

Maxwell Bridge: Past & Present

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Abstract: In this research paper, we report the details about the Maxwell Bridge including the history of the same, which contains the discoverer, when discovered, initial structure, amendments (modification in the Maxwell Bridge), from where the idea came and mathematical relations for the Maxwell Bridge.

Keywords: Maxwell bridge, Wheatstone bridge, Quality Factor (Q), capacitance, resistance

I. Introduction

Maxwell Bridge is an AC bridge used for the measurement of induction of the bridge and used for the construction of the different bridges as well as for the analysis for the bridge of the same kind. It is the modified model of Wheat Stone Bridge, used for the calculation of unknown induction in terms of calibrated induction and resistance in parallel or calibrated capacitance and resistance in parallel. This is used for the coil having low quality factor 'Q'. Quality factor or Q factor is the dimensionless quantity which gives the information about how the undamped the resistor is, and is defined as the ratio of centre frequency to the bandwidth of a resistor when the resistor is derived by a oscillating driving force. In other words, we can say that quality factor is the sum of maximum energy stored in the each active and passive element of the circuit or the network.

Description

Maxwell Bridge is configured from Wheat Stone bridge, it is named after the scientist who described it in the year 1873, James Clerk Maxwell, who was a great mathematician and physicist. It consists of four arms as shown in figure given below.

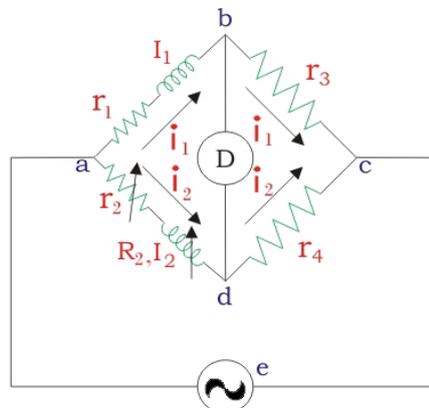


Fig.1: Schematic diagram of Maxwell Bridge

In balanced condition the potential at A and B is same; so , the current through the galvanometer will be zero hence the current through R1 and C2+R2 is same and in case of calculation of unknown inductance , the R1 and R4 is fixed and R2 and C2 is known variable entities to balance the bridge .

So unknown resistance R3 and unknown inductance L3 and be calculated by given relation:

$$l_1 = \frac{r_3}{r_4} \cdot l_2 \text{ and } r_1 = \frac{r_3}{r_4} (r_2 + R_2)$$

equation 1- formula to calculate the unknown resistance and inductance

The phasor diagram of the Maxwell Bridge is as shown in Fig. 2.

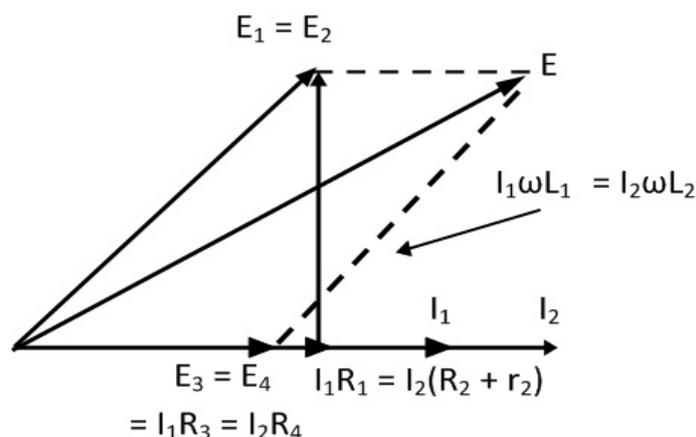


Fig.2: Phasor diagram of Maxwell bridge

As discussed earlier that Maxwell Bridge is used for low quality factor of the coil so , it is important to calculate the quality factor or Q factor.
 equation 2- formula to calculate the quality factor of the inductor.

Principal used is that the positive phase angle of inductive impedance is cancelled by the negative capacitive impedance when they are in resonance. Using the same principal, the Maxwell Bridge is modified to the Maxwell Wien Bridge, Anderson Bridge and Wien Bridge. One by one all three are discussed as the topic goes in detail.

Maxwell-Wien Bridge – it is also called the Maxwell inductance capacitance bridge and by using this bridge, we can calculate resistance and inductance of the third branch using the capacitance in parallel with resistance with known value of both element. As a result, it is used for a wide range of audio frequency in inductor. It is quite useful to calculate inductance when frequency is not given because in both the equation there is no frequency component. Both equation mean when the bridge is in balanced condition, we get two equations, one which have imaginary and other which have real part and for an AC bridge both the equation must satisfy (one for magnitude and other for phase). It is one of the useful results for using the Maxwell Wien Bridge. There are few disadvantages in Maxwell Wien Bridge. For that reason, other bridges were developed. Those disadvantages are as follows.

1. The variable capacitance used in the circuit is expensive so it increases the expense of the measurement.
2. The main disadvantage is that it can not measure the inductance of the coil which have high quality factor or Q-factor of that coil in the range of 1 to 10 and it can not measure inductance for low quality factor in the range below 1 like 0.1.

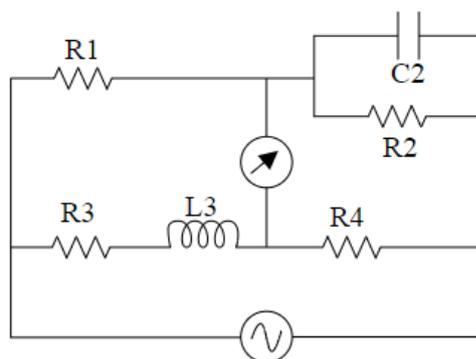


Fig 3: Maxwell Wien Bridge

$$R_3 = \frac{R_1 \cdot R_4}{R_2}$$

$$L_3 = R_1 \cdot R_4 \cdot C_2$$

equation 2- formula to calculate the unknown parameter of Maxwell Wien Bridge

$$Q = \frac{\omega L}{R}$$

equation 3- formula to quality factor of bridge .

The phasor diagram of Maxwell Wien bridge is shown below.

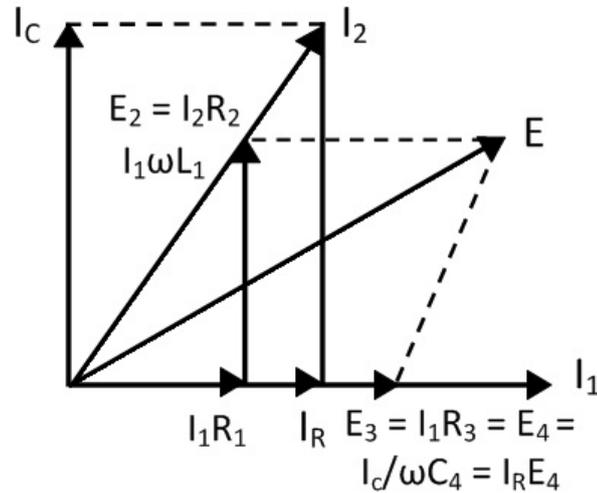


Fig.4: Phasor diagram for Maxwell Wien bridge

Anderson Bridge – It is the modified version of the Maxwell Wien bridge and it measures the inductance accurately and for wider range, and in this bridge the balance point is easy to obtain as compared to the Maxwell Wien Bridge. One advantage of this bridge is that it uses fixed value of capacitor which plays a huge role in giving the good accuracy. As a result, it measures the more accurate capacitance in terms of inductance. There are few disadvantages of using the Anderson Bridge such as

1. As shown below the circuit of this Bridge, we can find out that it has more arms as compared to the Maxwell Wien Bridge that makes it more complex circuit thus the equation of the circuit also be complex.
2. The bridge have one additional function as shown in the figure and that increase the difficulty in shielding the Bridge , that's why the Maxwell Bridge is used more as compared to the Anderson Bridge .

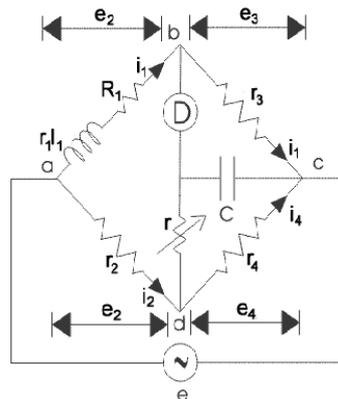


Fig.5: Anderson Bridge

It is the modified version of the Hay and Maxwell and used to calculate the quality factor of the bridge .it is well known for the accuracy in measuring the inductance of the inductor from few Henry to several Henry. It is use the same principal but in deferent manner, it compare the known value of electrical resistance and capacitance. The unknown value can be calculated by using the formula given below

$$r_1 = \frac{r_2 r_3}{r_4} - R_1 r_2$$

$$\text{and } l_1 = \frac{C \cdot r_3}{r_4} [r(r_4 + r_2) + r_2 r_4] r_2$$

And the phasor diagram for the bridge is shown in the given figure . From the graph, we can analyse that the current I (1) and E(3) both are in the same phase which is shown on the absisa of the graph. Voltage across the branch bc and ec are equal when the bridge is in balanced condition.

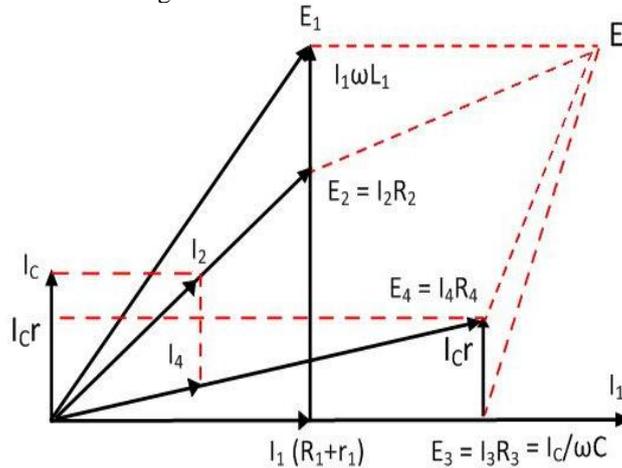


Fig. 6: Phasor Diagram of Anderson Bridge

The total current is divided into two part on is I(1) and other is I(2) . On further moving, the I(1) current enters in the branch ab and then some amount of voltage gets dropped which is equal to the I(1){R(1)+R} as both the current are in phase , then this is also in phase with the I(1).

Wien Bridge –it is lastly modified bridge and more efficient among the all above discussed. This bridge is used to measure the capacitance and it is the most sensitive among the above all bridges, its accuracy is quite normal in range with 0.1 to 0.6.

The circuit diagram of Wien Bridge is as follows

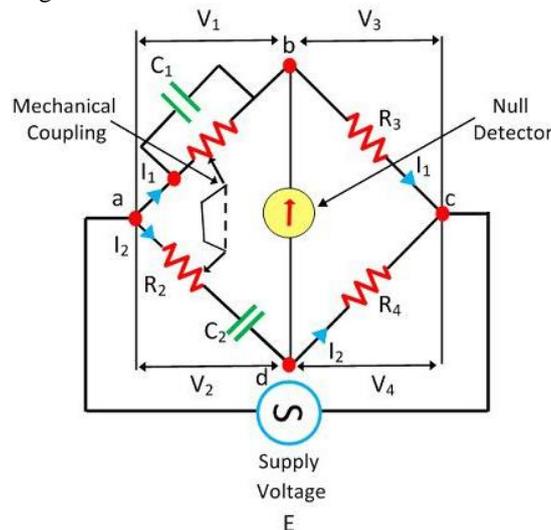


Fig.7: Wien Bridge

Bridge is sensitive to the frequency for that reason it is difficult to handle or we can say that in Wien bridge, it is difficult to find the balance point . this happens because we can not make a ideal source so that the sinusoidal source used in the bridge is not truly pure some noise were add to the source and that noise changes the frequency

of the system so that the balance point is difficult to calculate . To over to this issue we use filter in series with the null point which reduces the quantity of the noise in the source signal.
 The process to find the balance point is same as above one. So, at the balance condition

$$\left(\frac{R_1}{1 + j\omega C_1 R_1}\right) R_4 = \left(R_2 - \frac{j}{\omega C_2}\right) R_3$$

where all symbols have their usual meaning. On further solving the equation and equating the real and imaginary part, we get real part as

$$R_1 R_4 C_2 = R_2 C_2 R_3 + R_3 C_1 R_1$$

$$\frac{R_1 R_4 C_2}{R_1 R_3 C_2} = \frac{R_2 C_2 R_3}{R_1 R_3 C_2} + \frac{R_3 C_1 R_1}{R_1 R_3 C_2}$$

$$\frac{R_4}{R_3} = \frac{R_2}{R_1} + \frac{C_1}{C_2}$$

And imaginary part as

$$R_3 R_2 \omega^2 C_2 C_1 R_1 = R_3$$

$$R_2 \omega^2 C_2 C_1 R_1 = 1$$

$$\omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

And the frequency of the N/W is as follows

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

Future scope and conclusion

Maxwell bridge is used in communication systems, as communication technology reaching to peak from audio call than video call than virtual reality than mixed reality after that augmented reality. In future their might be some technology that make communication more smoother so Maxwell Bridge will defiantly use in that. It is being used in the many electronic circuit for different purpose and with advancing in technology the use and scope will also increase to make the advancement more compact and futuristic. And it is used in calculating the unknown inductance, compare inductance , used in audio and power frequency circuit , it also used in measuring medium quality factor of the coil . It is used in power conversion circuit and in filter circuit, instrumentation , linear and non-linear circuit .and many more use of Maxwell Bridge in future and in present as well. The main aim was to develop a AC bridge that can be used to measure unknow inductance value and compare it with standard value and develop a bridge of high quality where error can be minimized.

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