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The Analysis and Experiment of the Wheatstone Bridge

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Abstract

Wheatstone bridge is a bridge circuit composed of four resistors. It uses the change of resistors to measure the change of physical quantity. In this paper, the basic concept of the Wheatstone bridge is first introduced, then the theoretical analysis and practical experiment are carried out. Finally, how to build, test and characterize a Wheatstone bridge is understood. It is also pointed out that in application, a Wheatstone bridge circuit is typically used to measure small variations in resistance that the sensing element produces in response to stress, temperature and other phenomena.

Keywords

Wheatstone bridge, Quarter-bridge, Difference.

1. Introduction

Wheatstone bridge, also known as single arm bridge, is an instrument that can accurately measure small outputs such as resistance, capacitance or inductance of an electronic device [1]. In this lab, a Wheatstone bridge is used to convert the change in resistance of a sensor into a voltage output. As shown in Fig. 1, the Wheatstone bridge is essentially a circuit consisting of four resistors: R_1, R_2, R_3 and R_4. There is a voltage input V_{in} and a voltmeter to measure V_{out} (the voltage difference between points A and B).

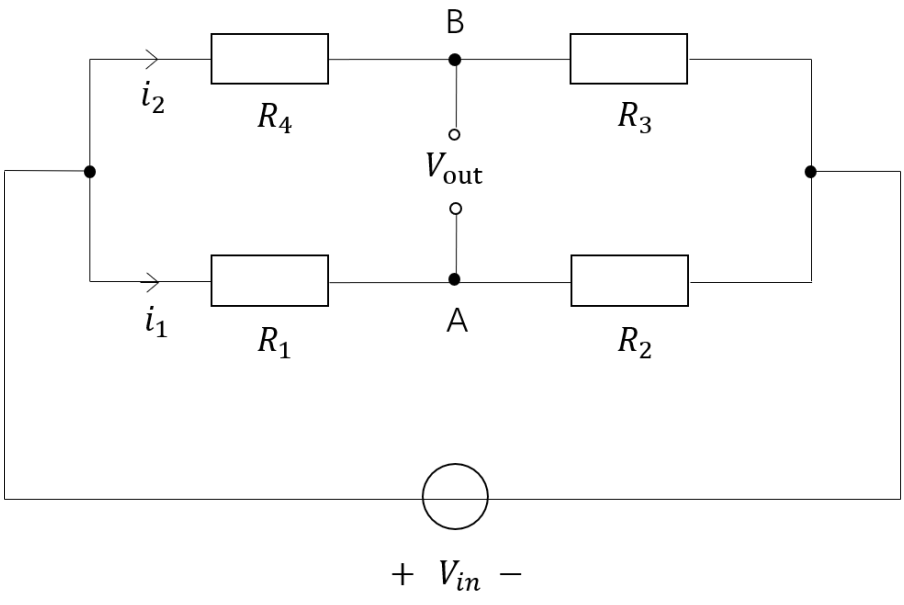

Fig. 1 The general Wheatstone bridge

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2. Theoretical analysis

For the Wheatstone bridge shown in Fig. 1, the general voltage difference between the points A and B is

$$V_{out} = V_{R2} - V_{R3} = i_1 R_2 - i_2 R_3 = V_{in}\left(\frac{R_2}{R_1 + R_2} - \frac{R_3}{R_3 + R_4}\right) \tag{1}$$

When the Wheatstone bridge is balanced, that is $\frac{R_2}{R_1} = \frac{R_3}{R_4}$, the voltage difference between the points A and B is

$$V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2} - \frac{R_3}{R_3 + R_4}\right) = V_{in}\frac{R_2 R_4 - R_1 R_3}{(R_1 + R_2)(R_3 + R_4)} = 0 \tag{2}$$

When there is a change ΔR in one of the four resistors, then the bridge becomes unbalanced with quarter-bridge. Assume $R_1 = R_2 = R_3 = R$, $R_4 = R + \Delta R$ and ΔR is small in Fig. 1, the voltage difference between the points A and B is

$$V_{out} = V_{in}\left(\frac{R}{R + R} - \frac{R}{R + R + \Delta R}\right) = V_{in}\frac{\Delta R}{4R + 2\Delta R} \cong \frac{V_{in}}{4}\frac{\Delta R}{R} \tag{3}$$

3. Practical experiment

3.1 Operation

In order to build the Wheatstone bridge circuit on a bread board and measure the current through each resistor, the procedure includes the following steps:

(i) Read the Wheatstone bridge circuit shown in Fig. 2.

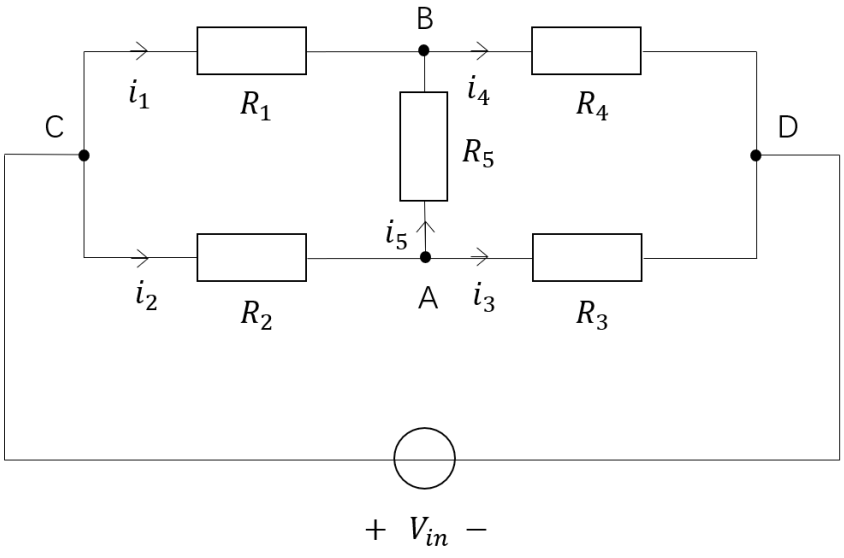

Fig. 2 The specific Wheatstone bridge

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(ii) Find four resistors which makes $R_1 \approx R_2 \approx R_3 \approx R_4 \approx R_5 \approx 390\Omega$, and measure them by using the Digital Multimeter, get $R_1 = 389\Omega$, $R_2 = 380\Omega$, $R_3 = 382\Omega$, $R_4 = 385\Omega$, $R_5 = 385\Omega$.

(iii) Place each resistor in the correct configuration on bread board to make the bridge as balance as possible as shown in Fig. 3.

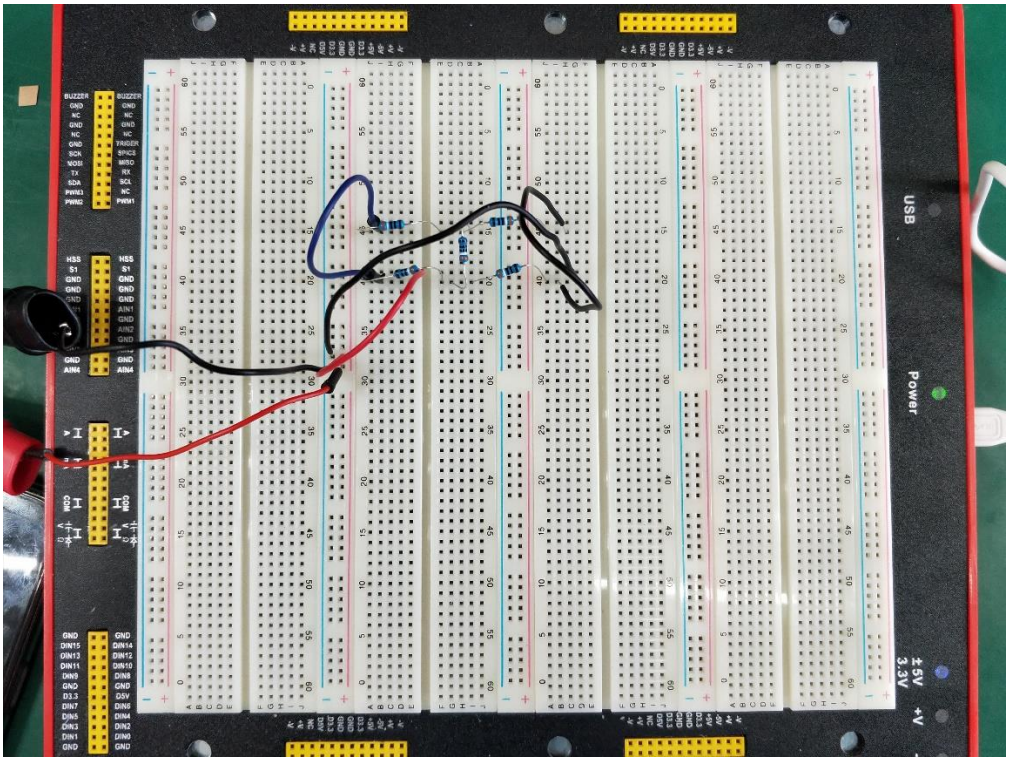

Fig. 3 The actual circuit

(iv) Connect the GWINSTEK GPE-4323C DC Power Supply to the Wheatstone bridge circuit by using CH4 supplying a voltage of 5V at 1A between the points C and D.

(v) Measure the current flowing through each resistor by using the Digital Multimeter.

3.2 Analysis

Using circuit analysis method, compute the current flowing through each resistor for the Wheatstone bridge and get Table 1.

Table 1 Comparison of measured current and calculated current

Resistor	Measured current (mA)	Calculated current (mA)	Error (%)
$R_1(I_1)$	6.39	6.41	-0.312
$R_2(I_2)$	6.40	6.41	-0.156
$R_3(I_3)$	6.40	6.41	-0.156
$R_4(I_4)$	6.42	6.41	0.156
$R_5(I_5)$	0.02	0	2

Compare the current measured experimentally with the computed current, it is concluded that due to the difference between the ideal resistance value and the actual resistance value, the resistance value

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of R_1, R_2, R_3, R_4 is not the same, resulting in the actual current flowing through the four resistors is not the same, and the current flowing through R_5 is not 0. But because the resistance difference is not big, so the current difference and error is not big, and the circuit can be approximately balanced state.

4. Conclusion

In this lab, it helps to understand how to build, test and characterize a Wheatstone bridge, and study its configuration along with theory and principle. For quarter-bridge configuration, if one of the resistors is used as a sensing element to measure mechanical stress applied to a structure such as aircraft or wind turbine [2], the stress will change the resistance value of the sensing element in the Wheatstone bridge and the voltage difference will change as a result.

References

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