

DC BRIDGES

4.1 Fundamental Concept of Bridges Circuit

In DC measurement circuits, the circuit configuration known as a *bridge* can be a very useful way to measure unknown values of resistance.

To review, the bridge circuit works as a pair of two-component voltage dividers connected across the same source voltage, with a *null-detector* meter movement connected between them to indicate a condition of "balance" at zero volts:

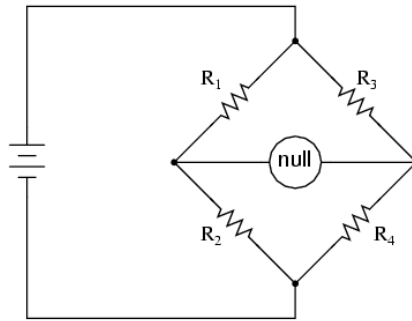


Figure 4.1 : Basic schematic diagram of standard bridges

Any one of the four resistors in the above bridge can be the resistor of unknown value, and its value can be determined by a ratio of the other three, which are "calibrated," or whose resistances are known to a precise degree. When the bridge is in a balanced condition (zero voltage as indicated by the null detector), the ratio works out to be this:

*In a condition of **balance**:*

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \quad \text{or} \quad R_1 R_4 = R_3 R_2$$

One of the advantages of using a bridge circuit to measure resistance is that the voltage of the power source is irrelevant. Practically speaking, the higher the supply voltage, the easier it is to detect a condition of imbalance between the four resistors with the null detector, and thus the more sensitive it will be. A greater supply voltage leads to the possibility of increased measurement precision. However, there will be no fundamental error introduced as a result of a lesser or greater power supply voltage unlike other types of resistance measurement schemes.

4.2 Principle of DC Bridges

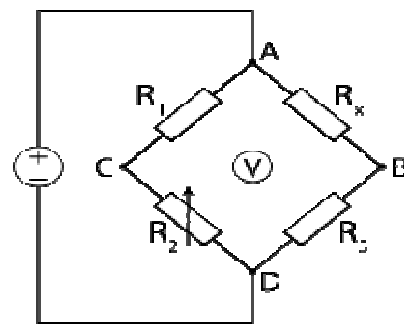
4.2.1 Type of DC Bridges

1. Wheatstone Bridges
2. Kelvin Bridges

WHEATSTONE BRIDGE

The best-known bridge circuit, the Wheatstone bridge and is used for measuring resistance. It is constructed from four resistors, one of which has an unknown value (R_x), one of which is variable (R_2), and two of which are fixed and equal (R_1 and R_3), connected as the sides of a square. Two opposite corners of the square are connected to a source of electric current, such as a battery. A galvanometer is connected across the other two opposite corners.

The variable resistor is adjusted until the galvanometer reads zero. When the voltage between point C and the negative side of the battery is equal to the voltage between point B and the negative side of the battery, the null detector will indicate zero and the bridge is said to be "balanced." It is then known that the ratio between the variable resistor and its neighbour is equal to the ratio between the unknown resistor and its neighbour, and this enables the value of the unknown resistor to be calculated.



Bridges balance equation :

$$\frac{R_1}{R_2} = \frac{R_x}{R_3}$$

Figure 4.2 : Wheatstone bridge schematic diagram

From Figure 4.2 :

R_x = unknown value of resistor
 R_1, R_3 = Fixed resistor
 R_2 = Variable resistor
 V = Galvanometer with high sensitivity
 E = Source

The bridge is balance when no current through the galvanometer ($I_g = 0$) ;

$$V_{AB} = V_{AC} \quad \text{or} \quad V_{BD} = V_{CD}$$

$$V_{AB} = V_{AC}$$

$$\frac{R_x}{R_x + R_3} \times E = \frac{R_1}{R_2 + R_1} \times E$$

$$R_x (R_1 + R_2) = R_1 (R_x + R_3)$$

$$R_1 R_x + R_x R_2 = R_1 R_x + R_1 R_3$$

$$R_X R_2 = R_1 R_3$$

$$R_X = (R_1 R_3) / R_2$$

EXAMPLE 1

Given value $R_1 = 2\text{K}\Omega$, $R_2 = 1\text{K}\Omega$, $R_3 = 1.5\text{K}\Omega$ dan $R_X = 3\text{K}\Omega$. Prove the bridges in balance condition.

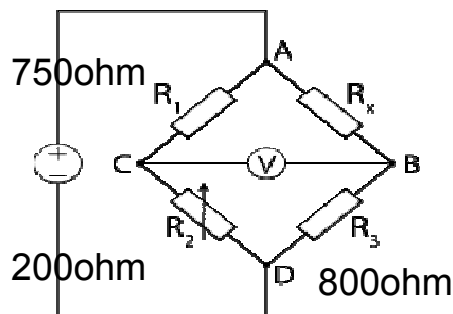
Solution:

The bridges in balance condition when:

(The bridges is in balance condition)

EXAMPLE 2

Refer figure 4.1, calculate the R_X when the bridges balance.



Solution:

$$R_X = (R_1 R_3) / R_2$$

$$R_X = (800)(750) / (200)$$

$$R_X = 3\text{ Kohm}$$

KELVIN BRIDGE

A **Kelvin bridge** (also called a **Kelvin double bridge** and some countries **Thomson bridge**) is a measuring instrument invented by William Thomson, 1st Baron Kelvin. It is used to measuring very low resistances (typically less than 1/10 of an ohm)

Its operation is similar to the Wheatstone bridge except for the presence of additional resistors. These additional low value resistors and the internal configuration of the bridge are arranged to substantially reduce measurement errors introduced by voltage drops in the high current (low resistance) arm of the bridge.

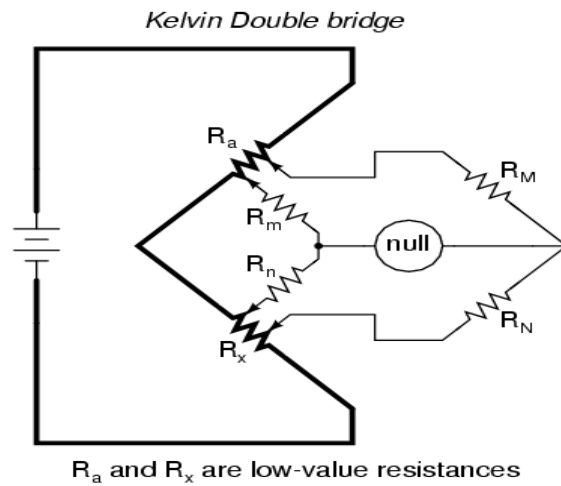


Figure 4.3 : Kelvin bridge schematic diagram

The low-value resistors are represented by thick-line symbols, and the wires connecting them to the voltage source (carrying high current) are likewise drawn thickly in the schematic. This oddly-configured bridge is perhaps best understood by beginning with a standard Wheatstone bridge set up for measuring low resistance, and evolving it step-by-step into its final form in an effort to overcome certain problems encountered in the standard Wheatstone configuration.

If we were to use a standard Wheatstone bridge to measure low resistance, it would look something like this:

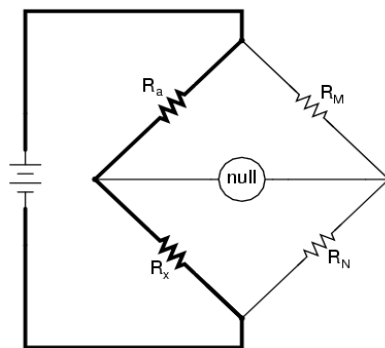
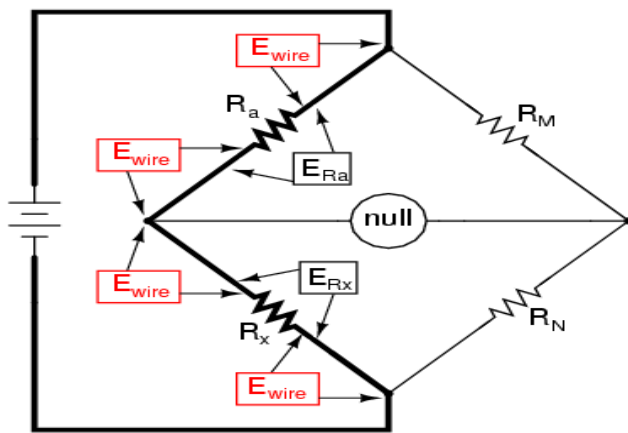


Figure 4.4 : Kelvin bridge schematic diagram

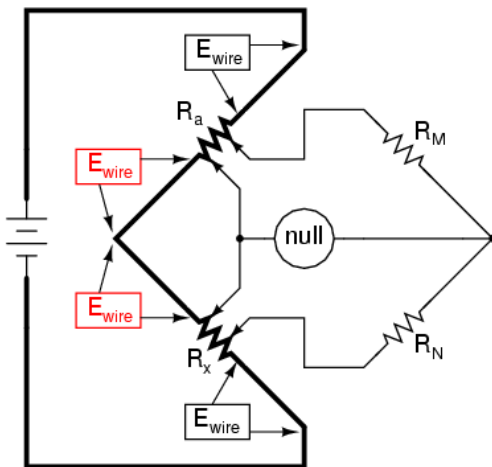
When the null detector indicates zero voltage, we know that the bridge is balanced and that the ratios R_a/R_x and R_M/R_N are mathematically equal to each other. Knowing the values of R_a , R_M , and R_N therefore provides us with the necessary data to solve for R_x . . . almost.

We have a problem, in that the connections and connecting wires between R_a and R_x possess resistance as well, and this stray resistance may be substantial compared to the low resistances of R_a and R_x . These stray resistances will drop substantial voltage, given the high current through them, and thus will affect the null detector's indication and thus the balance of the bridge:



Stray E_{wire} voltages will corrupt the accuracy of R_x 's measurement

Since we don't want to measure these stray wire and connection resistances, but only measure R_x , we must find some way to connect the null detector so that it won't be influenced by voltage dropped across them. If we connect the null detector and R_M/R_N ratio arms directly across the ends of R_a and R_x , this gets us closer to a practical solution:

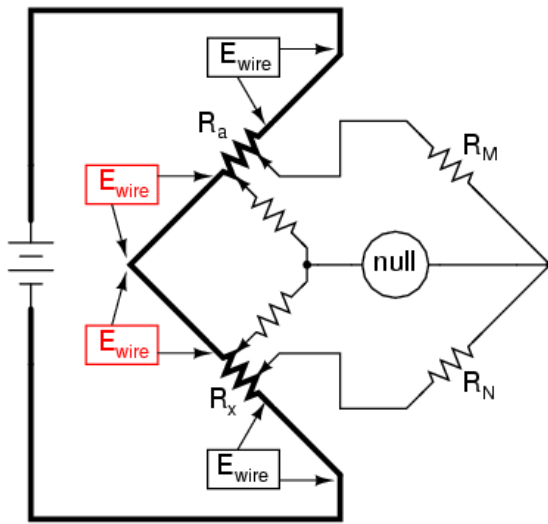


Now, only the two E_{wire} voltages are part of the null detector loop

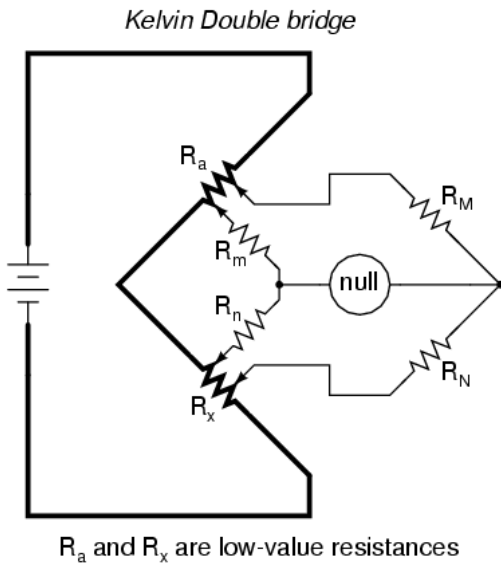
Now the top two E_{wire} voltage drops are of no effect to the null detector, and do not influence the accuracy of R_x 's resistance measurement. However, the two remaining E_{wire} voltage drops will cause problems, as the wire connecting the lower end of R_a with the top end of R_x is now shunting across those two voltage drops, and will conduct substantial current, introducing stray voltage drops along its own length as well.

Knowing that the left side of the null detector must connect to the two near ends of R_a and R_x in order to avoid introducing those E_{wire} voltage drops into the null detector's loop, and that any direct wire connecting those ends of R_a and R_x will itself carry substantial current and create more stray

voltage drops, the only way out of this predicament is to make the connecting path between the lower end of R_a and the upper end of R_x substantially resistive:



We can manage the stray voltage drops between R_a and R_x by sizing the two new resistors so that their ratio from upper to lower is the same ratio as the two ratio arms on the other side of the null detector. This is why these resistors were labeled R_m and R_n in the original Kelvin Double bridge schematic: to signify their proportionality with R_M and R_N :



With ratio R_m/R_n set equal to ratio R_M/R_N , rheostat arm resistor R_a is adjusted until the null detector indicates balance, and then we can say that R_a/R_x is equal to R_M/R_N , or simply find R_x by the following equation:

$$R_x = R_a \frac{R_N}{R_M}$$

The actual balance equation of the Kelvin Double bridge is as follows (R_{wire} is the resistance of the thick, connecting wire between the low-resistance standard R_a and the test resistance R_x):

$$\frac{R_x}{R_a} = \frac{R_N}{R_M} + \frac{R_{\text{wire}}}{R_a} \left(\frac{R_m}{R_m + R_n + R_{\text{wire}}} \right) \left(\frac{R_N}{R_M} - \frac{R_n}{R_m} \right)$$

So long as the ratio between R_M and R_N is equal to the ratio between R_m and R_n , the balance equation is no more complex than that of a regular Wheatstone bridge, with R_x/R_a equal to R_N/R_M , because the last term in the equation will be zero, canceling the effects of all resistances except R_x , R_a , R_M , and R_N .

In many Kelvin Double bridge circuits, $R_M=R_m$ and $R_N=R_n$. However, the lower the resistances of R_m and R_n , the more sensitive the null detector will be, because there is less resistance in series with it. Increased detector sensitivity is good, because it allows smaller imbalances to be detected, and thus a finer degree of bridge balance to be attained. Therefore, some high-precision Kelvin Double bridges use R_m and R_n values as low as 1/100 of their ratio arm counterparts (R_M and R_N , respectively). Unfortunately, though, the lower the values of R_m and R_n , the more current they will carry, which will increase the effect of any junction resistances present where R_m and R_n connect to the ends of R_a and R_x . As you can see, high instrument accuracy demands that *all* error-producing factors be taken into account, and often the best that can be achieved is a compromise minimizing two or more different kinds of errors.

REVIEW:

- Bridge circuits rely on sensitive null-voltage meters to compare two voltages for equality.
- A *Wheatstone bridge* can be used to measure resistance by comparing unknown resistor against precision resistors of known value, much like a laboratory scale measures an unknown weight by comparing it against known standard weights.
- A *Kelvin Double bridge* is a variant of the Wheatstone bridge used for measuring very low resistances. Its additional complexity over the basic Wheatstone design is necessary for avoiding errors otherwise incurred by stray resistances along the current path between the low-resistance standard and the resistance being measured.