MSL Technical Guide 5

Using the Leeds & Northrup 8078 Resistance Bridge

Introduction

The Leeds and Northrup 8078 resistance bridge (also sold by Minco in the USA) is a direct-reading resistance bridge with a range from 0 Ω to 299.99 Ω. The bridge is balanced manually using thumbwheel switches on the front panel. The balance condition of the bridge is indicated on the front-panel meter and as a voltage through the recorder output terminals, also on the front panel. The thumbwheel switches give the bridge a resolution of 0.01 Ω, but the bridge is capable of higher accuracy if an extra digit is interpolated either using the front panel meter or the chart recorder output.

This technical note gives guidance on how to minimise the errors in the bridge readings and obtain the best accuracy. With care the bridge is capable of accuracies approaching 0.001 Ω.

Setting the Bridge Zero

For the best accuracy the bridge zero should be set or measured before resistance measurements are made. This is done by connecting a four-terminal short circuit to the bridge. However, the shorting plug recommended in the L&N 8078 manual does not give a perfect four-terminal zero. Instead, a shorting plug with the connections shown in Figure 1 should be used.

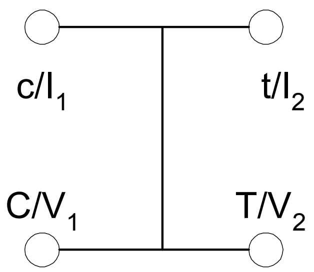

Figure 1. Connections for the 4-terminal shorting plug.

Interpolating Bridge Readings

For the best measurement uncertainty, one of the following two interpolating procedures should be used. If calibrated by MSL, the bridge will have been calibrated using one of these two procedures. Interpolation using a digital volt meter (DVM) will generally yield a slightly lower uncertainty than that for visual interpolation.

Option 1: Visual Interpolation

- Turn the bridge on and set it to OHMS mode.
- Wait at least 1 hr for the bridge to settle before commencing measurements.
- Connect the four-terminal shorting plug to the bridge and adjust the thumbwheel switches so that they read 00.00 Ω.
- Adjust the screw on the front of the meter so that the meter reads zero.
- Now connect the resistance (thermometer) you wish to measure.
- Adjust the thumbwheel switches so that the meter indicates as close as possible to zero. This ensures that the meter non-linearity does not affect the reading.
- Use the front panel meter to read the next digit of the reading. One small division on the meter is approximately 0.001 Ω. You will need to add or subtract up to 0.005 Ω to the thumbwheel switch setting.

Option 2: DVM Interpolation

- Turn the bridge on and set it to OHMS mode.
- Wait at least 1 hr for the bridge to settle before commencing measurements.
- Connect the four-terminal shorting plug to the bridge and adjust the thumbwheel switches so that they read 00.00 Ω.
- Record the voltage at the recorder output. This voltage is V_0 in the equation below.
- Now connect the resistance (thermometer) you wish to measure.
- Adjust the thumbwheel switches so that the meter indicates as close as possible to zero. There will generally be two dial settings (R_1 and R_2) that differ by 0.01 Ω, corresponding to the meter indications either side of zero.
- For each of the two readings R_1 and R_2, measure the corresponding recorder output voltages (V_1 and V_2). V_1 and V_2 will differ by about 50 mV.
- The interpolated reading is then

$$R = R_1 + 0.01\left(\frac{V_1 - V_0}{V_1 - V_2}\right).$$

The DVM interpolation can be easily implemented using a spreadsheet application.

Correcting Bridge Errors

The L&N 8078 resistance bridge employs an ac voltage divider based on a transformer to form one arm of a Wheatstone bridge. The thumbwheel switches are used to select the appropriate transformer ratio to balance the bridge. Figure 2 shows a typical error characteristic for an L&N 8078 bridge. Note that 10 mΩ on the left-hand scale of the graph corresponds to

0.01 Ω on the thumbwheel switches, so the errors are actually quite small. There are three main sources of error in the readings, and all three effects are apparent in Figure 2.

The Meter Offset Error

The meter offset causes a constant error for all resistance readings. Ideally the calibration line should show zero error at zero ohms reading. In Figure 2 it causes the calibration line to intersect just below the zero. The offset error is minimized by adjusting the meter using the shorting plug and the interpolation procedures given above. For highest accuracy, use DVM interpolation.

The Reference Resistor Error

The bridge has an internal resistor with a value chosen so that the thumbwheel switch settings correspond to the measured resistance in ohms. The internal resistor is not perfect so there is a small error that affects all readings in proportion to the reading. This is apparent in Figure 2 from the overall upward slope of the calibration line.

The Transformer Error

The transformer divider used in the bridge is not a perfect divider, so there are small errors that depend on which dials of the thumbwheel switches are used. The error is most pronounced in the most significant digits and gives rise to the 'sawtooth' shape in the calibration line.

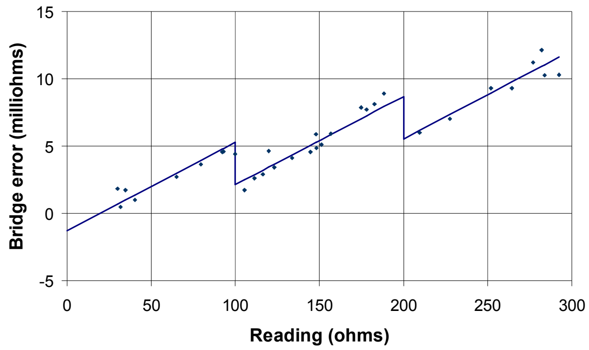

Figure 2. Typical error characteristic of an L&N 8078 resistance bridge. The points indicate measured errors and the 'sawtooth' shaped line indicates the calibration equation.

Correcting the Errors

As already described, the offset error is minimised by following the adjustment and interpolation procedures given above. The errors due to the reference resistor and the transformer can only be eliminated by having the bridge calibrated and applying corrections.

In the calibration certificate provided by MSL we give a calibration equation of the form

$$\text{resistance} = (1 + A_1)R + A_2\text{Frac}(R/100\Omega)\ ,$$

where Frac(x) is the fractional part of x, e.g. Frac(1.47) = 0.47.

This equation converts the bridge reading, R, (actually the dial setting for the thumbwheel switches) into resistance (Ω). The A_1 term corrects for the error in the reference resistor, and the A_2 term corrects for the transformer errors. Note that the values of A_1 and A_2 vary from one bridge to another.

Because of the rapid changes in the calibration line near readings in the ranges 99.99 Ω to 100.00 Ω and 199.99 Ω to 200.00 Ω, you must use the dial setting and not the interpolated reading in the calibration equation.

With the meter offset properly adjusted and the correction equation used, the L&N 8078 bridge is capable of measuring resistance with uncertainties as low as 0.001 Ω.

Prepared by D R White, September 2003.