernier.com.
2. *LabPro® Technical Reference Manual* (Vernier Software & Technology, Beaverton, OR, 2000), p. 77.
3. Logger Pro 2.2.1 uses a quite different approach for identifying and configuring probes. Files and instructions for using this resistance probe with Logger Pro 2.2.1 can be found on our website; http:// www.physics.pdx.edu/~bodegom/ohmmeter.
4. This is not true for Logger Pro 2.2.1, since this version requires specific probe configuration files. The files needed to use the LabPro as multimeter are available on our website; http://www.physics.pdx.edu/~bodegom/ohmmeter.

PACS codes: 01.50P, 07.50, 06.70Hs