Discipline Course-I

Semester-II

Paper No: Electricity and Magnetism

Lesson: Chapter 6.2 : A C Bridges for measurement of Capacitances and Inductances

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LEARNING OBJECTIIVES

Going through this chapter, the reader would know

- the basic design of the A C wheat stone bridge.
- ‘balance condition’ for the A C wheat stone bridge.
- different (simple) circuit design for the measurement of Capacitances
- different (simple) circuit design for the measurement of inductances.
- using Kirchhoff's laws for analyzing different types of the A C circuits.

INTRODUCTION

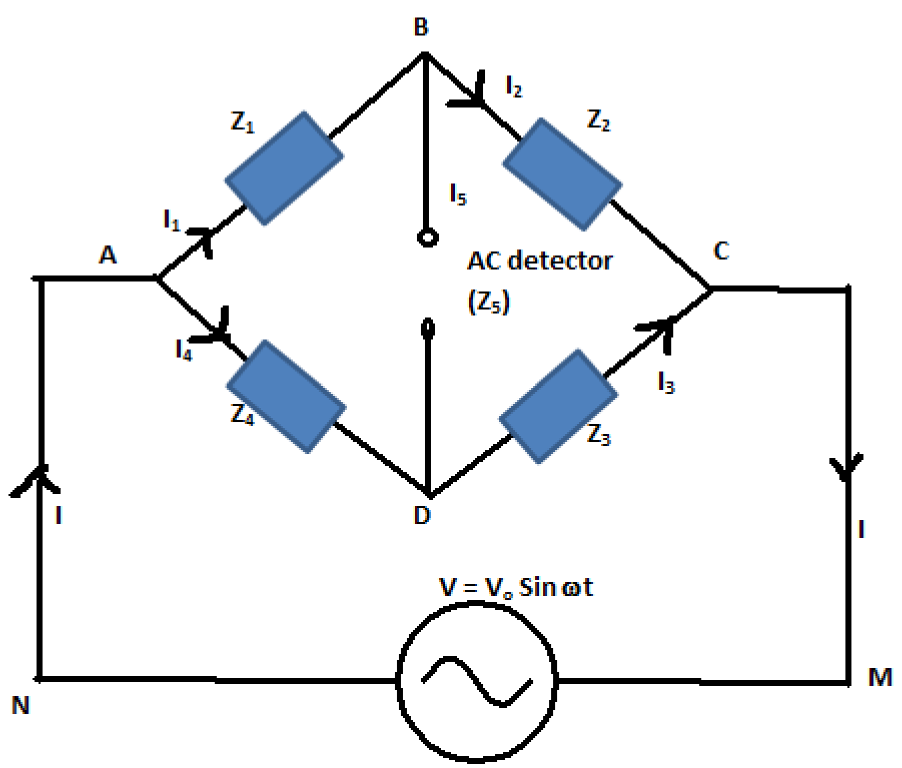
We start this chapter by introducing the idea of the AC Wheatstone bridge. Kirchhoff's laws, in their complex form are used for obtaining the 'balance condition'. The reader is made to realize that this 'balance condition', in general, implies two balance conditions that need to be satisfied simultaneously.

The reader is made familiar with the De Sauty Bridge and the wien bridge that are used for measurement of capacitances. Subsequently, the Owen's Bridge and the Anderson's bridge, used for measurement of inductances, are introduced and discussed. Examples, to further illustrate the use of Kirchhoff's laws, are given towards the end of the chapter.

<u>The A C Wheatstone Bridge:</u>

We now use Kirchhoff's laws to obtain the balance condition for the 'A C Wheatstone Bridge'. This has the form of the usual Wheatstone bridge but with the following differences:

(i) The source of voltage used is an A C source
(ii) The detector of the null or balance point is not the conventional galvanometer but some device (like a pair of 'headphones') that responds to the flow of an alternating current through it.



(iii) The impedance, present in the four arms of the bridge, need not be resistive impedances alone. They can, and, in general, include inductive and capacitive impedances also.

The general form of the A C Wheatstone Bridge is shown in the figure above. Let Z_1, Z_2 and Z_3 and Z_4 be the complex impedances of the four arms of the bridge. Let Z_5 be the complex impedance of the detector.

The applied sinusoidal AC voltage, of the source, $V\,(= V_o\, Sin\, \omega t)$ can be replaced by its complex equivalent voltage, $V_o\, e^{j\omega t}$. If $I_1,\ I_2,\ I_3,\ I_4 and\ I_5$ represents the complex currents in the branches shown, we have, as per Kirchhoff's first law

$$I = I_1 + I_4 = I_2 + I_3$$

$$I_1 = I_2 + I_5\ and\ I_3 = I_4 + I_5$$

Again, implying Kirchhoff's second law, we have

For loop ABDA: $-I_1Z_1 - I_5Z_5 + I_4Z_4 = 0$

For loop BCDB: $-I_2Z_2 + I_3Z_3 + I_5Z_5 = 0$

For loop ABCMNA: $-I_1Z_1 - I_2Z_2 + V_o\, e^{j\omega t} = 0$

We can use these equations to arrive at the 'balance condition' for the Wheatstone stone. The bridge would be balanced when $I_5 = 0$.

For $I_5 = 0$, we have

$$I_1 = I_2\ and\ I_4 = I_3$$

Also

$$-I_1Z_1 + I_4Z_4 = 0\ or\ I_1Z_1 = I_4Z_4$$

$$-I_2Z_2 + I_3Z_3 = 0\ or\ I_2Z_2 = I_3Z_3$$

We thus get

$$\frac{I_1Z_1}{I_2Z_2} = \frac{I_4Z_4}{I_3Z_3}$$

Or, $I_1 = I_2\ and\ I_4 = I_3$ (at balance), we have

$$\frac{Z_1}{Z_2} = \frac{Z_4}{Z_3}$$

This, then, is the balance condition for the AC Wheatstone Bridge.

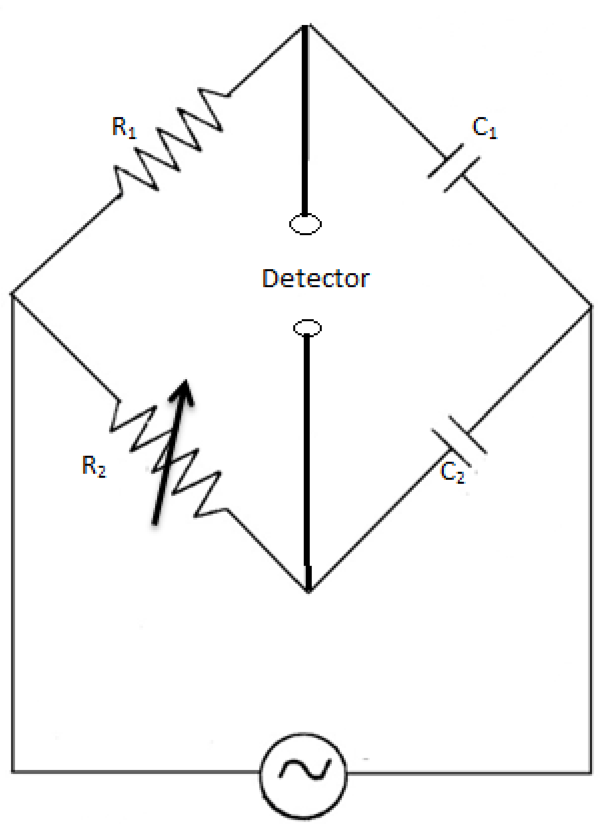
This balance condition, though apparently similar to the balance condition for the usual DC Wheatstone Bridge, differs from it in a very important respect. We know that the equality of two complex numbers really implies two equalities: the equality of their 'real parts' to each other and the equality of their 'complex parts' to each other. It follows that, in general, an AC Wheat stone bridge can be 'balanced' only if its parameters satisfy, simultaneously, two conditions.

The practical task, of balancing an AC Wheatstone Bridge, is therefore, much more challenging and difficult. However, there are a number of practical Wheatstone bridges that have been designed for measuring (unknown) capacitances, and inductances.

One important feature, of these practical AC Wheatstone bridges, is that the design of these bridges is such that the two balance conditions, that need to be simultaneously satisfied for balancing them, do not depend on the frequency of the applied ac voltage source. We know that the impedances, of the inductor, and the capacitor, are frequency dependent. However, the practical bridges are (usually) so designed that the frequency dependence of the inductive and capacitive impedances, does not get reflected in the two balance conditions of the bridge. This frequency independence is a very important requirement of all the (usual) practical used AC bridges.

We now proceed to obtain, one by one, the balance condition for some practical bridges used for

(i) Measurement of capacitances and
(ii) Measurement of self-inductances



We start our discussion by analyzing two simple AC (Wheatstone) bridges, used for measurement of an unknown capacitance.

<u>Measurement of capacitance</u>

The two simple AC bridges, used for measuring an unknown capacitance, are the 'De-Sauty' bridge and the 'Wien Bridge'.

<u>De- Sauty Bridge</u>

The de-sauty bridge uses two (adjustable) resistances, a known capacitance and the (unknown value) capacitance to be measured. This bridge because it can be 'balanced' by satisfying only one balance condition.

The usual practical form of the de sauty bridge is as shown. The detector is usually a pair of headphones.

The (complex) form of the balance condition, for this bridge, would be

$$\frac{R_1}{\left(1/_{j\omega C_1}\right)} = \frac{R_2}{\left(1/_{j\omega C_2}\right)}$$

$$or\ j\omega C_1 R_1 = j\omega C_2 R_2$$

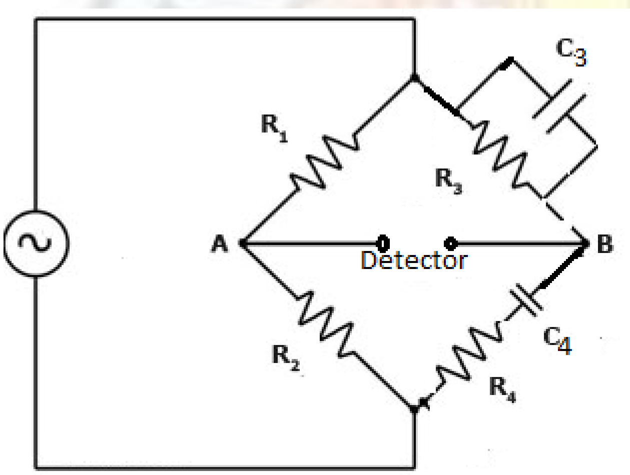
$$or\ C_1R_1 = C_2R_2$$

$$or\ \frac{C_1}{C_2} = \frac{R_2}{R_1}$$

Thus we effectively have only one balance condition for this bridge. The balance is usually obtained by adjusting the value of one of the (two) resistors so that the detector (usually a pair of headphones) indicates 'zero current flow' in the 'detector' branch. It is important to ensure that the resistors, used in this bridge, are non-inductive in nature.

Wien Bridge

The Wien Bridge, another version of an A C Wheatstone bridge, has been designed to measure an unknown capacitance in terms of a standard capacitance. The bridge has the form shown here.



As seen in the diagram, this bridge has two resistors in the two arms of its Wheatstone bridge. There is (i) a combination of a resistor and a capacitor, in series, in one of the two arms and (ii) a combination, of a resistor and a capacitor, in parallel, in the fourth arm of this bridge.

As seen from the theory of this bridge, it turns out that the ratio of the two capacitors, in the two arms of the bridge, can be expressed in terms of the four resistors in this bridge. However, this relation or the balance condition has to be attained along with a second 'balance condition' for this bridge. This second 'balance condition' requires the two capacitors and their associated resistors, to have their values in a way that shows the equality of the inverse of the product ($R_3R_4C_3C_4$) to the square of the angular frequency of the ac voltage source used in the bridge. This frequency dependent nature of one of the balance conditions makes the bridge rather difficult to 'use and operate'.

Let us now apply the standard Wheatstone bridge balance condition to this bridge and obtain the two balance conditions relevant to it.

We first notice that

$$\frac{1}{Z_3} = \left(1/_{R_3}\right) + j\omega C_3 = \frac{1 + j\omega C_3 R_3}{R_3}$$

$\therefore\ Z_3 = \frac{R_3}{1+ j\omega C_3 R_3}$

and $Z_4 = R_3 + \frac{1}{j\omega C_4} = \frac{1+ j\omega C_4 R_4}{j\omega C_4}$

$$\frac{Z_3}{Z_4} = \frac{R_3}{1 + j\omega C_3 R_3} \times \frac{j\omega C_4}{1 + j\omega C_4 R_4}$$

$$\frac{Z_3}{Z_4} = \frac{j\omega C_4\, R_3}{1 + j\omega\,(C_3 R_3 + C_4 R_4) - \omega^2\, C_3 C_4 R_4 R_3}$$

$$\frac{Z_3}{Z_4} = \frac{j\omega C_4\, R_3}{(1 - \omega^2\, C_3 C_4 R_4 R_3) + j\omega (C_3 R_3 + C_4 R_4)}$$

Also,

$$\frac{Z_1}{Z_2} = \frac{R_1}{R_2}$$

Therefore, for balance, we have

$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$.

Hence the balance condition, for the bridge is

$$\frac{R_1}{R_2} = \frac{j\omega C_4\, R_3}{(1 - \omega^2\, C_3 C_4 R_4 R_3) + j\omega (C_3 R_3 + C_4 R_4)}$$

$$R_1\,[1 - \omega^2\, C_3 C_4 R_4 R_3] + j\omega\, R_1 (C_3 R_3 + C_4 R_4) = j\omega R_2 C_4\, R_3$$

Equating real and imaginary parts, on both sides, we get

$$1 - \omega^2\, C_3 C_4 R_4 R_3 = 0$$

Or $\omega^2 = \frac{1}{C_3 C_4 R_4 R_3}$

And

$$R_1 (C_3 R_3 + C_4 R_4) = \omega R_2 C_4\, R_3$$

Dividing both sides by $R_1 C_4$, we get

$$\left(\frac{C_3}{C_4} R_3 + R_4\right) = \frac{R_2}{R_1} R_3$$

$$\therefore\ \frac{C_3}{C_4} = \frac{R_2}{R_1}\frac{R_3}{R_3} - \frac{R_4}{R_3} = \frac{R_2}{R_1} - \frac{R_4}{R_3}$$

Thus the two conditions, that need to be satisfied (together) for balancing the wien bridge, are

$$\omega^2 = \frac{1}{C_3 C_4 R_4 R_3}$$

And

$$\frac{C_3}{C_4} = \left(\frac{R_2}{R_1} - \frac{R_4}{R_3}\right)$$

For the special case where $C_3 = C_4$ and $R_3 = R_4$, the second condition becomes:

$$\frac{R_2}{R_1} = 2$$

These conditions show that the wien bridge can be used to find an unknown capacitance, say C_3, in terms of 'frequency' and resistances. The frequency dependent nature of the balance conditions for this bridge, make it a difficult to balance bridge. However, this very feature of this bridge was put to use in the initial stages where it was used as a method of measuring audio frequencies.

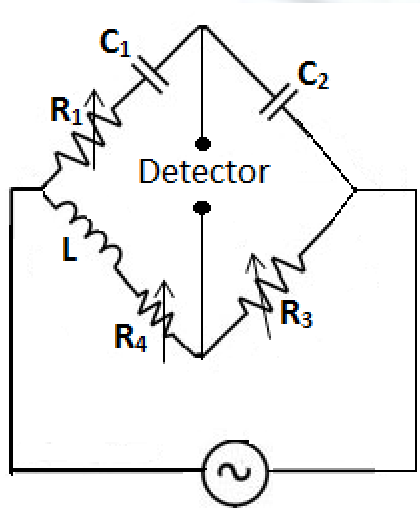
<u>Measurement of Inductance</u>

Over the years, a number of AC bridge have been designed for measuring inductances to measure the given (unknown) inductance in terms of a standard (or known) inductance. This bridge has essentially the same form as the wien's bridge for measurement of capacitance. The unknown capacitor and the standard capacitor, in the wien's bridge are replaced here with the unknown inductor and standard inductor. It is easy to arrive at the two 'balance conditions' that need to be simultaneously satisfied by the bridge.

The bridges, used more often in practice, are not like the Maxwell Bridge. This bridge, as we know, aims to measure the unknown inductance and some resistances. The bridge used in practice, used a known capacitance and some resistances to balance out the bridge. These bridges thereby get the (unknown) value of the inductance in terms of the (known) values of the resistors that capacitance and the values of the resistors that satisfy the 'balance condition/s' of the bridge.

Two of such bridges, used quite often in the laboratory, are the Owen's bridge and the Anderson Bridge. We can think of both these bridges as bridges of the 'L/C' type.

<u>Owen's Bridge</u>



The Owen's bridge is almost a 'standard part' of the laboratory work done by the undergraduate students. This bridge helps us to measure the given (unknown value) inductance in terms of the values of the standard capacitances and the values of two resistances adjusted to have values that satisfies the two balance conditions of the bridge.

The practical form of the Owen's bridge is as shown here. Clearly the bridge would get 'balanced' when

$$\frac{\left(1/_{j\omega C_1}\right) + R_1}{j\omega L + R_4} = \frac{\left(1/_{j\omega C_2}\right)}{R_3}$$

Or

$$\frac{\left(1/_{j\omega C_1}\right) + R_1}{\left(1/_{j\omega C_2}\right)} = \frac{j\omega L + R_4}{R_3}$$

or

$$\frac{C_2}{C_1} + j\omega C_2 R_1 = \frac{j\omega L}{R_3} + \frac{R_4}{R_3}$$

This is equivalent to two balance conditions, namely

$$L = R_1 R_3 C_2$$

And

$$\frac{C_2}{C_1} = \frac{R_4}{R_3}$$

The value of R_3 present in the equation for L has to be consistent with the second balance condition.

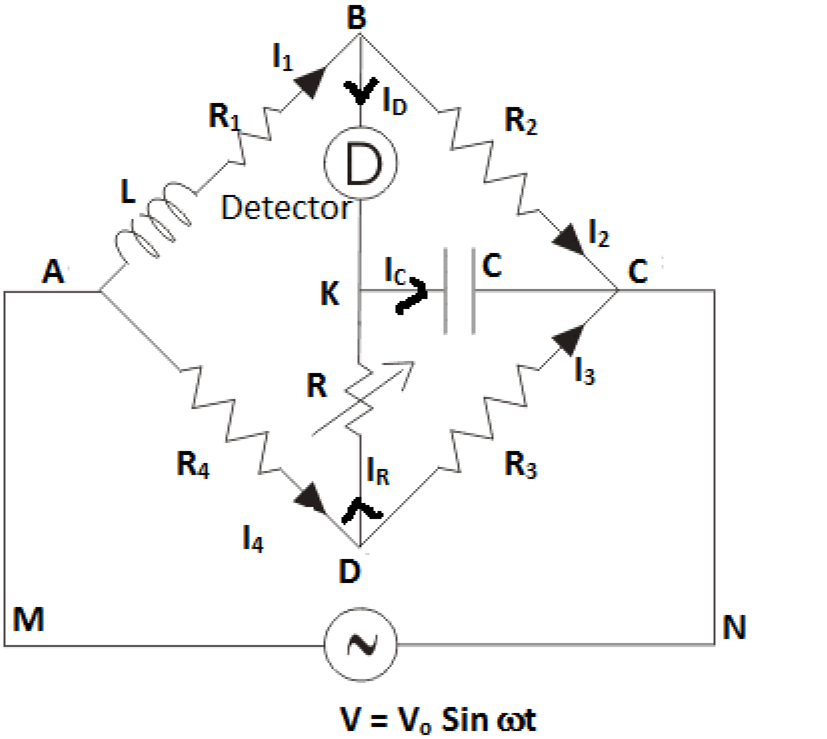
Owen's bridge though not very accurate, is used quite often in laboratory because it

(i) Is easy to assemble and can be operated in a simple way.
(ii) Can be used over relatively wide range of values of inductances.

Anderson's Bridge

The Anderson's bridge is one of the more accurate bridges designed for measurement and standardization, of the inductances. It measures the unknown inductance in terms of a fixed standard capacitor and a set of four (initially adjusted) resistance values.

The Anderson Bridge, shown here is not the usual, or standard, Wheatstone bridge. It has additional branch of its own and its balance condition is not the standard Wheatstone bridge balance condition. We now proceed to apply Kirchhoff's laws to this bridge and obtain its characteristics (set of two) 'balance condition'



The Complex currents, in the various branches of the circuit, are as shown.

Application of Kirchhoff's first law then gives these equations:

$$I_1 = I_2 + I_D \; (junction\ point\ B)$$

$$I_4 = I_3 + I_R \; (junction\ point\ D)$$

$$I_R = I_C + I_D \; (junction\ point\ K)$$

We could also write

$$I = I_4 + I_1 = I + I_3 + I_2 (junction\ point\ A\ and\ C)$$

We are interested in finding the 'balance condition' of the bridge. At balance, we have $I_D = 0$. Hence, at balance, we would have the following relations between currents:

$I_1 = I_2$, $I_4 = I_3 + I_R$ and $I_R = I_C$

We now apply Kirchhoff's second law to the mesh ABKDA and the mesh BCKB. These give us the equations

$$-I_1(j\omega L + R_1) + I_R R + I_4 R_4 = 0$$

And

$$-I_2 R_2 + I_C . \frac{1}{j\omega C} = 0$$

Note that we have made use of the fact that $I_D = 0$, at balance. These equations are therefore, the special forms of these mesh equations, valid only for the balanced bridge.

Thus

$$I_1(j\omega L + R_1) = I_R R + I_4 R_4$$

And $I_2 R_2 = I_C \cdot \frac{1}{j\omega C}$

Dividing these equations, and making use of the fact that $I_1 = I_2$ and $I_R = I_C$, (for the balanced bridge), we get

$$\frac{(j\omega L + R_1)}{R_2} = j\omega CR + \frac{I_4}{I_C} R_4 j\omega C$$

Now applying Kirchhoff's second law to the mesh DKCD, we get

$$-I_R R - I_C \frac{1}{j\omega C} + I_3 R_3 = 0$$

Or $I_R\left(R + \frac{1}{j\omega C}\right) = R_3(I_4 - I_R)\ [\because\ I_R = I_C\ (at\ balance)\ and\ _3 = (I_4 - I_R)]$

$$\therefore\ I_R\left(R + \frac{1}{j\omega C} + R_3\right) = I_4 R_3$$

$$\therefore\ \frac{\left(R + \frac{1}{j\omega C} + R_3\right)}{R_3} = \frac{I_4}{I_R} = \frac{I_4}{I_C}$$

We now substitute this value of $\frac{I_4}{I_C}$ in the equation obtained above. We thus get

$$\frac{(j\omega L + R_1)}{R_2} = j\omega CR + \frac{\left(R + \frac{1}{j\omega C} + R_3\right)}{R_3} R_4 j\omega C$$

$$\frac{R_1}{R_2} + j\ \frac{\omega L}{R_2} = \frac{R_4}{R_3} + \ j\omega C\left(R + \frac{R_4}{R_3}(R + R_3)\right)$$

We thus have the two balance conditions, for this bridge, as

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

And

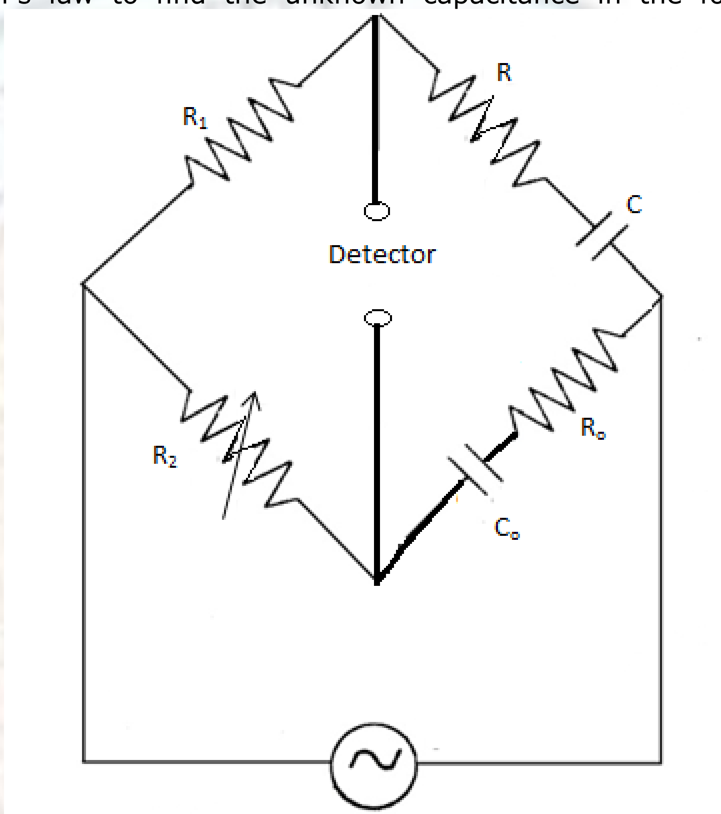
$$\frac{L}{R_2} = \frac{C}{R_3}(RR_3 + R_4 R + R_4 R_3)$$

Or

$$L = \frac{C}{R_3}.R_2(R(R_3 + R_4) + R_4R_3)$$

We observe that the first of these two conditions is the usual standard Wheatstone bridge condition, or, as is often referred to as the 'DC' balance condition. In practice, it is usual to first ensure that the bridge satisfies this condition. After that, it is (usually) the resistor R, whose value is adjusted so that the second balance condition also gets verified. We can then calculate L in terms of C and the values of R_2, R_3, R_4 *and* R, consistent with the two balance conditions of the bridge.

Example: Use Kirchhoff's law to find the unknown capacitance in the following circuit.



The bridge will get balance when

$$\frac{\left(1/_{j\omega C}\right) + R}{\left(1/_{j\omega C_0}\right) + R_0} = \frac{R_1}{R_2}$$

Or

$$\left(R_2/_{j\omega C}\right) + RR_2 = R_0R_1 + \left(R_1/_{j\omega C_0}\right)$$

or

$$j\left(-R_2/_{\omega C}\right) + RR_2 = R_0R_1 + j\left(-R_1/_{\omega C_0}\right)$$

This balance condition, between (complex) impedances, implies two balance conditions, namely

$$RR_2 = R_0R_1 \quad \text{or}$$

$$\frac{R}{R_0} = \frac{R_1}{R_2}$$

And $\left(-R_2/_{\omega C}\right) = \left(-R_1/_{\omega C_0}\right)$ or

$$\frac{C_0}{C} = \frac{R_1}{R_2}$$

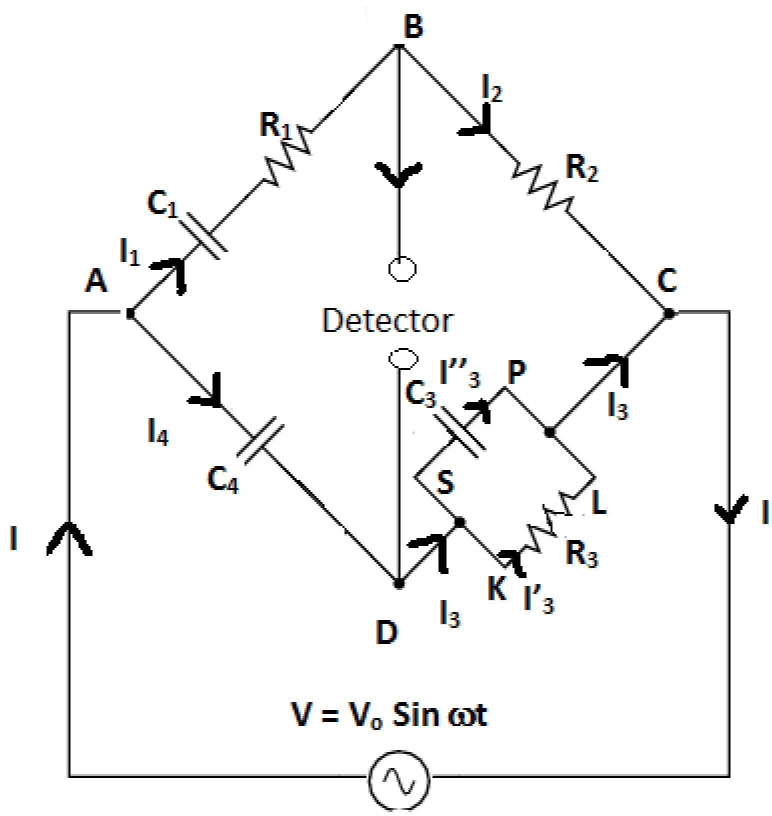
The bridge gets balanced when, these two balance conditions, expressed through the equation

$$\frac{R}{R_0} = \frac{R_1}{R_2} = \frac{C_0}{C}$$

gets satistfied simultaneously. In practice, it is usual to adjust R_0 and R_2 to ensure that both these conditions get satisfied. The value of unknown capacitance, C, is then obtained through the relation

$$C = C_0 \frac{R_2}{R_1}$$

Example 2: Use Kirchhoff's laws for AC bridges to obtain the conditions under which the current, in the arm BD, of the set up shown, becomes zero.



Using Kirchhoff's law we get

$$I = I_1 + I_4 = I_2 + I_3$$

$$I_1 = I_2 + I_5$$

$$I_4 + I_5 = I_3$$

And

$$I_3' + I_3'' = I_3$$

We need to find the conditions under which I_5 becomes zero. For $I_5 = 0$, we get

$$I_1 = I_2 \; and \; I_4 = I_3$$

We now apply Kirchhoff's second law to the loop KLPSK. We get

$$-I_3'.R_3 + I_3''.{}^1/_{j\omega C_3} = 0$$

$$\therefore I_3'' = I_3'.R_3.j\omega C_3$$

Also

$$I_3' + I_3'' = I_3$$

$$\therefore I_3'(1 + R_3.j\omega C_3) = I_3$$

$$\therefore I_3' = \frac{1}{(1 + R_3.j\omega C_3)} I_3$$

Now apply Kirchhoff's second law to the loop ABDA taking $I_5 = 0$,we get

$$I_1\left(\frac{1}{j\omega\, C_1} + R_1\right) + I_4.\frac{1}{j\omega\, C_4} = 0$$

$$\therefore I_1\left(\frac{1}{j\omega\, C_1} + R_1\right) = I_4.\frac{1}{j\omega\, C_4}$$

We now apply Kirchhoff's second law to the loop BCLKDB. We get (taking $I_5 = 0$)

$$-I_2R_2 + I_3' \; R_3 = 0$$

$$or \; I_2R_2 = I_3' \; R_3 = R_3.\frac{1}{(1 + R_3.j\omega C_3)} I_3$$

$$\therefore \quad \frac{I_1\left(\frac{1}{j\omega\, C_1} + R_1\right)}{I_2R_2} = \frac{I_4.\frac{1}{j\omega\, C_4}}{R_3.\frac{1}{(1 + R_3.j\omega C_3)} I_3}$$

For $I_5 = 0$, we have $I_1 = I_2$ and $I_4 = I_3$

Therefore, the above condition becomes

$$\frac{\left(\frac{1}{j\omega\, C_1} + R_1\right)}{R_2} = \frac{\frac{1}{j\omega\, C_4}}{R_3 . \frac{1}{(1 + R_3 . j\omega C_3\,)}}$$

$$or\ \frac{1}{j\omega\, R_2 C_1} + \frac{R_1}{R_2} = \frac{1}{j\omega\, C_4}\,\frac{(1 + R_3 . j\omega C_3\,)}{R_3}$$

$$or\ \frac{1}{j\omega\, R_2 C_1} + \frac{R_1}{R_2} = \frac{1}{j\omega\, C_4}\,\frac{(1 + R_3 . j\omega C_3\,)}{R_3}$$

$$or\ \frac{1}{j\omega\, R_2 C_1} + \frac{R_1}{R_2} = \frac{C_3}{C_4} + \frac{1}{j\omega C_4 R_3}$$

Equating the real and the imaginary parts on the two sides, we get

$$\frac{R_1}{R_2} = \frac{C_3}{C_4}$$

$$and\ \frac{1}{j\omega\, R_2 C_1} = \frac{1}{j\omega C_4 R_3}$$

$$or\ C_4 R_3 = R_2 C_1$$

$$or\ \frac{R_3}{R_2} = \frac{C_1}{C_4}$$

Thus the currents, in the arm BD of the set up shown, becomes zero when the two conditions

$$\frac{R_1}{R_2} = \frac{C_3}{C_4}\ and\ \frac{R_3}{R_2} = \frac{C_1}{C_4}$$

are satisfied simultaneously.

Summary

1. Here we have studied the use of Kirchhoff's law to obtain the balance condition of different bridges.
2. We started with the idea of Wheatstone bridge, which under balance condition helps to determine one of the unknown components attached in one of the four arms of the bridge
3. Then we take some bridges like De Sauty and Wien Bridge specially designed to measure the unknown capacitance
4. After that we move to Owen's and Anderson's bridge designed to measure the value of inductance.

Questions

1. Fill in the blanks:
   - (i) An example a A C Wheatstone Bridge, used for measuring capacitances, is the _____________.
   - (ii) An AC Wheatstone Bridge generally has ________ balance conditions that need to be satisfied simultaneously.
   - (iii) The A C Wheatstone bridge, would, in general, get balanced when _______ conditions are ___________satisfied.

(iv) The ____________bridge is an example of an AC Wheatstone bridge, used for measurement of capacitance.
(v) The Ac bridges, often used in the laboratory, for measurement of an unknown inductance, are the _________ bridge or the _________bridge.

Answers

(i) De-sauty bridge
(ii) two
(iii) De sauty (or wien)
(iv) Owen; Anderson

True of False

State whether the following statements are 'True' or 'False'.

(i) The de-sauty bridge has only one balance condition.
(ii) The Wien bridge balance conditions are frequency dependent in nature.
(iii) The Anderson bridge can be used for measuring both inductances and capacitances.
(iv) We do not have any AC Wheatstone bridge that has only one 'balance condition'.
(v) The actual current in any branch of its circuit is taken as imaginary part of its complex form when the applied AC voltage has the form: $V = V_o \cos \omega t$.

Answers

(i) True (This is correct statement).
(ii) True (This is correct statement).
(iii) False (The Anderson bridge can be used for measuring inductances).
(iv) False (There is only one balance condition for the bridges like De Sauty Bridge)
(v) False (we need to take the real part here as the applied AC voltage is the real part of its equivalent complex form)

<u>Multiple Choice Questions</u>

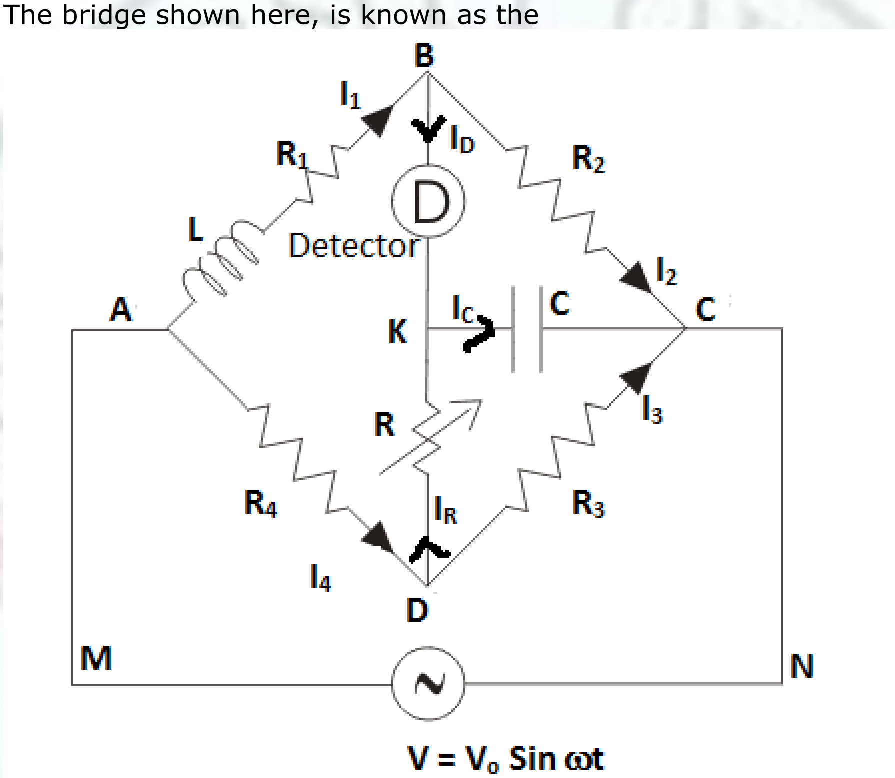
Select the best alternative in each of the following:

(i) From the following well known AC bridges, the only one, that is often used for measuring capacitances is the
  (a) Wien's Bridge
  (b) Owen's Bridge
  (c) Anderson's Bridge
  (d) Maxwell's Bridge
(ii) Two A C Bridges, that have been designed for measurement of inductances and capacitances, are the
  (a) Anderson's Bridge and De Sauty Bridge, respectively.
  (b) Anderson's Bridge and Owen's Bridge, respectively.
  (c) De Sauty Bridge and Anderson's Bridge, respectively..
  (d) Owen's Bridge and Anderson's Bridge, respectively.
(iii) A general Ac circuit, having 'cross connections' like those in Wheatstone bridge, can be analyzed
  (a) Either by using the modified AC form of the rules for series-parallel circuits or by using Kirchhoff's laws for AC circuits.

(b) Neither by using the modified AC form of the rules for series-parallel circuits nor by using Kirchhoff's laws for AC circuits.
(c) By using the modified (AC circuits) form of the rules for series-parallel circuits and not by using Kirchhoff's laws for AC circuits.
(d) Not by using the modified (AC circuits) form of the rules for series-parallel circuits but by using Kirchhoff's laws for AC circuits.

(iv) The number of balance conditions, that need to be simultaneously satisfied, in an Anderson's bridge and a Wien's bridge, are
(a) 2 and 1, respectively.
(b) 1 and 2, respectively.
(c) 2 and 2, respectively.
(d) 1 and 1, respectively.

(v) The bridge shown here, is known as the



(a) Owen's bridge and the loop equation, for the mesh KCDK, in it is
$$I_C.j\omega C - I_3R_3 + I_RR = 0$$
(b) Anderson's bridge, and the loop equation, for the mesh KCDK is
$$-I_C.j\omega C + I_3R_3 - I_RR = 0$$
(c) Anderson's bridge, and the loop equation, for the mesh KCDK is
$$-I_C.\frac{1}{j\omega C} + I_3R_3 - I_RR = 0$$
(d) Owen's bridge and the loop equation, for the mesh KCDK, in it is
$$-I_C.\frac{1}{j\omega C} + I_3R_3 + I_RR = 0$$

Answers

1. (a)
Justification/Feedback for the correct answer:

(a) Wien's bridge is designed to measure an unknown capacitance in terms of a standard capacitance.
(b) Owen's bridge is used to measure inductance and not capacitance.
(c) Anderson's bridge has been designed for measuring inductances and not capacitances.
(d) Maxwell's bridge is suitable for inductance measurements.

2. (a)

Justification/Feedback for the correct answer:
(a) Of the three bridges, mentioned in the question, the De sauty bridge is used for measuring capacitances while Anderson and Owen's bridge, are used for measuring inductances. Hence choice (a) is correct.
(b) Of the three bridges, mentioned in the question, the De sauty bridge is used for measuring capacitances while Anderson and Owen's bridge, are used for measuring inductances. Hence choice (a) is correct.
(c) Of the three bridges, mentioned in the question, the De sauty bridge is used for measuring capacitances while Anderson and Owen's bridge, are used for measuring inductances. Hence choice (a) is correct.
(d) Of the three bridges, mentioned in the question, the De sauty bridge is used for measuring capacitances while Anderson and Owen's bridge, are used for measuring inductances. Hence choice (a) is correct.

3. (d)

Justification/Feedback for the correct answer:
(a) For analyzing any general AC circuit, having cross-connections like that in a Wheatstone bridge, we do not use to modified (AC circuit from) of the rules for series-parallel circuits. We need to use the modified (AC circuits) form of Kirchhoff's laws.
(b) For analyzing any general AC circuit, having cross-connections like that in a Wheatstone bridge, we do not use to modified (AC circuit from) of the rules for series-parallel circuits. We need to use the modified (AC circuits) form of Kirchhoff's laws.
(c) For analyzing any general AC circuit, having cross-connections like that in a Wheatstone bridge, we do not use to modified (AC circuit from) of the rules for series-parallel circuits. We need to use the modified (AC circuits) form of Kirchhoff's laws.
(d) For analyzing any general AC circuit, having cross-connections like that in a Wheatstone bridge, we do not use to modified (AC circuit from) of the rules for series-parallel circuits. We need to use the modified (AC circuits) form of Kirchhoff's laws.

4. (c)

Justification/Feedback for the correct answer:
(a) Both the Anderson Bridge and the Wien bridge, belong to the general category of AC bridges in which the bridge attains its 'balance' only when two conditions are satisfied simultaneously.
(b) Both the Anderson Bridge and the Wien bridge, belong to the general category of AC bridges in which the bridge attains its 'balance' only when two conditions are satisfied simultaneously.
(c) Both the Anderson Bridge and the Wien bridge, belong to the general category of AC bridges in which the bridge attains its 'balance' only when two conditions are satisfied simultaneously.

(d) Both the Anderson Bridge and the Wien bridge, belong to the general category of AC bridges in which the bridge attains its 'balance' only when two conditions are satisfied simultaneously.

5. (c)

Justification/Feedback for the correct answer:

(a) The bridge shown is Anderson's bridge and the correct loop equation, for the mesh KCDK, is

$$-I_C.\frac{1}{j\omega C} + I_3R_3 - I_RR = 0$$

(b) The bridge shown is Anderson's bridge and the correct loop equation, for the mesh KCDK, is

$$-I_C.\frac{1}{j\omega C} + I_3R_3 - I_RR = 0$$

(c) The bridge shown is Anderson's bridge and the correct loop equation, for the mesh KCDK, is

$$-I_C.\frac{1}{j\omega C} + I_3R_3 - I_RR = 0$$

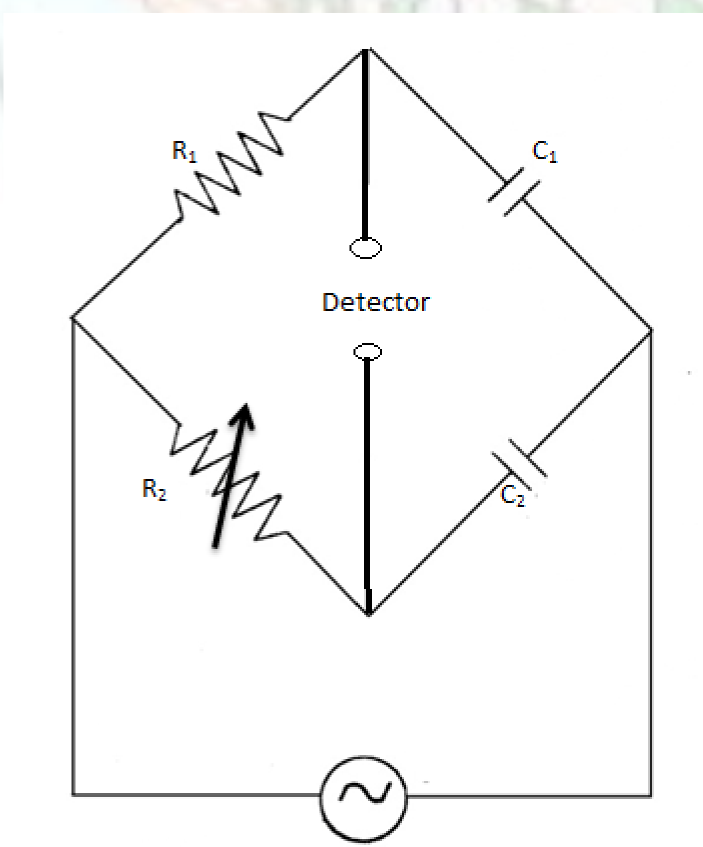
(d) The bridge shown is Anderson's bridge and the correct loop equation, for the mesh KCDK, is

$$-I_C.\frac{1}{j\omega C} + I_3R_3 - I_RR = 0$$

<u>Short note type:</u>

Write short note on

(a) AC Wheatstone bridge
(b) De Sauty Bridge
(c) Use of Kirchhoff's laws for analysis of AC circuits
(d) 'Frequency dependent' and 'frequency independent nature of the balance.

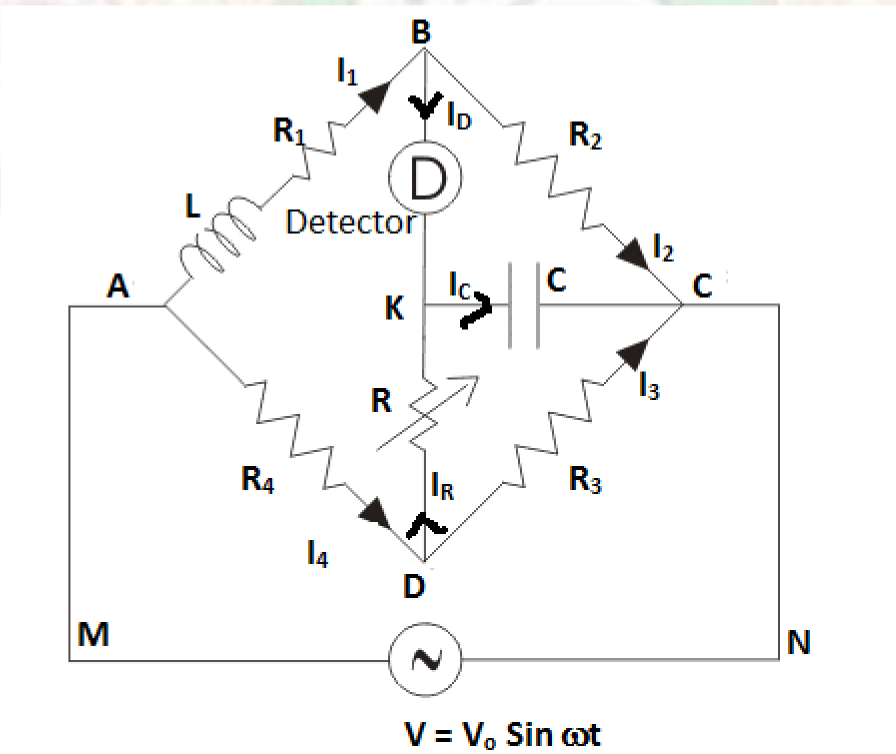


(e) Reasons for the general requirement of simultaneous satisfaction of two balance conditions in an AC (Wheatstone bridge) like circuit.

Essay Type

(a) Draw the circuit of Wien bridge and obtain its balance condition.
(b) Identify the circuit drawn here and obtain its balance condition.

(c) The circuit diagram for Anderson bridge is shown here. Use Kirchhoff's rules, for AC circuits, to obtain its two balance conditions.



(d) Use Kirchhoff's rules, for AC circuits, to obtain the two balance conditions for the Wien's bridge circuit shown here.

(e) Draw an arbitrary AC Wheatstone bridge, containing resistors and/or inductors in its four arms. Obtain the balance conditions for the bridge drawn by you.