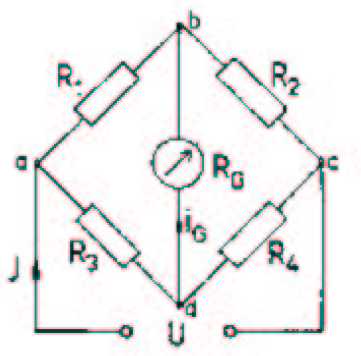
Bridge Circuit
(BRÜ)

Manuel Staebel – 2236632 / Michael Wack 2234088

1 Introduction

In this experiment, a method for a very exact measurement of resistances will be applied. The bridge circuit makes use of the fact that current can be measured more precisely than resistance (when measuring resistance directly, at least the internal resistor of the measurement device falsifies the results and you have to measure voltage and current). When using the bridge circuit only the ratio of resistors can be determined. Let's assume Resistor R_1 is unknown, and R_2 is variable, then the position of R2 has to be found were no current i_G is flowing. The R_1 can be calulated.



bridge circuit *(copy from the experiment instructions)*

2 Results

2.1 Specify for the circuits shown in figure 6a and 6b the conditions for adjustment for the real and the imaginary part.
As given in the manual, the conditions for adjustment are:

figure 6a:

$$\frac{1}{Z_1}=\frac{1}{R_1}+i\omega C_1;\quad Z_2=R_2-\frac{i}{\omega C_2};\quad Z_3=R_3;Z_4=R_4;$$

figure 6b:

$$\frac{1}{Z_1}=\frac{1}{R_1}-\frac{i}{\omega L_1};\quad Z_2=R_2+i\omega L_2;\quad Z_3=R_3;\quad Z_4=R_4;$$

2.2 Calculate ...

2.2.1 ... the ohmic resistance of the potentiometer out of the three performed measurements. Are the values within the measuring inaccuracy?

$$\frac{R_1}{R_2}=\frac{A}{1000-A}\Rightarrow R_2=\frac{R_1\cdot(1000-A)}{A}$$ (Used voltage: $(0{,}5\pm 0{,}2)\,\mathrm{V}$)

Comparator resistor R_1	***Scale (A)***	***Resistor R_2***
$10\,\Omega$	82	$112\,\Omega$
$20\,\Omega$	157	$107\,\Omega$
$100\,\Omega$	475	$111\,\Omega$

arithmetic mean value: $\bar{R}_1 = 110\ \Omega$
mean square deviation: $\sigma_{R1} = 2{,}6\ \Omega$
measuring inaccuracy: $u_{R1} = \sigma_{R1}\cdot 0.76 = 2{,}0\ \Omega$

$R_1=110{,}0\pm 2{,}0\,\Omega$

Only the measurement with the $20\,\Omega$ comparator resistor isn't within the range of the measuring inaccuracy.

2.2.2 ... the resistance of the light bulb from the measurements with three comparator resistors. Are these values within the measuring inaccuracy?

$$\frac{R_1}{R_2}=\frac{A}{1000-A}\Rightarrow R_2=\frac{R_1\cdot(1000-A)}{A}$$ (Used voltage: $(3\pm 0{,}2)\,\mathrm{V}$)

Comparator resistor R_1	*Scale (A)*	*R_2 (light bulb)*
$10\,\Omega$	102	$88{,}0\,\Omega$
$100\,\Omega$	724	$38{,}1\,\Omega$
$200\,\Omega$	883	$26{,}5\,\Omega$

arithmetic mean value: $\bar{R}_2 = 50{,}9\ \Omega$

mean square deviation: $\sigma_{R2} = 3 \cdot 10^1\ \Omega$

measuring inaccuracy: $u_{R2} = \sigma_{R2} \cdot 0.76 = 2 \cdot 10^1\ \Omega$

$R_2 = 5 \pm 2 \cdot 10^1\,\Omega$

Obviously most of the values are out of the measurement inaccuracy.

2.2.3 ... the ohmic resistance of the light bulb from the series of measurements 1c. Calculate the currents through the light bulb and plot R over I. Discuss the determined characteristic line.

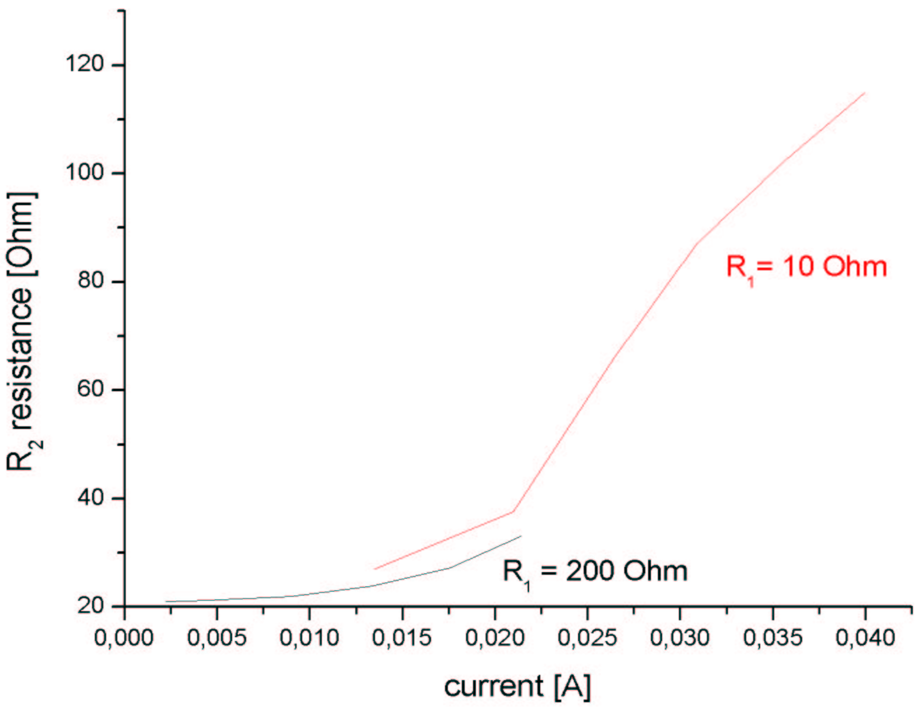
The current can be determined by the following formula: $I = \dfrac{U}{R_1 + R_2}$; R_2 is calculated as above.

R1 = 200

U [V]	A	R2 [Ohm]	I [A]
0,5	905	20,99	0,0023
1	904	21,24	0,0045
2	901	21,98	0,0090
3	893	23,96	0,0134
4	880	27,27	0,0176
5	858	33,1	0,0215

R1 = 10

U [V]	A	R2 [Ohm]	I [A]
0,5	270	27,04	0,0135
1	210	37,62	0,0210
2	132	65,76	0,0264
3	103	87,09	0,0309
4	89	102,36	0,0356
5	80	115	0,0400



For high currents (> 20 mA) thru the lamp, the resistance is proportional to the current. The reason for this is, that the glow wire is heated by the current and so its resistance rises, because the resistance of metal is proportional to the temperature. In case of lower currents the resistance gets more and more independent of the current. Perhaps the lamp is cooled down enough by the surrounding air in this case.

2.3 How large is the ohmic resistance of the two coils?

U = 0,5V

Comparator resistor: R_2 = 10 Ω

$$R_1 = \frac{A \cdot R_2}{1000 - A}$$

	A	R_1 [Ω]
small coil	209 ± 1	2,64
large coil	943 ± 1	165,4

It is not understandable why the larger coil has a much higher ohmic resistance than the small coil.

2.4 From the measured values, calculate the inductivity of the coils and the capacity of the capacitors. Which value do you theoretically expect for the inductivity of the half coil?

Coils:

$$\frac{R_1 + j\omega L_1}{R_2 + j\omega L_2} = \frac{A}{1000 - A}$$

Small coil:

A	R_V [Ω]
346 ± 1	78 ± 1
345 ± 1	79 ± 1
346 ± 1	80 ± 1
$\bar{A} = 346$	$\bar{R}_V = 79$

R_{big} = 165,4 Ù (see 2.3)

$R_{big} = R_2 + R_V$

$R_1 = R_{small}$ = 2,64 Ù

$L_2 = L_{big}$ = (0,023 ±0,001 H)

$$R_1 + j\omega L_1 = \frac{\bar{A}[(R_{big} + \bar{R}_V) + j\omega L_2]}{1000 - A} = 129\,\Omega + j\omega \cdot 0{,}012\,H$$

The calculated inductivity of the small coil is (0,012 ± 0,002) H.

Half of the big coil:

A = 855 ± 1

R_V = 29 Ω

R_{small} = 2,64 Ω

$R_2 = R_{small} + R_V$

$R_1 = R_{big}$ = 165,4 Ω

L_2 = 0,012 H

$$R_1 = j\omega L_1 = \frac{A[(R_{small}+R_V)+j\omega L_2]}{1000-A} = 187\Omega + j\omega\, 0{,}071\, H$$

Theoretical value of half of the big coil:

$L = \mu A \frac{N^2}{l}$ is the inductivity for long coils with a small diameter in comparison to the length. Using only half of the coil we have N/2 which gives us about L/4 of the inductivity.

Unfortunately it seems there were already rudimentary errors in our measurement in 2.3 (ohmic resistance of the large coil higher than the resistance of the small coil). This error is continued in the following calculations which leads to useless results for the inductivity of the coils.

Capacitor:

$$\frac{Z_1}{Z_2} = \frac{\frac{-j}{\omega C_1}}{\frac{-j}{\omega C_2}} = \frac{C_2}{C_1} = \frac{A}{1000-A} \qquad \Rightarrow C_1 = \frac{(1000-A)C_2}{A}$$

A = 330 ± 1

C_2 = 1 μF

These values give us a capacity of C_1 = 2,0 μF .