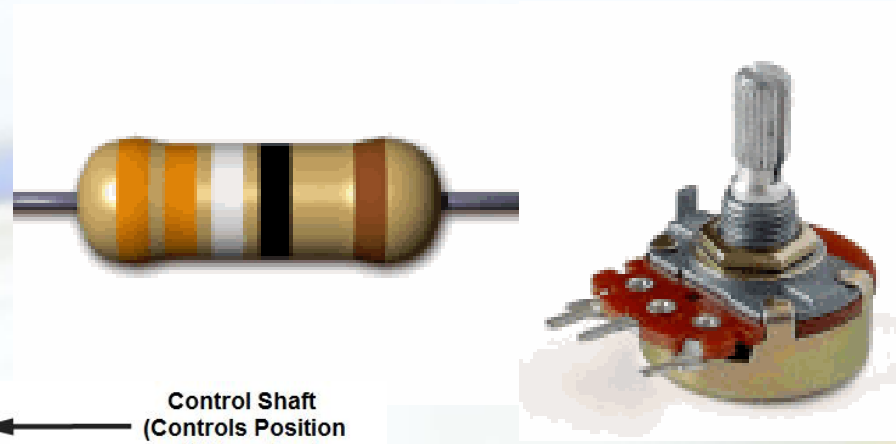
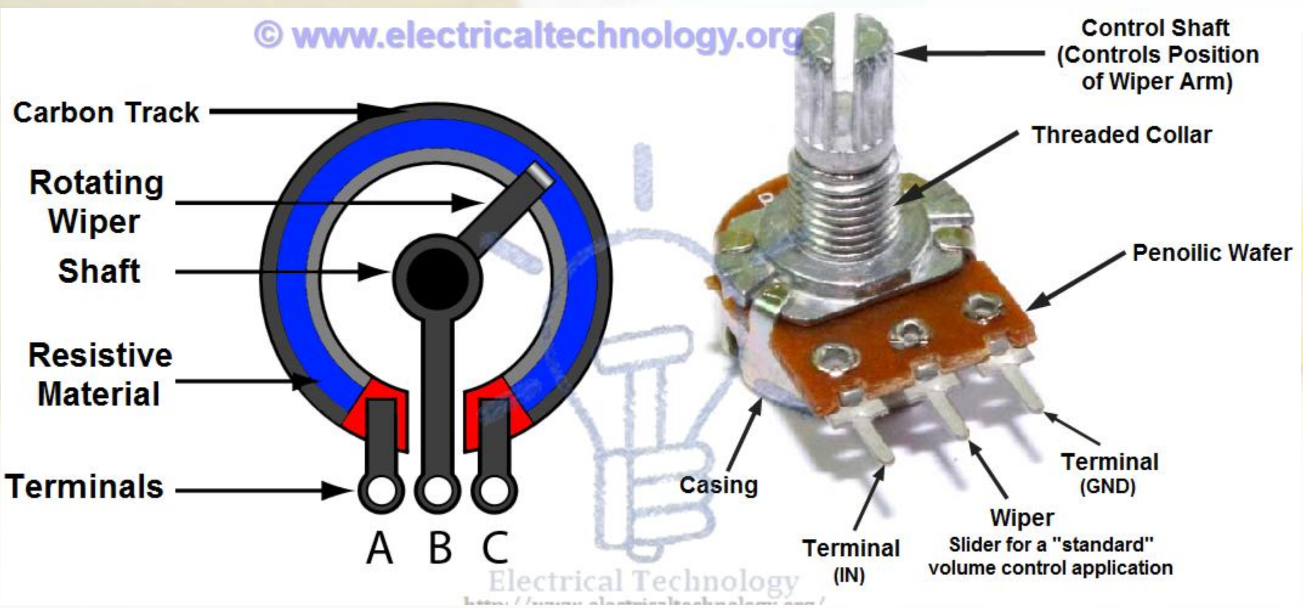
Chapter 5

Electrical circuit components

1- Resistance

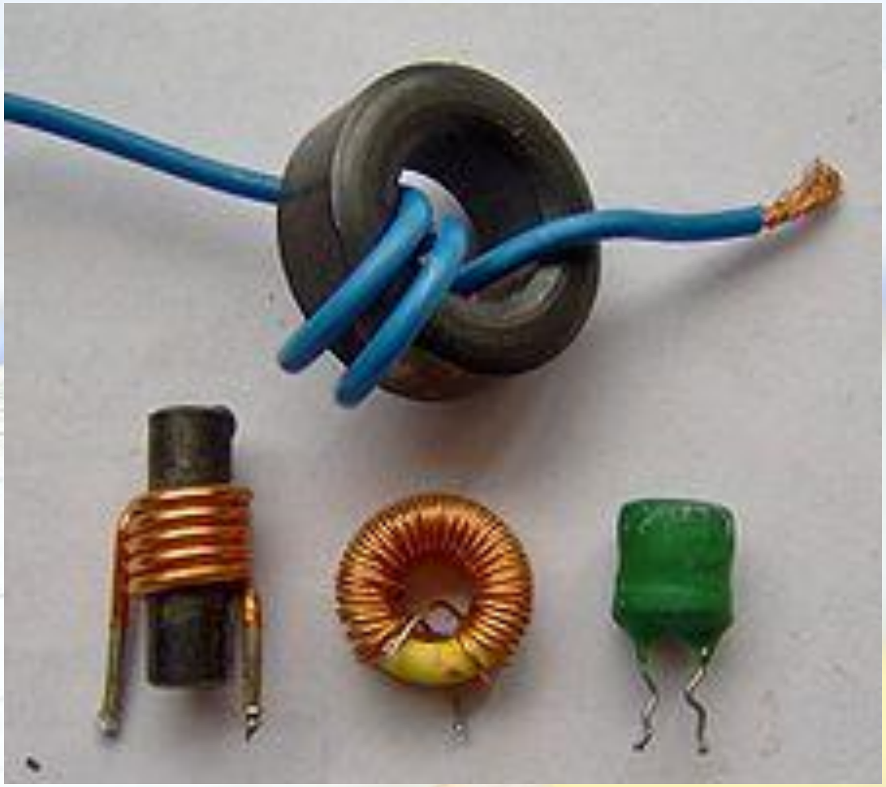
Variable & Fixed Resistors





Electrical circuit components

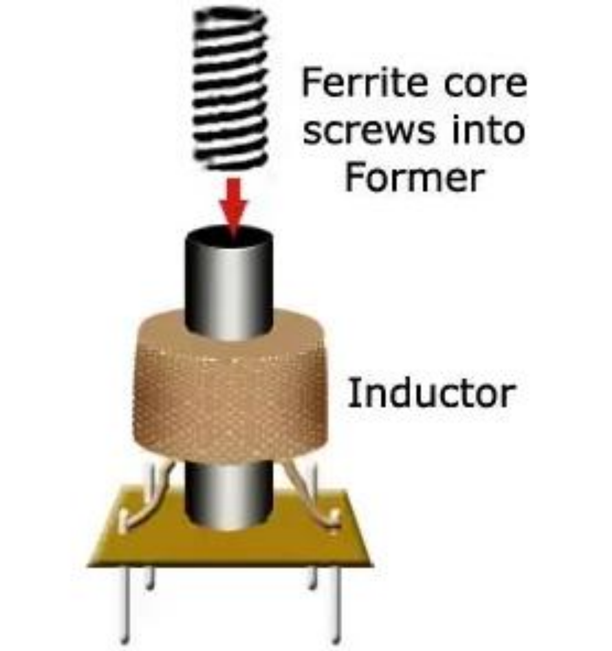
2- Inductance

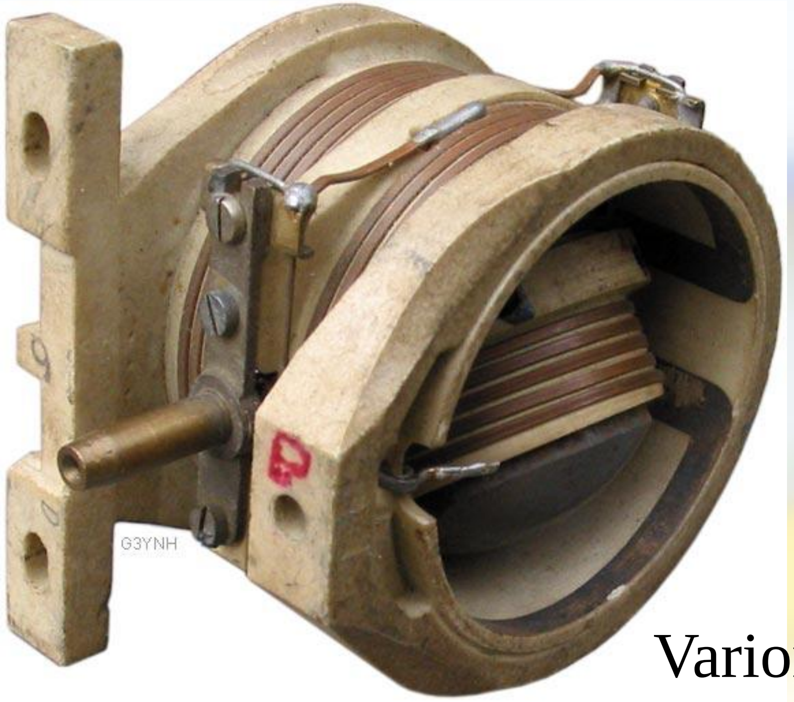


Fixed inductance

Electrical circuit components

2- Inductance





Variometer

Variable inductance

Electrical circuit components

3- Capacitance

Fixed capacitance

Electrical circuit components

3- Capacitance

Variable capacitance

Electrical circuit components

If we have an unknown resistance or inductance or capacitance, how can we accurately measure it???

The unknown resistance or inductance or capacitance sometimes represent a practical element such as:

- Determination of short circuit location in telephone lines or power cables.
- Determination of transformer winding inductance, capacitance and resistance.
- etc.

DC andAC Bridge can be considered the best choice.

DC Bridges

1. DC bridges are the most accurate method for measuring resistances.

2. AC bridges are most popular, convenient and accurate instruments for measurement of unknown inductance, capacitance and some other related quantities.

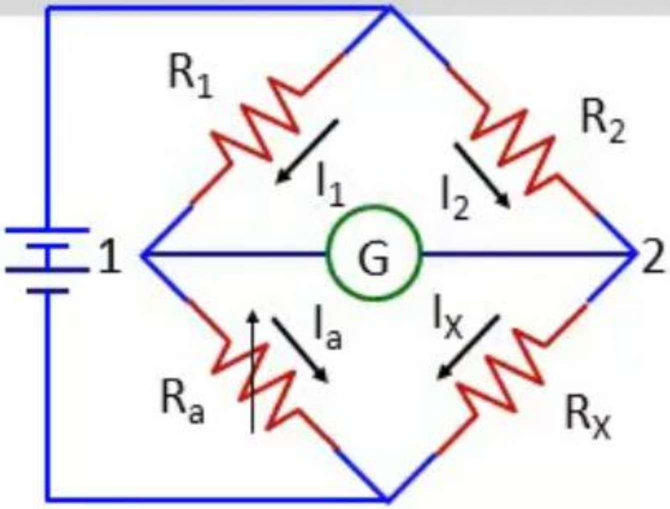
DC Bridges

Wheatstone bridge.

It is used for medium resistance measurements

Zero indication occurs when V_{Ra} is equal to V_{RX}

The balance is independent on the supply voltage



The resistances R_1 and R_2 are precision devices of known value

The resistance "R_a" is an adjustable resistance to reach the bridge-balanced condition

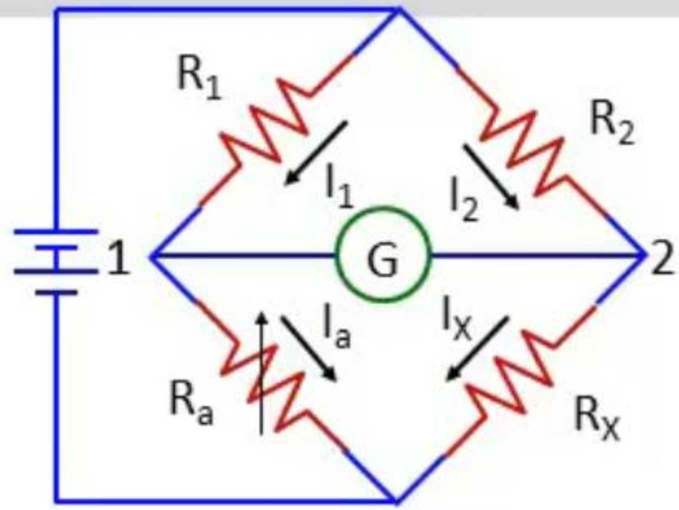
DC Bridges

Wheatstone bridge.

Under balanced conditions:

$$I_1 R_1 = I_2 R_2$$

$$I_a R_a = I_X R_X$$



The current "I_1" is equal to "I_a"

The current "I_2" is equal to "I_X"

$$I_1 R_1 = I_2 R_2$$

$$I_1 R_a = I_2 R_X$$

$$\frac{R_1}{R_a} = \frac{R_2}{R_X}$$

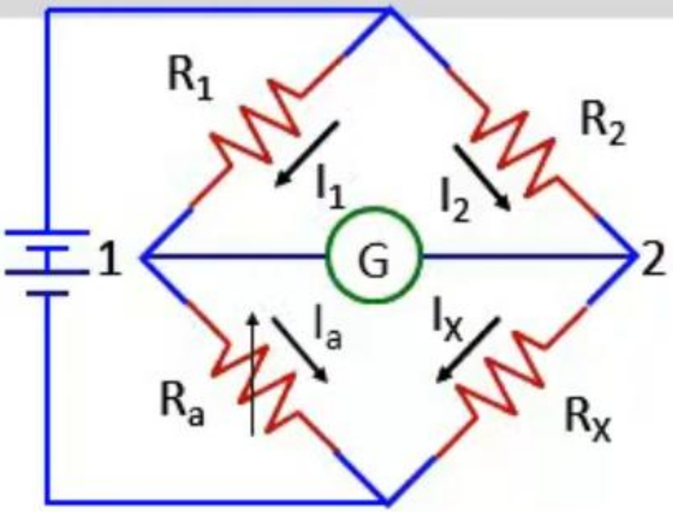
DC Bridges

Wheatstone bridge.

$$\frac{R_1}{R_a} = \frac{R_2}{R_X} \rightarrow R_X = \frac{R_a R_2}{R_1}$$

The standard adjustable resistor is called the ***rheostat***

The other two resistors are called the **ratio arms**

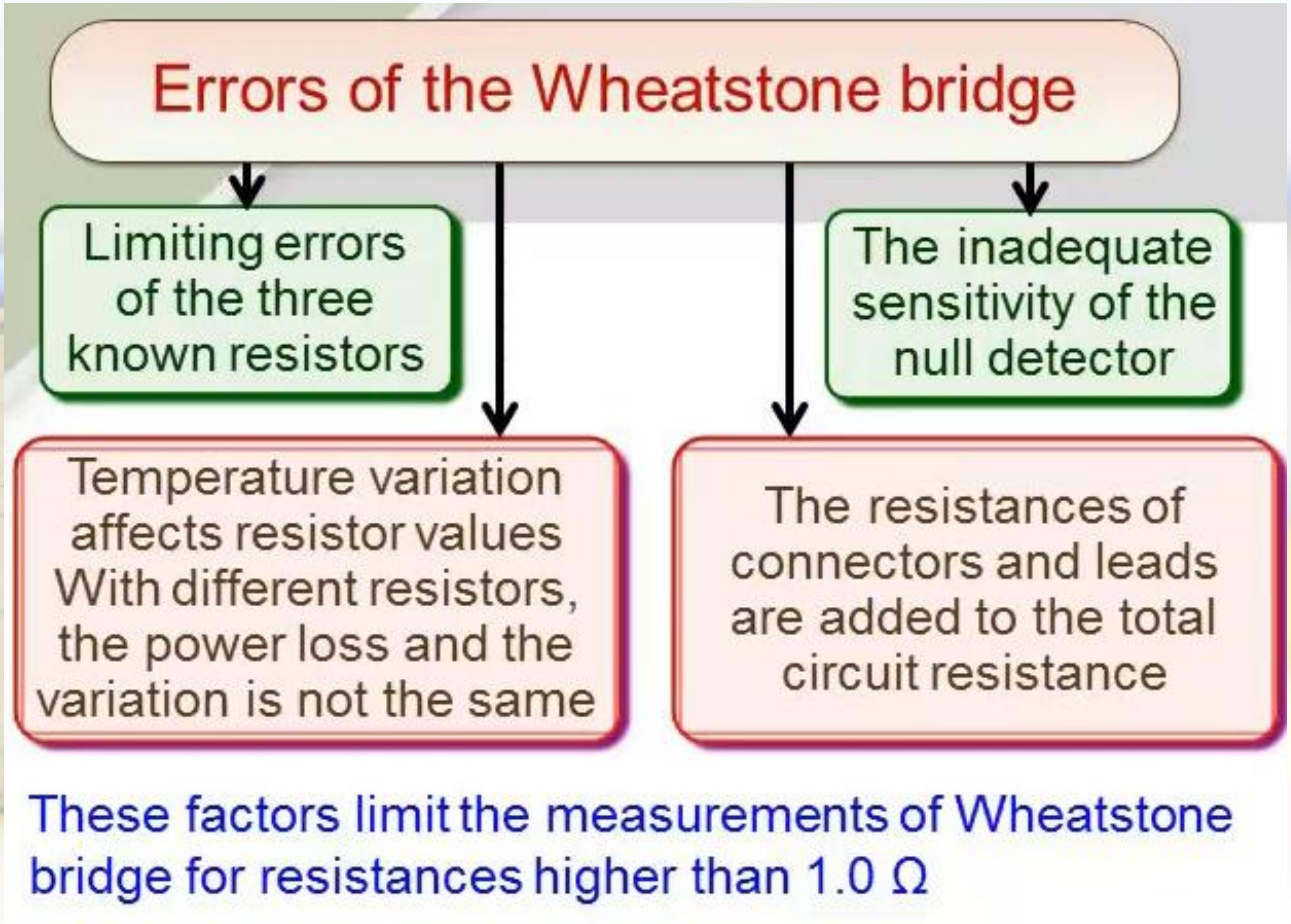


A number of known variable resistors is required

The accuracy of the resistance measurement can reach 99.5%

DC Bridges

Wheatstone bridge.



DC Bridges

Example:

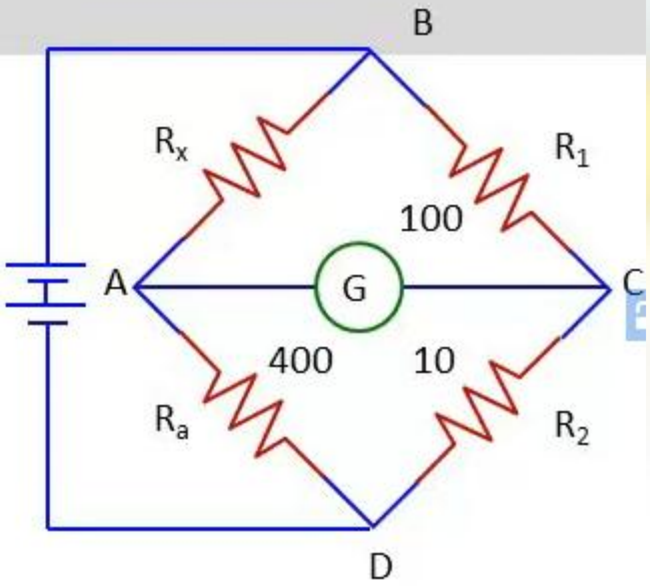
In a Wheatstone bridge ABCD, a galvanometer is connected between A and C, and a battery between B and D. A resistor of unknown value is connected between A and B. When the bridge is balanced, the resistance between B and C is 100 Ω, that between C and D is 10 Ω and that between D and A is 400 Ω. Calculate the value of the unknown resistance.

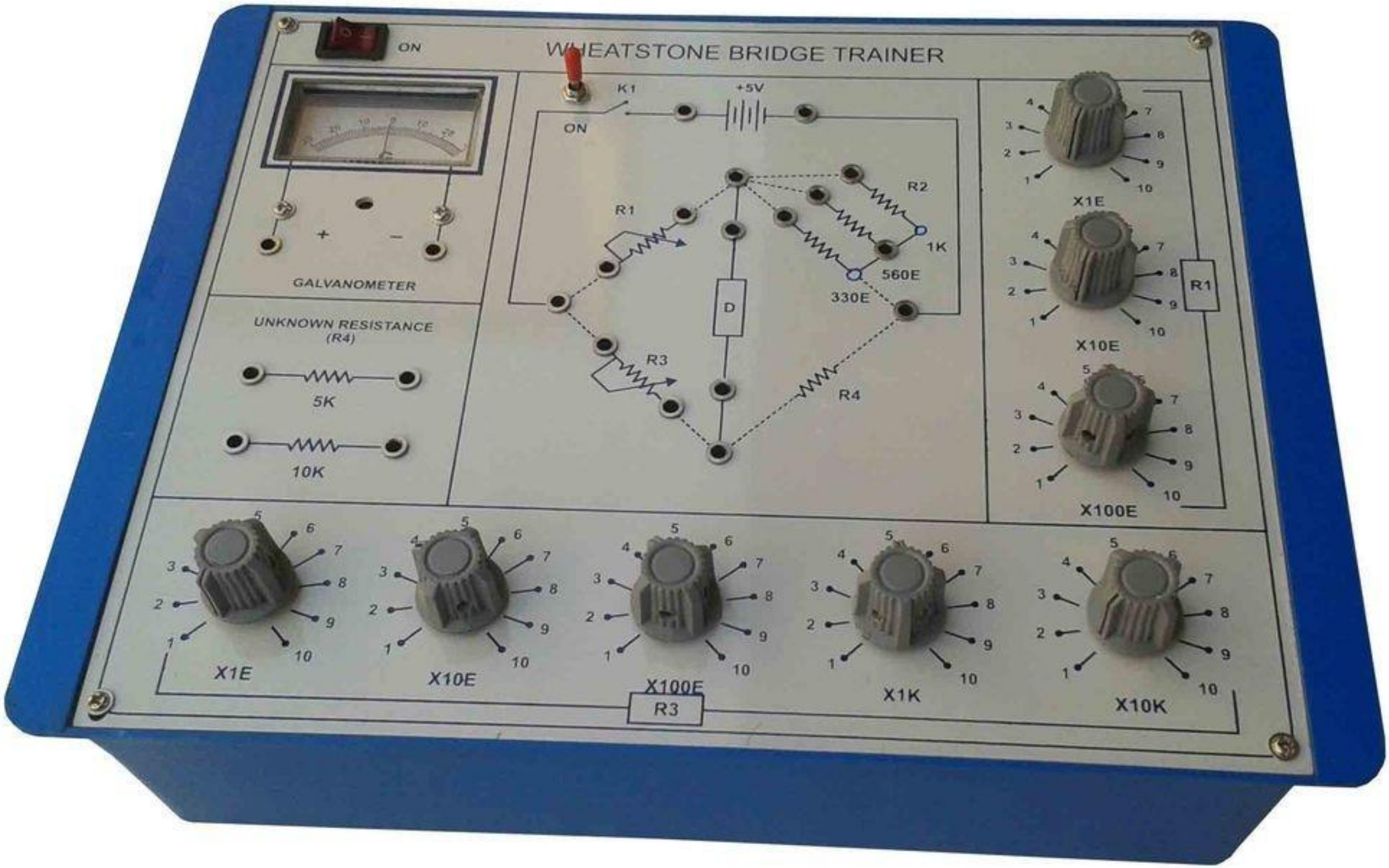
Solution:

The balance equation is given as:

$R_x * 10 = 100 * 400$

$R_x = 4000\ \Omega$





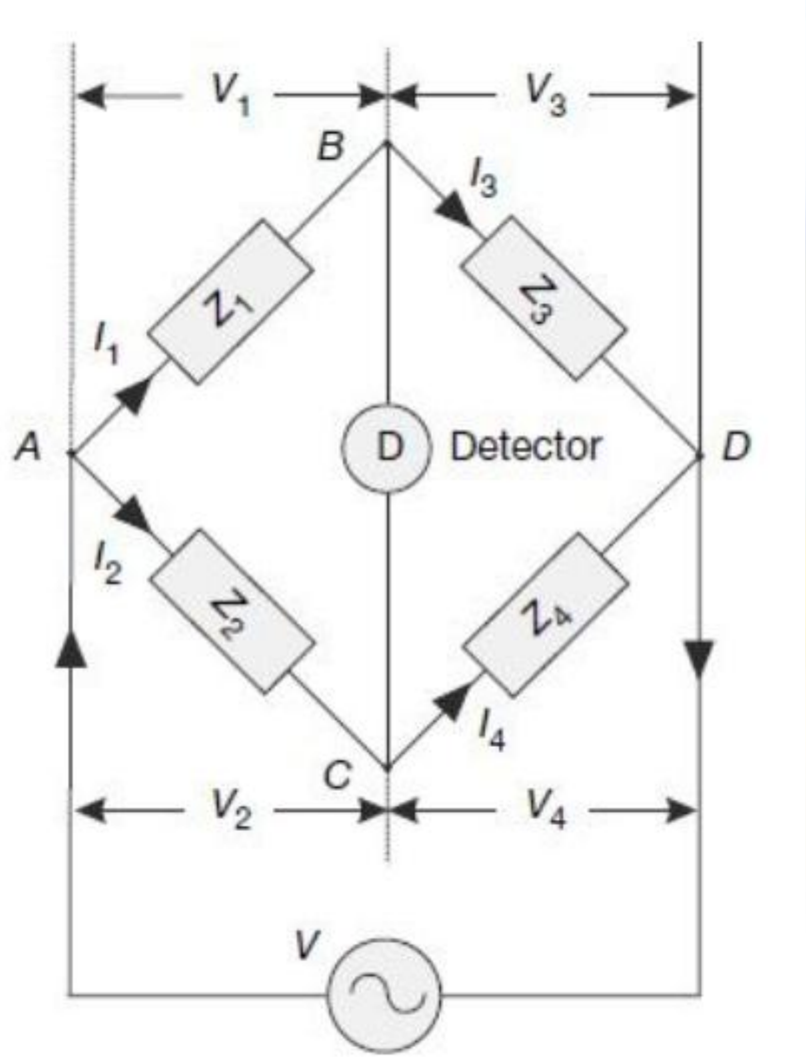
ON
WHEATSTONE BRIDGE TRAINER
K1
+5V
ON
GALVANOMETER
UNKNOWN RESISTANCE
(R4)
5K
10K
R1
R2
1K
560E
330E
D
R3
R4
X1E
X10E
X100E
R1
X1E
X10E
X100E
X1K
X10K
R3


EXT. BATT
RATIO
.001
.01
.1
1
10
100
1000
X 1000 Ω
WHEATSTONE BRIDGE
GALVO
X 10 Ω
X 1 Ω
DIRECT
GALVO
SHUNTED
ISO 9001:2008
Certified Company
K1
PRESS KEY
K2
RX
UNKNOWN RESISTANC

Introduction to AC Bridges

An ac bridge, in its basic form, consists of four arms, an alternating power supply, and a balance detector.

Balance is indicated by zero response of the detector. At balance, no current flows through the detector, i.e., there is no potential difference across the detector, or in other words, the potentials at points B and C are the same.



Introduction to AC Bridges

An ac bridge, in its basic form, consists of four arms, an alternating power supply, and a balance detector.

$$\bar{V}_1 = \bar{V}_2$$

$$\bar{I}_1\bar{Z}_1 = \bar{I}_2\bar{Z}_2$$

$$\bar{I}_1 = \bar{I}_3 = \frac{\bar{V}}{\bar{Z}_1 + \bar{Z}_3}$$

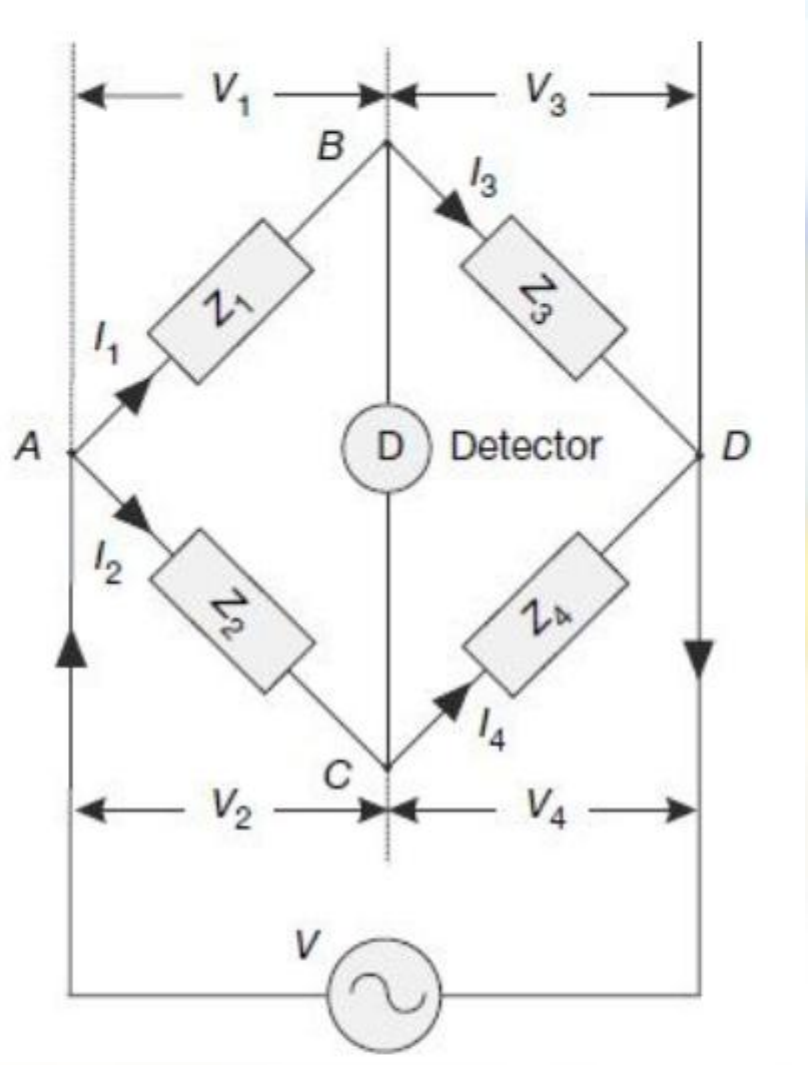
$$\bar{I}_2 = \bar{I}_4 = \frac{\bar{V}}{\bar{Z}_2 + \bar{Z}_4}$$

$$\frac{\bar{V}}{\bar{Z}_1 + \bar{Z}_3}\bar{Z}_1 = \frac{\bar{V}}{\bar{Z}_2 + \bar{Z}_4}\bar{Z}_2$$

$$\bar{Z}_1\bar{Z}_2 + \bar{Z}_1\bar{Z}_4 = \bar{Z}_2\bar{Z}_1 + \bar{Z}_2\bar{Z}_3$$

$$\bar{Z}_1\bar{Z}_4 = \bar{Z}_2\bar{Z}_3$$

$$\frac{\bar{Z}_1}{\bar{Z}_3} = \frac{\bar{Z}_2}{\bar{Z}_4}$$



Introduction to AC Bridges

An ac bridge, in its basic form, consists of four arms, an alternating power supply, and a balance detector.

$$\bar{Z}_1\bar{Z}_4 = \bar{Z}_2\bar{Z}_3$$

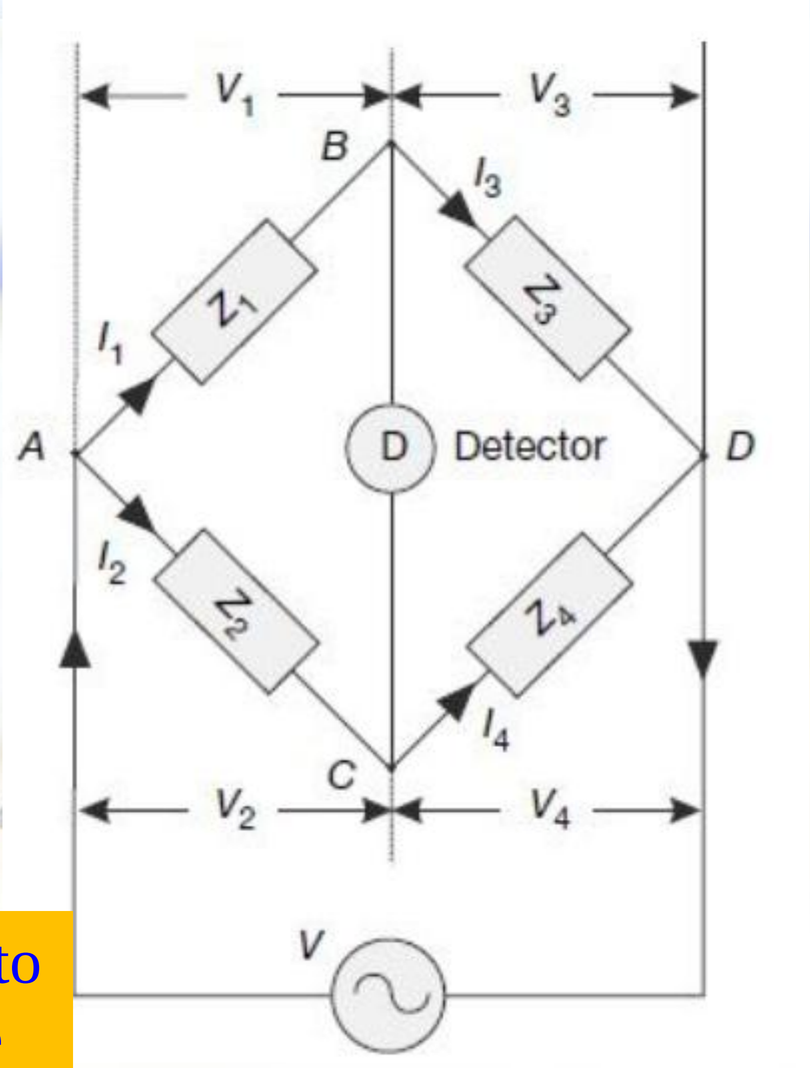
$$\frac{\bar{Z}_1}{\bar{Z}_3} = \frac{\bar{Z}_2}{\bar{Z}_4}$$

$$Z_1\angle\theta_1 \times Z_4\angle\theta_4 = Z_2\angle\theta_2 \times Z_3\angle\theta_3$$

$$Z_1Z_4\angle(\theta_1+\theta_4) = Z_2Z_3\angle(\theta_2+\theta_3)$$

$$Z_1Z_4 = Z_2Z_3$$

$$\angle(\theta_1+\theta_4) = \angle(\theta_2+\theta_3)$$

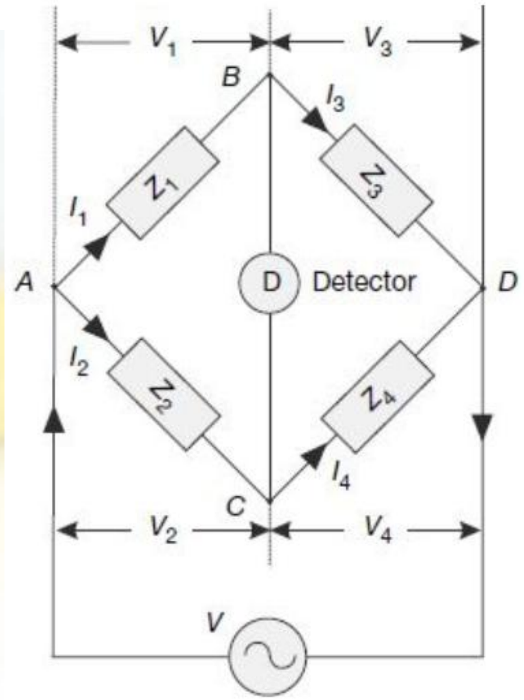


All AC bridges must have two variables to guarantee magnitude and phase balance

Introduction to AC Bridges

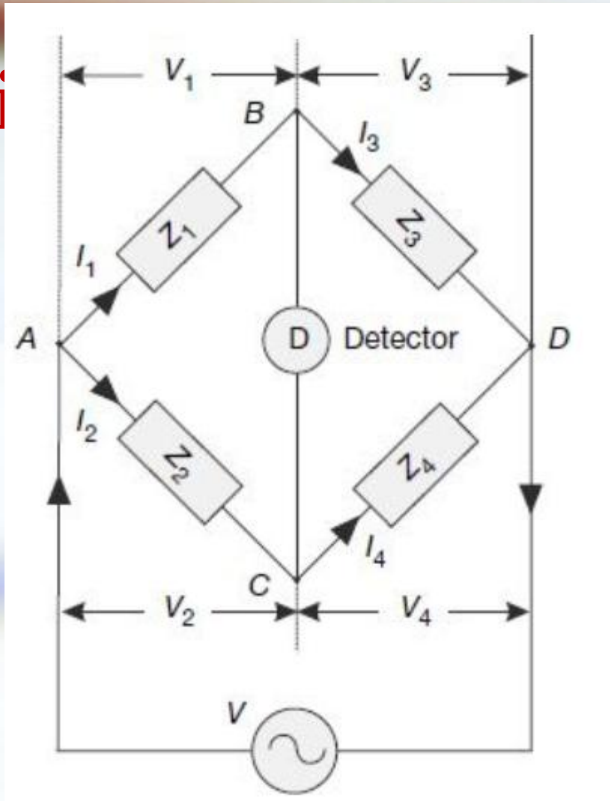
Example

In the AC bridge circuit shown in Figure , the supply voltage is 20 V at 500 Hz. Arm AB is 0.25 μF pure capacitance; arm BD is 400 Ω pure resistance and arm AC has a 120 Ω resistance in parallel with a 0.15 μF capacitor. Find resistance and inductance or capacitance of the arm CD considering it as a series circuit.



Introduction to AC Bri

In the AC bridge circuit shown in Figure *, the supply voltage is 20 V at 500 Hz. Arm AB is 0.25 μF pure capacitance; arm BD is 400 Ω pure resistance and arm AC has a 120 Ω resistance in parallel with a 0.15 μF capacitor. Find resistance and inductance or capacitance of the arm CD considering it as a series circuit.*



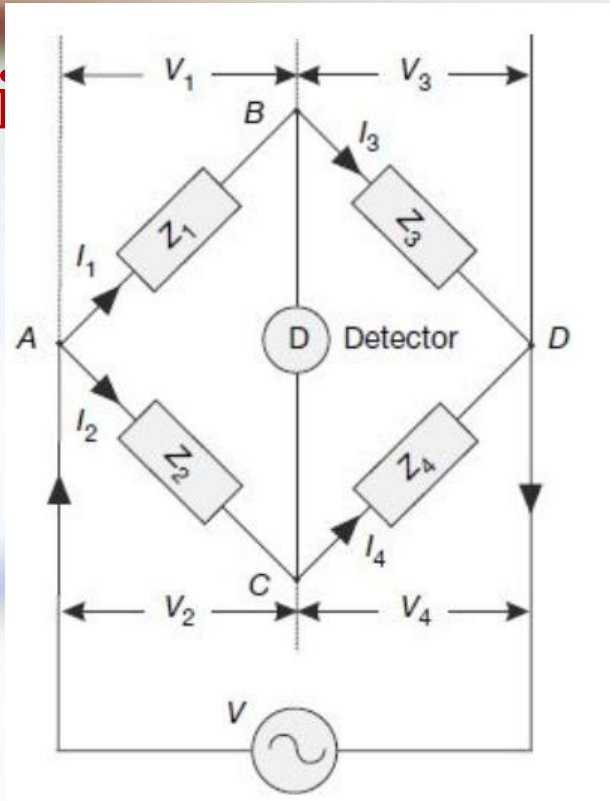
Solution Impedance of the arm *AB* is

$$Z_1 = \frac{1}{2\pi f C_1} = \frac{1}{2\pi \times 500 \times 0.25 \times 10^{-6}} = 1273\ \Omega$$

Since it is purely capacitive, in complex notation, $\overline{Z}_1 = 1273\angle -90^\circ\ \Omega$

Introduction to AC Bri

In the AC bridge circuit shown in Figure , the supply voltage is 20 V at 500 Hz. Arm AB is 0.25 μF pure capacitance; arm BD is 400 Ω pure resistance and arm AC has a 120 Ω resistance in parallel with a 0.15 μF capacitor. Find resistance and inductance or capacitance of the arm CD considering it as a series circuit.

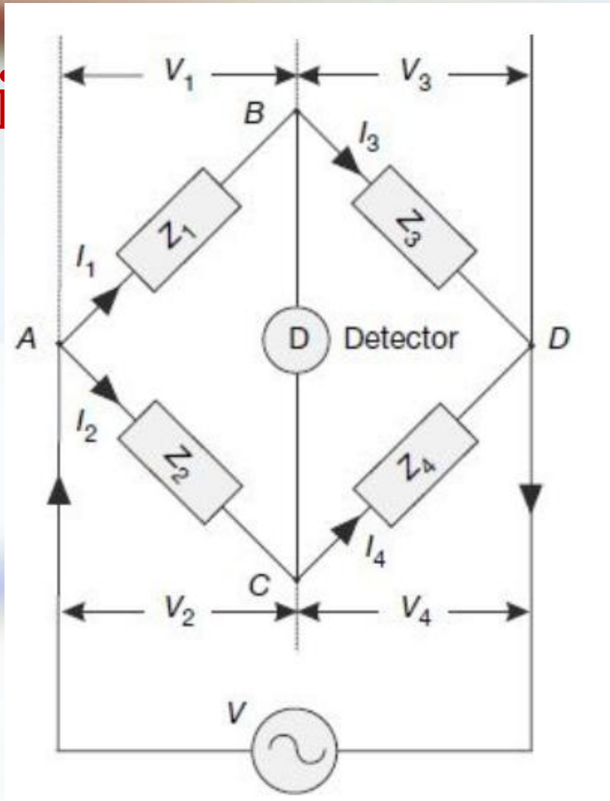


Impedance of arm *BD* is $Z_3 = 400\ \Omega$

Since it is purely resistive, in complex notation, $\bar{Z}_3 = 400\angle 0^\circ\ \Omega$

Introduction to AC Bri

In the AC bridge circuit shown in Figure *, the supply voltage is 20 V at 500 Hz. Arm AB is 0.25 μF pure capacitance; arm BD is 400 Ω pure resistance and arm AC has a 120 Ω resistance in parallel with a 0.15 μF capacitor. Find resistance and inductance or capacitance of the arm CD considering it as a series circuit.*



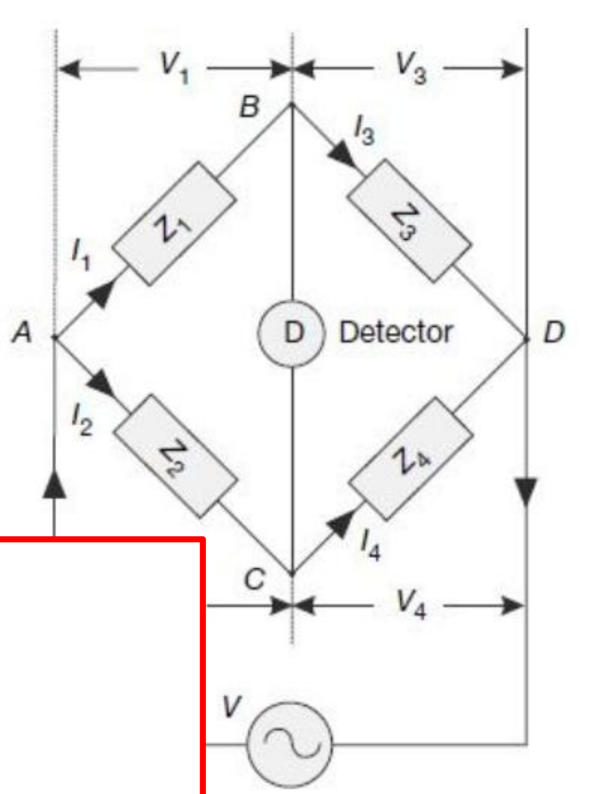
Impedance of arm AC containing 120 Ω resistance in parallel with a 0.15 μF capacitor is

$$\bar{Z}_2 = \frac{R_2}{1 + j2\pi f C_2 R_2} = \frac{120}{1 + j(2\pi \times 500 \times 0.15 \times 10^{-6} \times 120)}$$

$$= 119.8 \angle -3.2^\circ \ \Omega$$

Introduction to AC Bri

In the AC bridge circuit shown in Figure *, the supply voltage is 20 V at 500 Hz. Arm AB is 0.25 μF pure capacitance; arm BD is 400 Ω pure resistance and arm AC has a 120 Ω resistance in parallel with a 0.15 μF capacitor. Find resistance and inductance or capacitance of the arm CD considering it as a series circuit.*



For balance, $\overline{Z}_1\overline{Z}_4 = \overline{Z}_2\overline{Z}_3$

∴ impedance of arm *CD* required for balance is $\overline{Z}_4 = \dfrac{\overline{Z}_2\overline{Z}_3}{\overline{Z}_1}$

or, $\overline{Z}_4 = \dfrac{119.88 \times 400}{1273} \angle(-3.2° + 0° + 90°) = 37.65 \angle 86.8°$

The positive angle of impedance indicates that the branch consists of a series combination of resistance and inductance.

Resistance of the unknown branch $R_4 = 37.65 \times \cos(86.8°) = 2.1\ \Omega$

Inductive reactance of the unknown branch

$$X_4 = 37.65 \times \sin(86.8°) = 37.59\ \Omega$$

Inductance of the unknown branch $L_4 = \dfrac{37.59}{2\pi \times 500} H = 11.97$ mH

Introduction to AC Bridges

Measurement of inductance

Maxwell's Inductance Bridge
Hay's Bridge
Anderson's Bridge
Owen's Bridge

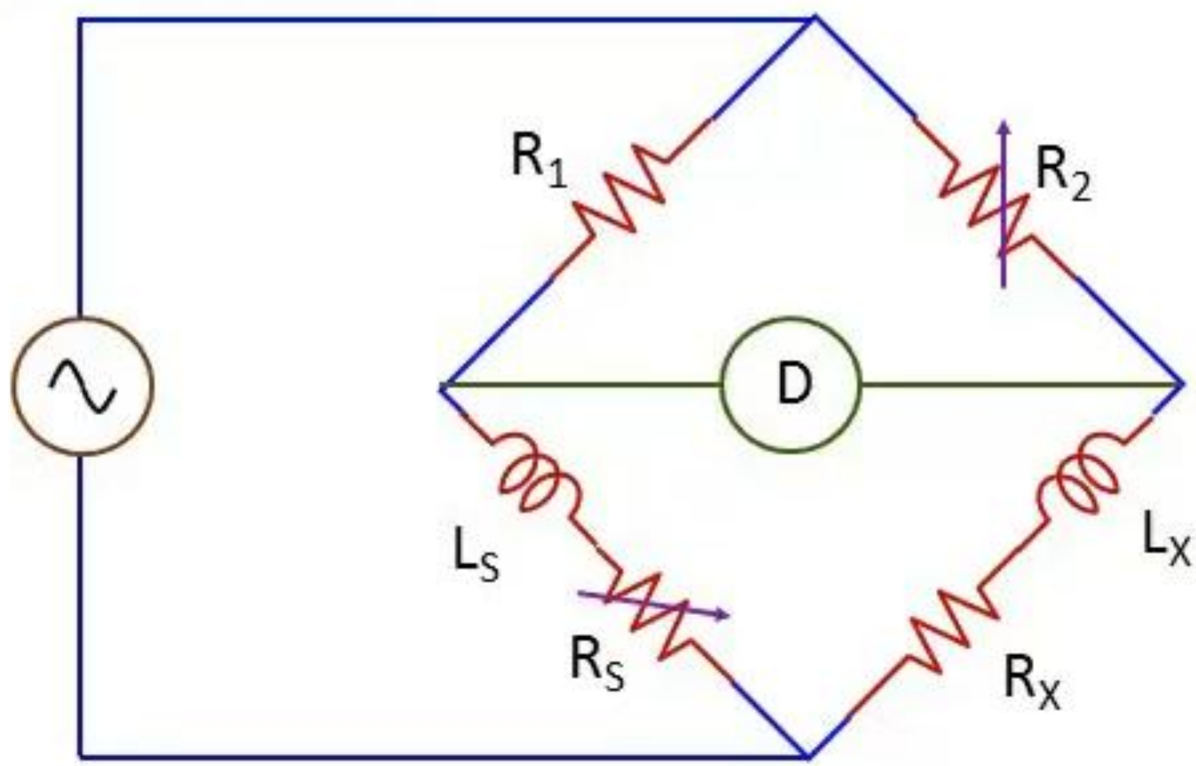
Measurement of capacitance

De Sauty's Bridge
Schering Bridge
Wien's Bridge

Maxwell's Inductance Bridge

This bridge is used to measure the value of an unknown inductance by comparing it with a variable standard self-inductance.

Used to determine the value of unknown impedance containing an inductance



Maxwell's Inductance Bridge

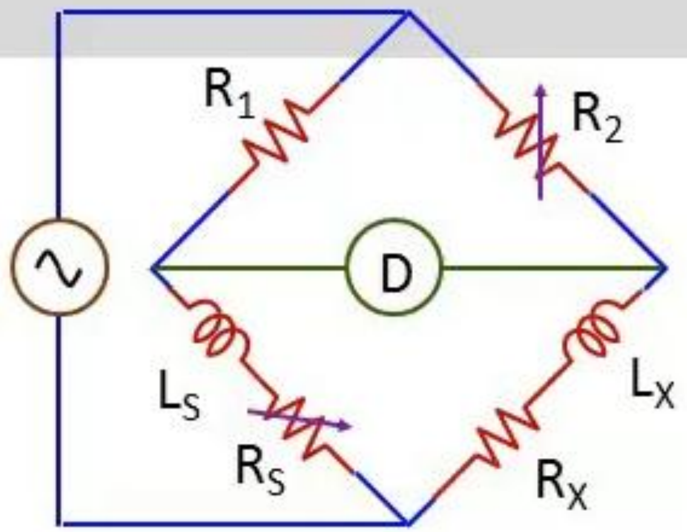
Simple analysis method

$$Z_1 = R_1$$

$$Z_2 = R_2$$

$$Z_3 = R_s + j\omega L_s$$

$$Z_4 = R_X + j\omega L_X$$



$$Z_1 * Z_4 = Z_2 * Z_3$$

$$R_1 \; (R_X + j\omega L_X) = R_2 \; (R_s + j\omega L_s)$$

$$R_1 R_X + j\omega R_1 L_X = R_2 R_s + j\omega R_2 L_s$$

Maxwell's Inductance Bridge

Simple analysis method

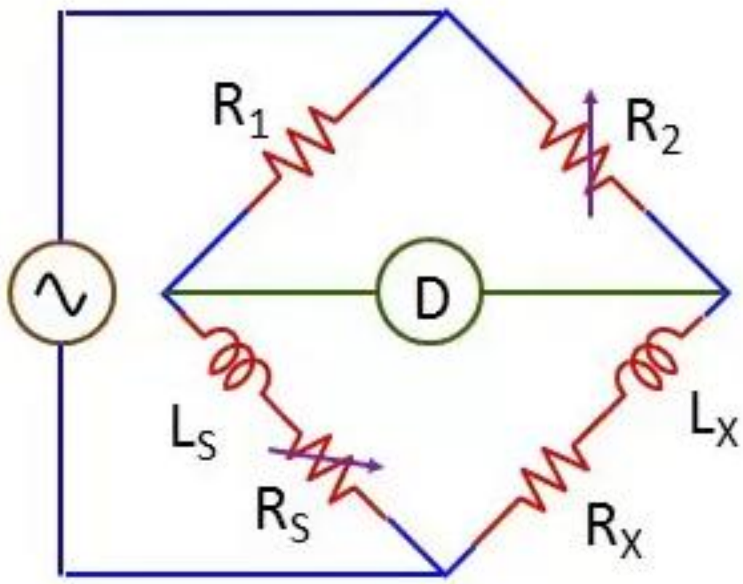
$$R_1 R_X + j\omega R_1 L_X = R_2 R_s + j\omega R_2 L_s$$

$$R_1 R_X = R_2 R_s$$

$$\omega R_1 L_X = \omega R_2 L_s$$

$$R_X = \frac{R_2}{R_1} R_s$$

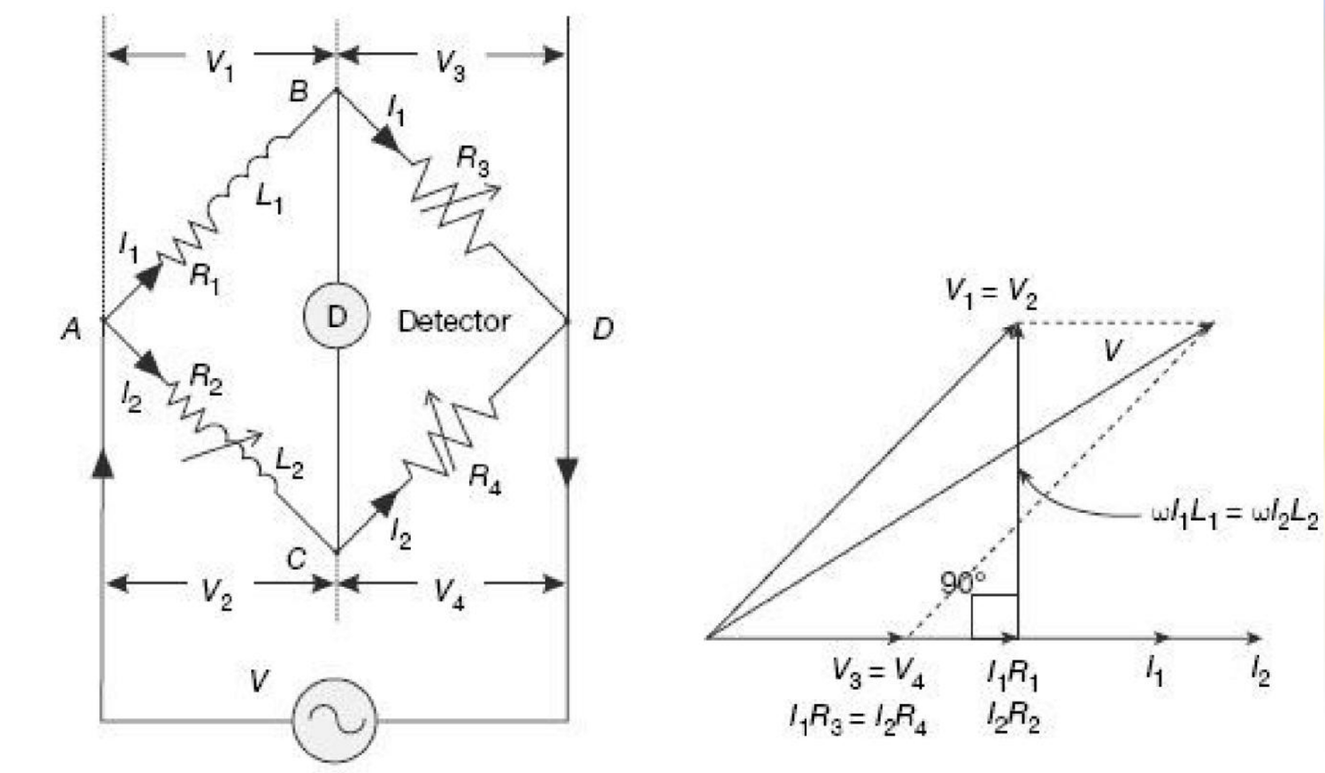
$$L_X = \frac{R_2}{R_1} L_s$$



Maxwell's Inductance Bridge

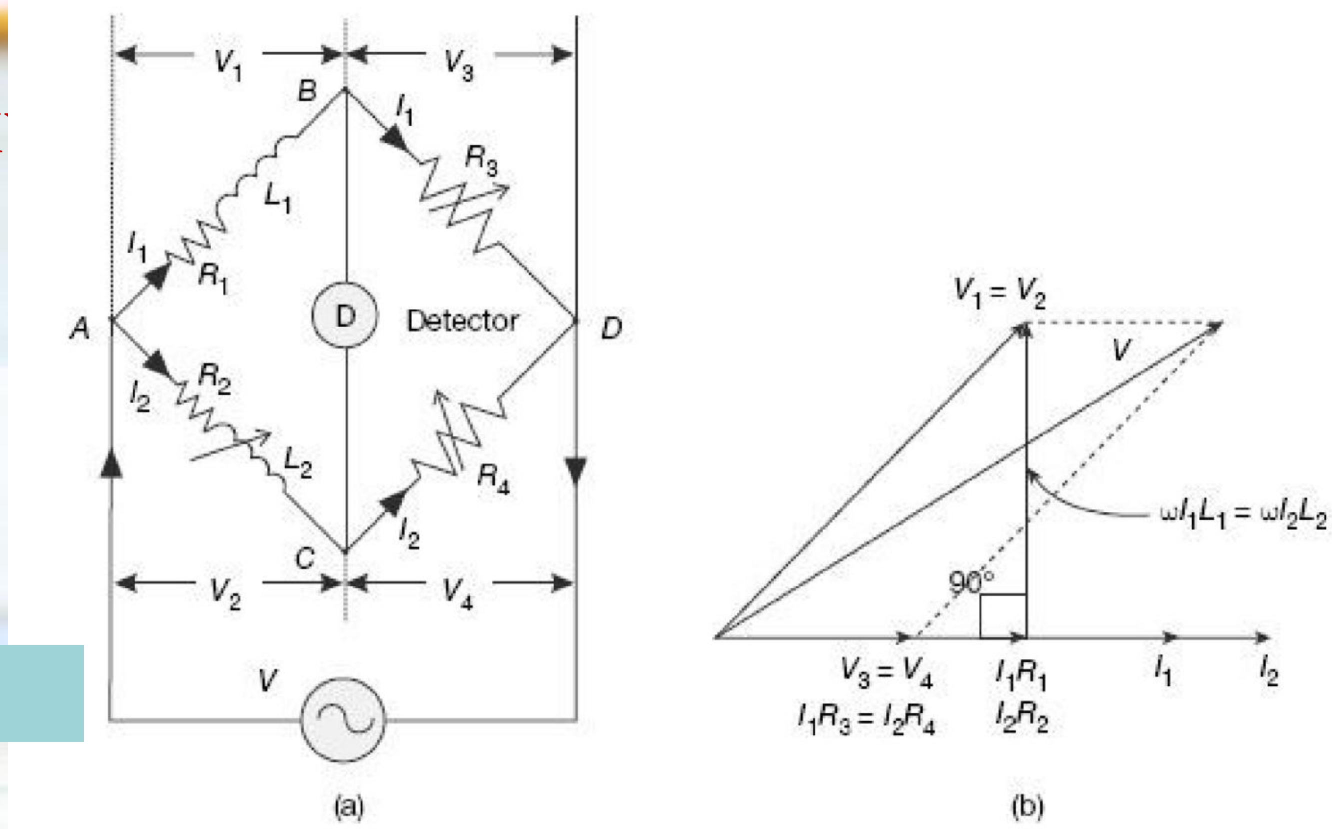
Detailed analysis method

This bridge is used to measure the value of an unknown inductance by comparing it with a variable standard self-inductance.



(a) (b)

Max

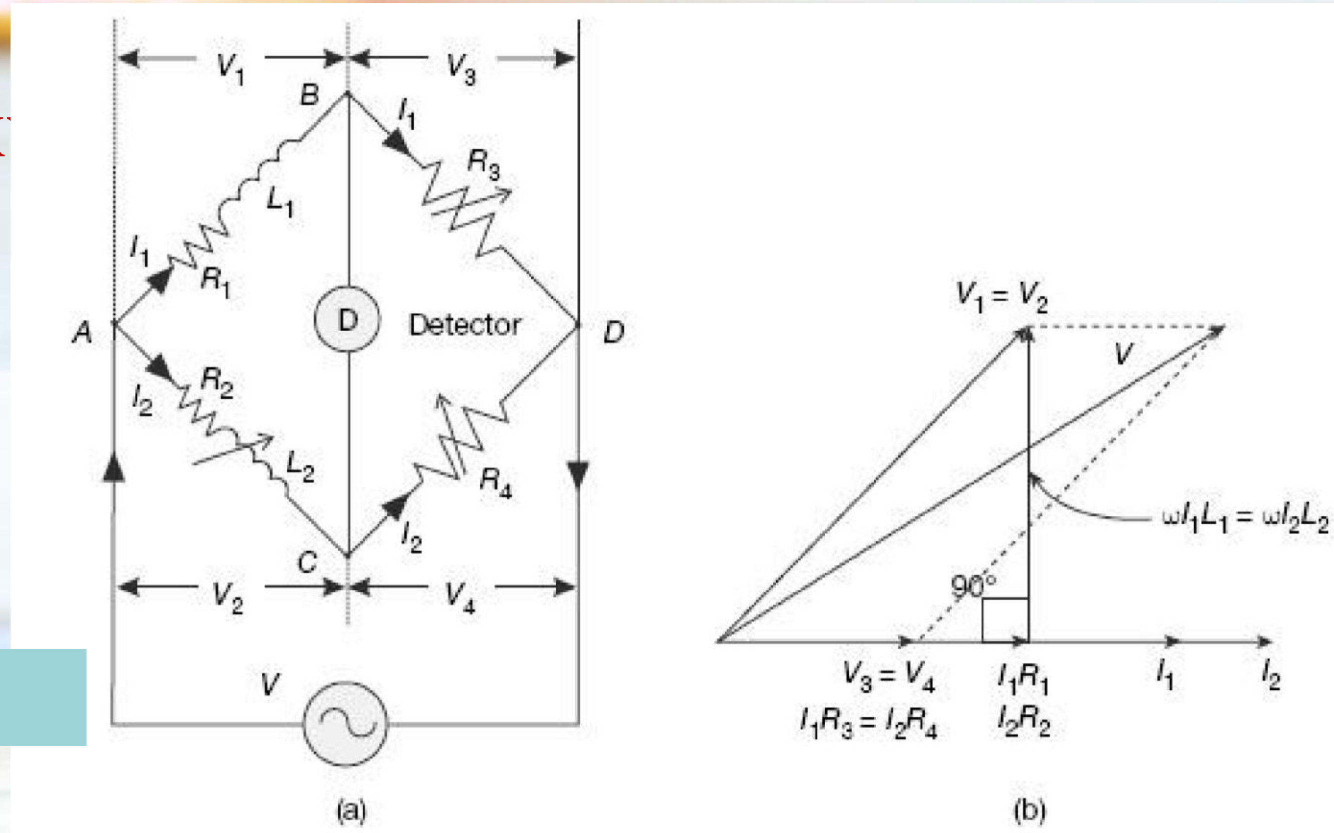


Bridge description

The unknown inductor L_1 of resistance R_1 in the branch AB is compared with the standard known inductor L_2 of resistance R_2 on arm AC.

Branch BD and CD contain known non-inductive resistors R_3 and R_4 respectively.

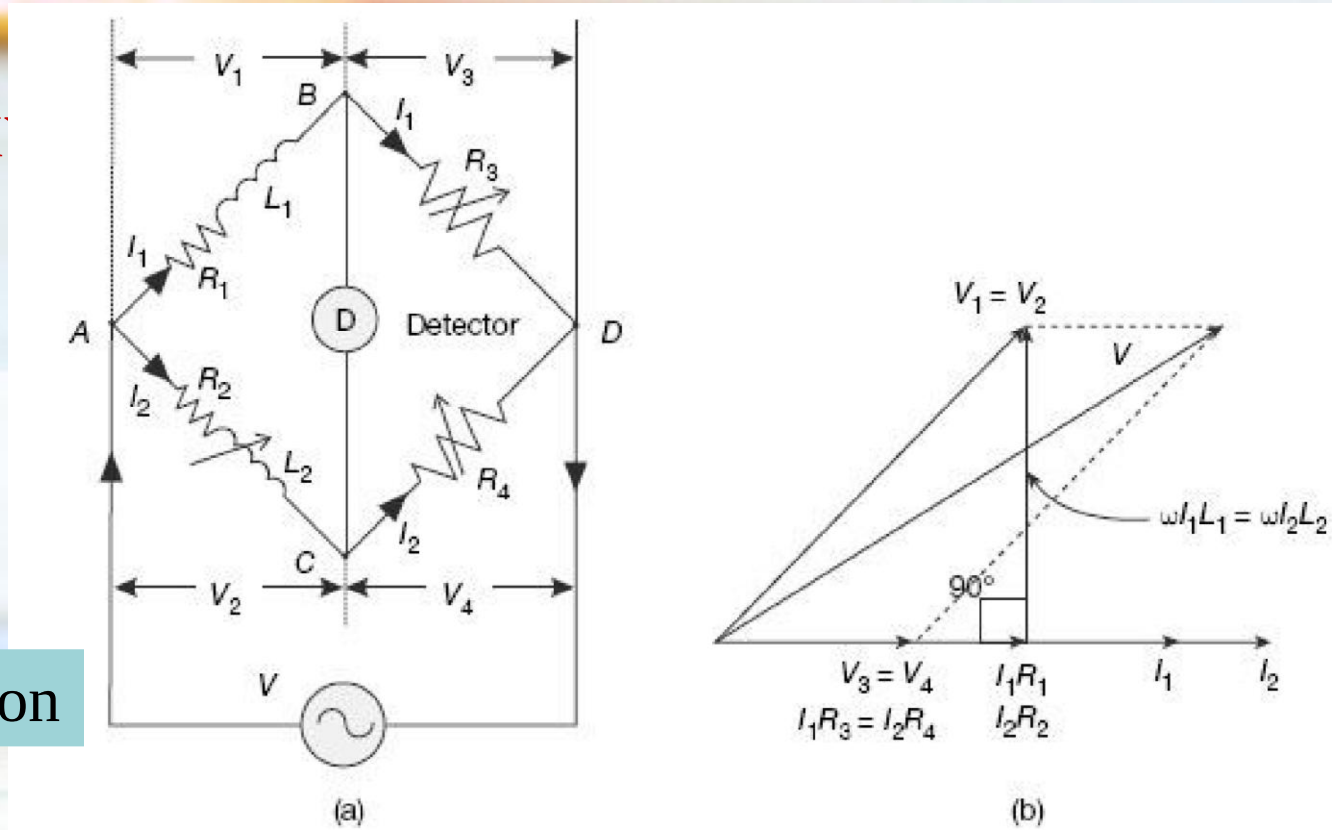
Max



Balance requirement

The bridge is balanced by varying L_2 and one of the resistors R_3 or R_4. Alternatively, varying R_3 (for magnitude balance) and R_2 (for phase balance).

Max

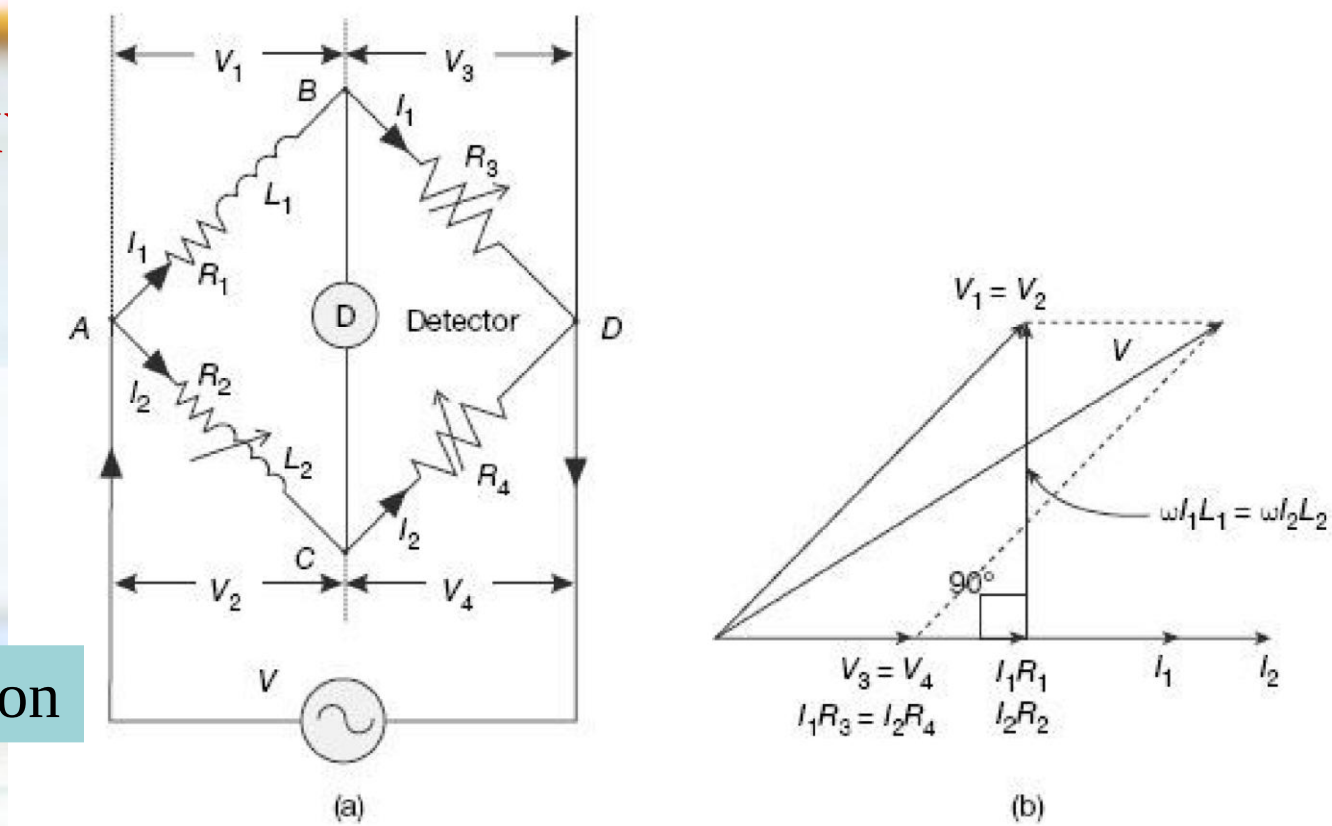


Under balance condition

Under balance condition, currents in the arms AB and BD are equal (I_1). Similarly, currents in the arms AC and CD are equal (I_2).

Under balanced condition, since nodes B and D are at the same potential, voltage drops across arm BD and CD are equal ($V_3 = V_4$); similarly, voltage drop across arms AB and AC are equal ($V_1 = V_2$).

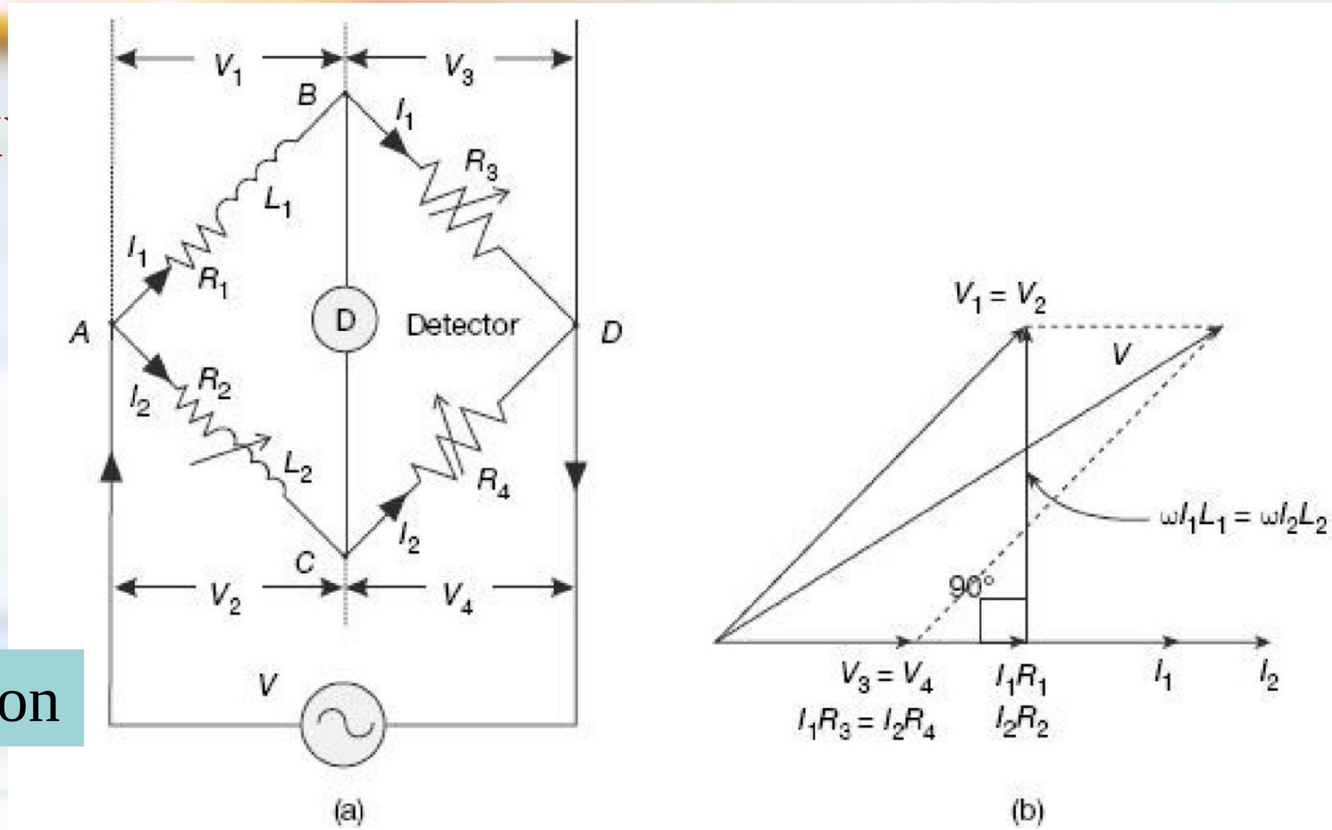
Max



Under balance condition

As shown in the phasor diagram, V_3 and V_4 being equal, they are overlapping. Arms BD and CD being purely resistive, currents through these arms will be in the same phase and in phase with the voltage drops across these two respective branches. Thus, currents I_1 and I_2 will be collinear with the phasors V_3 and V_4.

Max

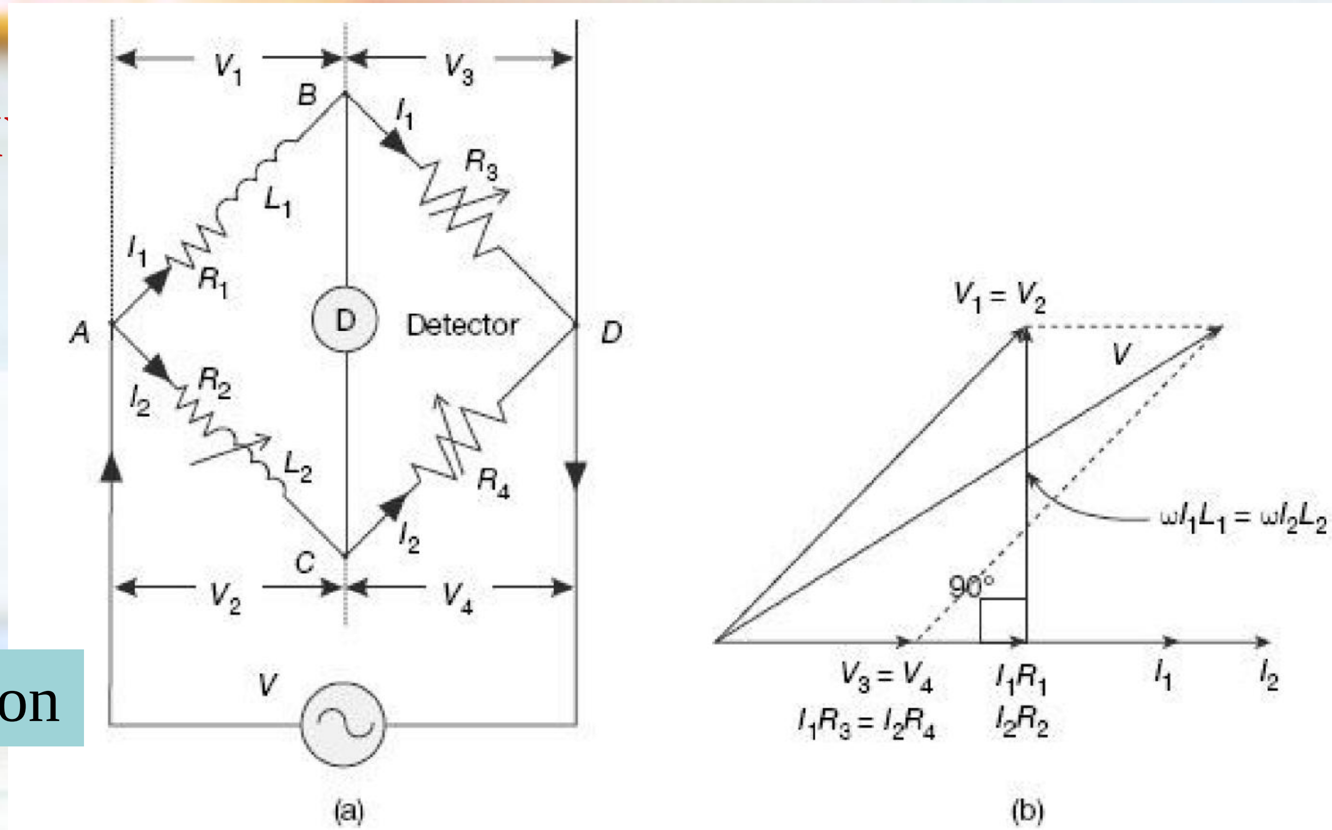


Under balance condition

The same current I_1 flows through branch AB as well, thus the voltage drop I_1R_1 remains in the same phase as I_1. Voltage drop wL_1I_1 in the inductor L_1 will be 90° out of phase (Leading) with I_1R_1. Phasor summation of these two voltage drops I_1R_1 and wL_1I_1 will give the voltage drop V_1 across the arm AB.

The voltage across the two branches AB and AC are equal, thus the two voltage drops V_1 and V_2 are equal and are in the same phase. Finally, phasor summation of V_1 and V_3 (or V_2 and V_4) results in the supply voltage V

Max



Under balance condition

$$V_1 = V_2 \qquad V_3 = V_4 \qquad \frac{V_1}{V_3} = \frac{V_2}{V_4}$$

$$\frac{R_1 + j\omega L_1}{R_3} = \frac{R_2 + j\omega L_2}{R_4}$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega L_2 R_3$$

Equating real and imaginary parts, we have

$$R_1 R_4 = R_2 R_3$$

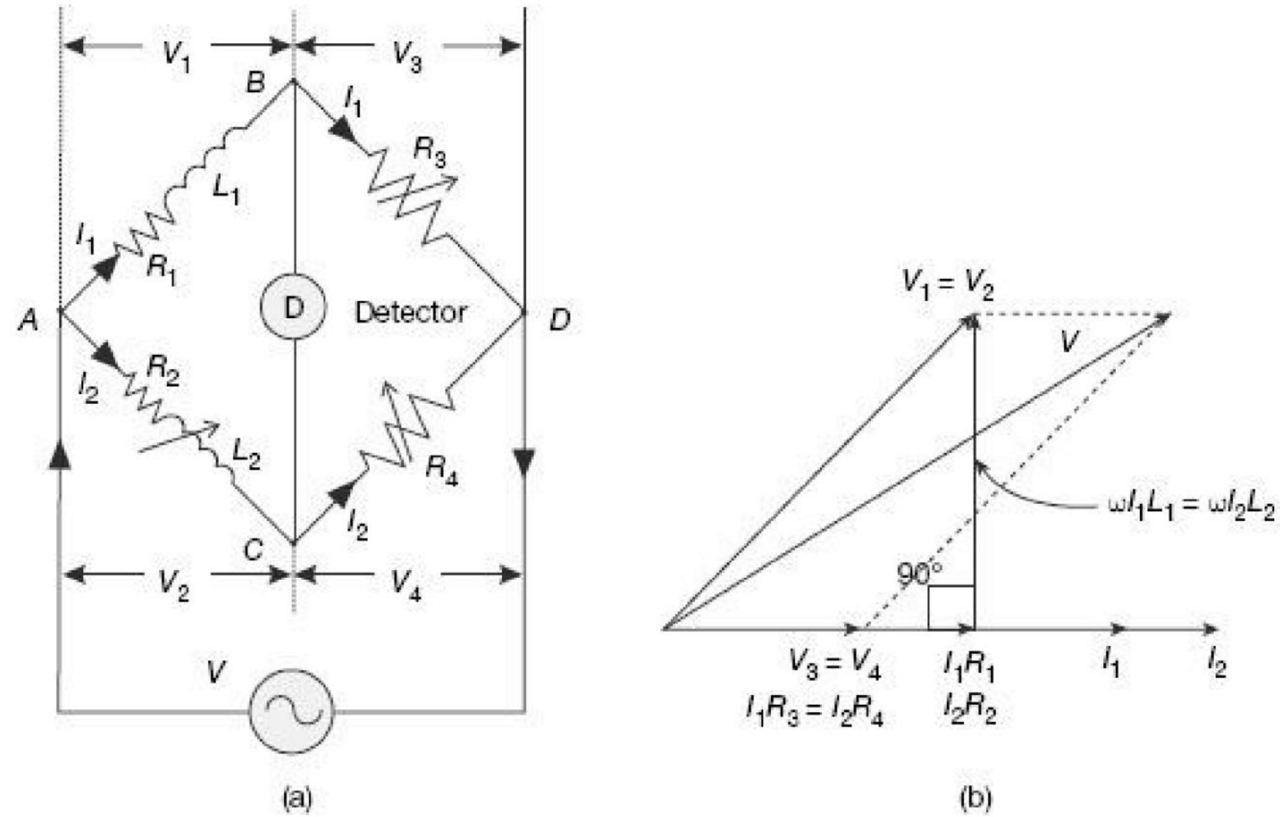
or,

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

and also,

$$j\omega L_1 R_4 = j\omega L_2 R_3$$

Max



Equating real and imaginary parts, we have

$$R_1 R_4 = R_2 R_3$$

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

and also,
$$j\omega L_1 R_4 = j\omega L_2 R_3$$

or,
$$\frac{L_1}{L_2} = \frac{R_3}{R_4}$$

Thus,
$$\frac{R_1}{R_2} = \frac{R_3}{R_4} = \frac{L_1}{L_2}$$

$$L_1 = L_2 \times \frac{R_3}{R_4} \text{ and } R_1 = R_2 \times \frac{R_3}{R_4}$$

Example 42-1. The arms of an a.c. Maxwell bridge are arranged as follows : AB and BC are non-reactive resistors of 100 Ω each, DA is a standard variable reactor L of resistance 32·7 Ω and CD comprises a standard variable resistor R in series with a coil of unknown impedance. Balance was obtained with L=47·8 mH and R=1·36 Ω. Find the resistance and inductance of the coil. (*B.E. III Elect. Inst. Osmania Univ.*)

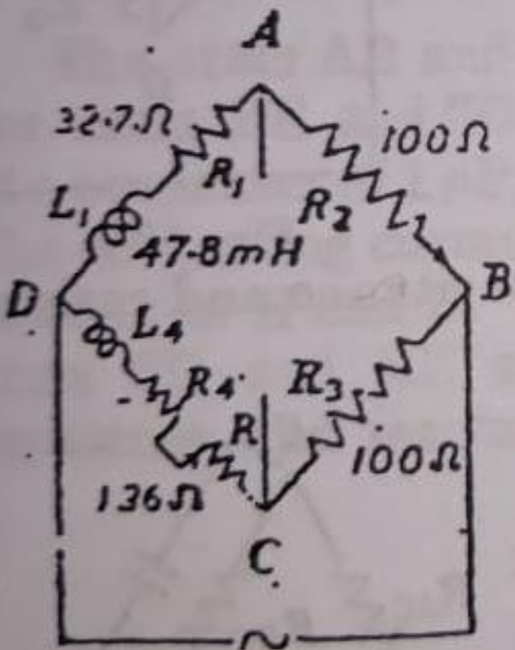


Fig. 42-4

Solution. The a.c. bridge is shown in Fig. 42-4.

Since the products of the resistances of opposite arms are equal

$$\therefore \quad 32{\cdot}7 \times 100 = (1{\cdot}36 + R_4)100$$

$$\therefore \quad 32{\cdot}7 = 1{\cdot}36 + R_4$$

or $$R_4 = 32{\cdot}7 - 1{\cdot}36 = 31{\cdot}34\ \Omega$$

Since $L_1 \times 100 = L_4 \times 100$

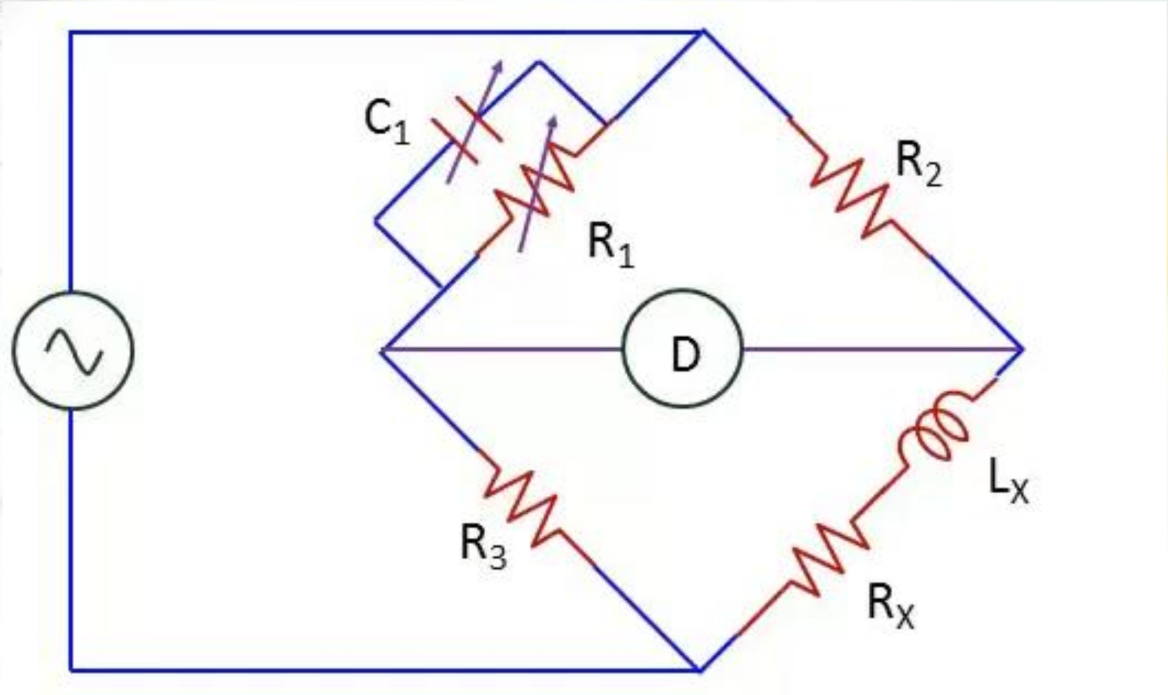
$$\therefore \quad L_4 = L_1 = 47{\cdot}8 \text{ mH}$$

(or because time constants are the same, hence $L_1/32{\cdot}7 = L_4/(31{\cdot}34 + 1{\cdot}36)$ $\therefore$ $L_4 = 47{\cdot}8$ mH)

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} = \frac{L_1}{L_2}$$

Maxwell’s Inductance–Capacitance Bridge
Maxwell’s-Wien Bridge

In this bridge, the unknown inductance is measured by comparison with a standard variable capacitance. It is much easier to obtain standard values of variable capacitors with acceptable degree of accuracy. This is however, not the case with finding accurate and stable standard value variable inductor as is required in the basic Maxwell’s bridge



Maxwell's Inductance–Capacitance Bridge
Maxwell's-Wien Bridge

Simple analysis method

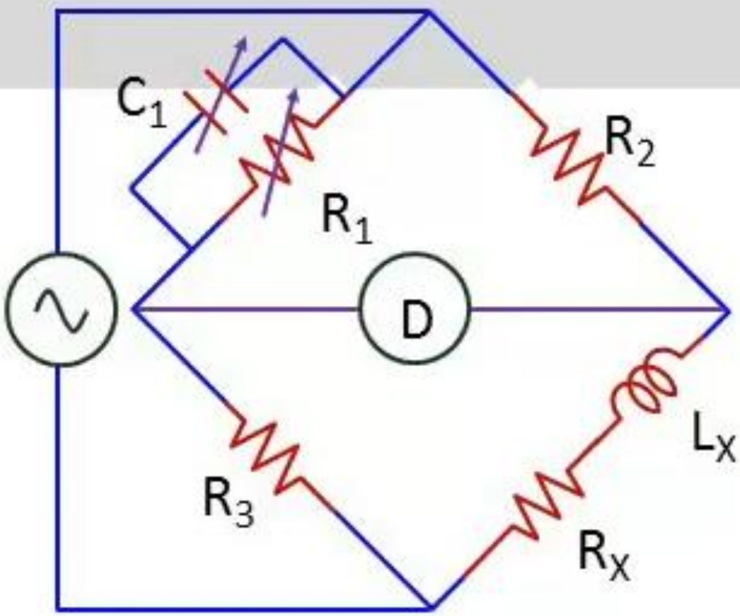
$$Z_1 = R_1 // (-jX_C)$$

$$Z_2 = R_2 \qquad Z_3 = R_3$$

$$Z_4 = R_X + j\omega L_X$$

$$Y_1 = \frac{1}{R_1} + j\omega C_1$$

$$Z_4 = Z_2 Z_3 Y_1$$



$$R_X + j\omega L_X = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1 \right)$$

Maxwell's Inductance–Capacitance Bridge
Maxwell's-Wien Bridge

Simple analysis method

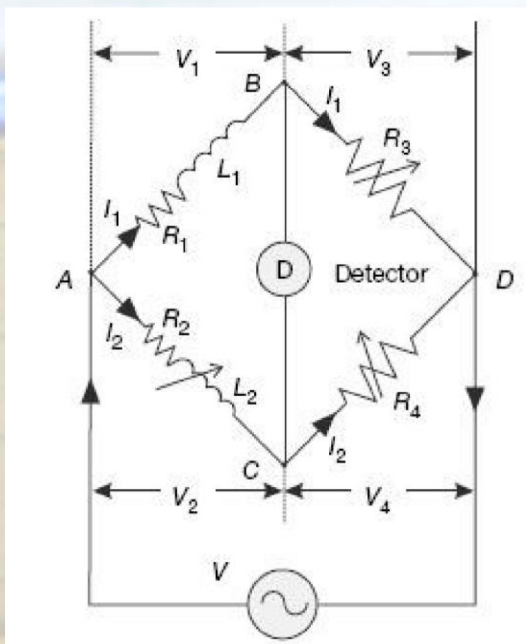
$$R_X + j\omega L_X = R_2\,R_3\left(\frac{1}{R_1} + j\omega C_1\right)$$

$$R_X = \frac{R_2\,R_3}{R_1}$$

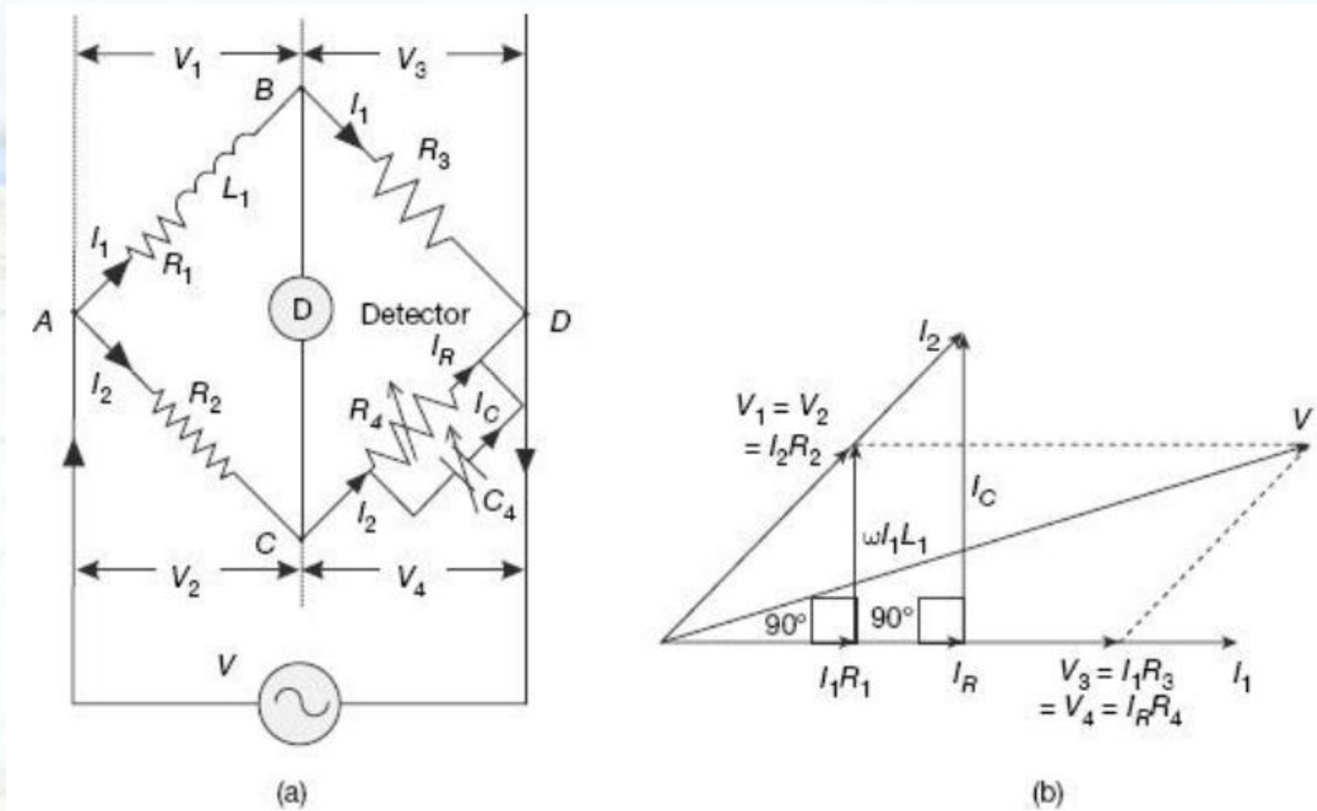
$$L_X = R_2\,R_3\,C_1$$

Maxwell's Inductance–Capacitance Bridge
Maxwell's Wien Bridge

Detailed analysis method

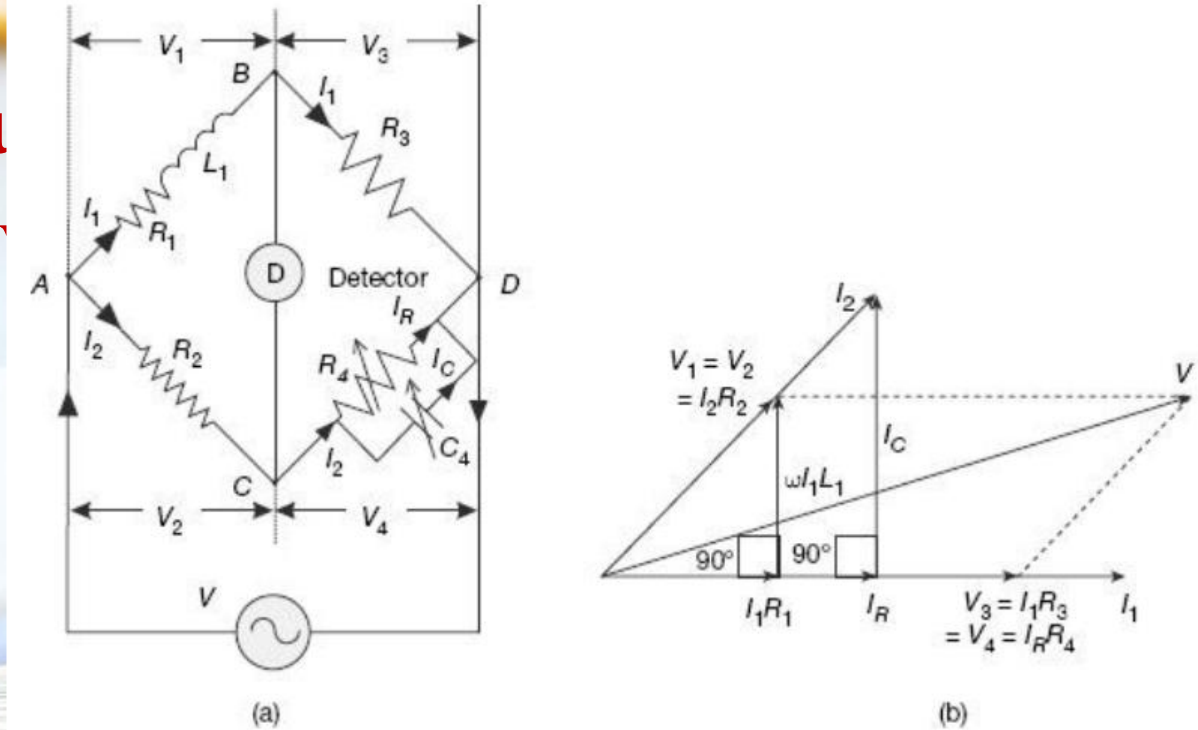


Basic Maxwell's bridge



Maxwell's Wien Bridge

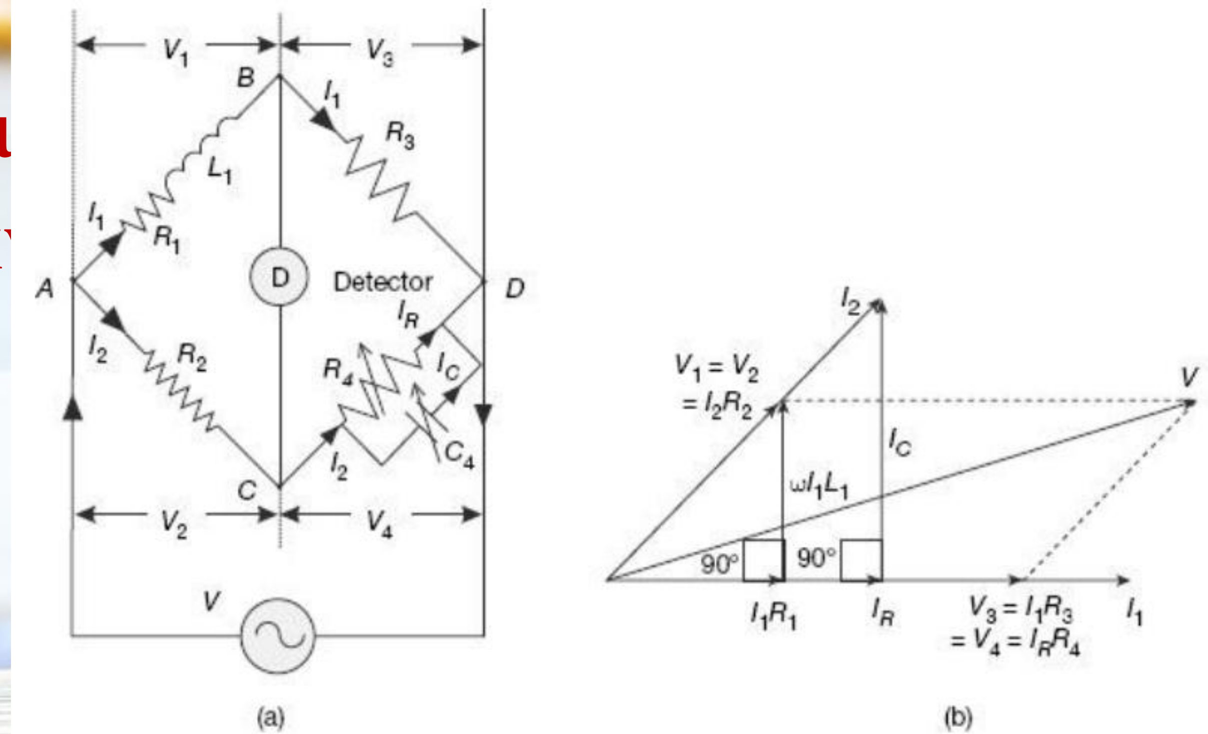
Maxwell’s Indu
Max



Bridge description

The unknown inductor L_1 of effective resistance R_1 in the branch AB is compared with the standard known variable capacitor C_4 on arm CD. The other resistances R_2, R_3, and R_4 are known as non– inductive resistors.

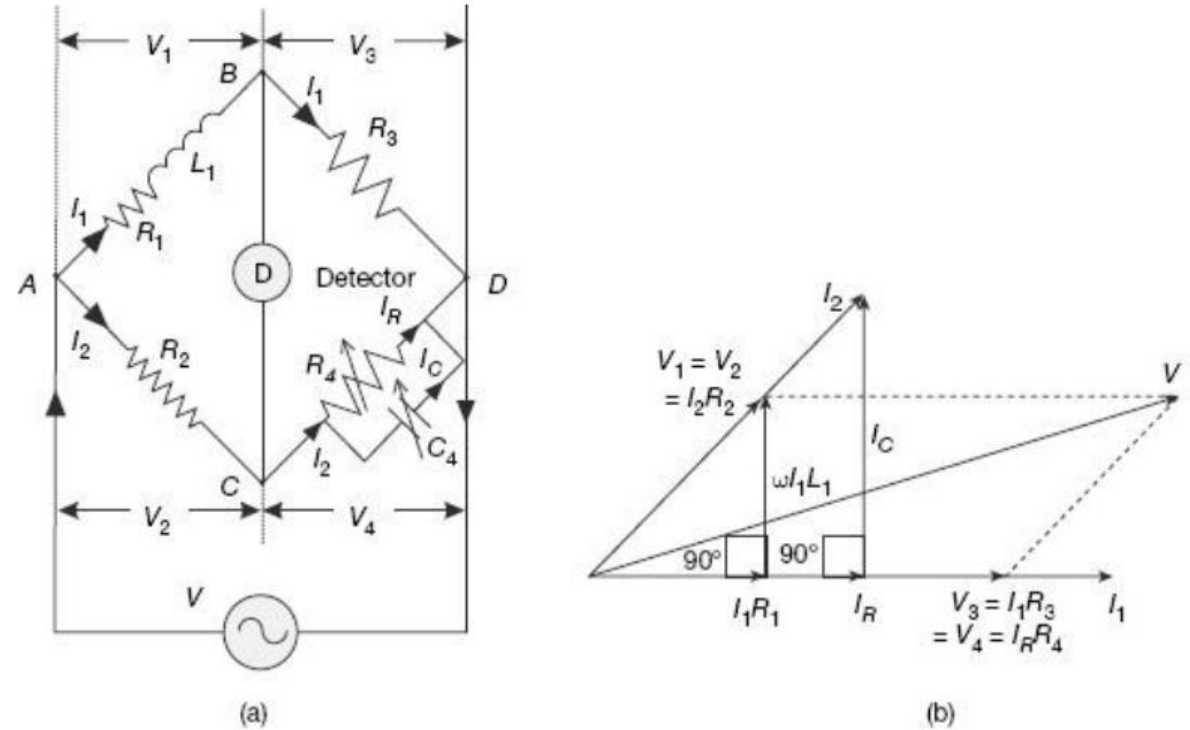
Maxwell's Indu
Max



Balance requirement

The bridge is preferably balanced by varying C_4 and R_4, giving independent adjustment settings.

Maxwell’s Indu
Max

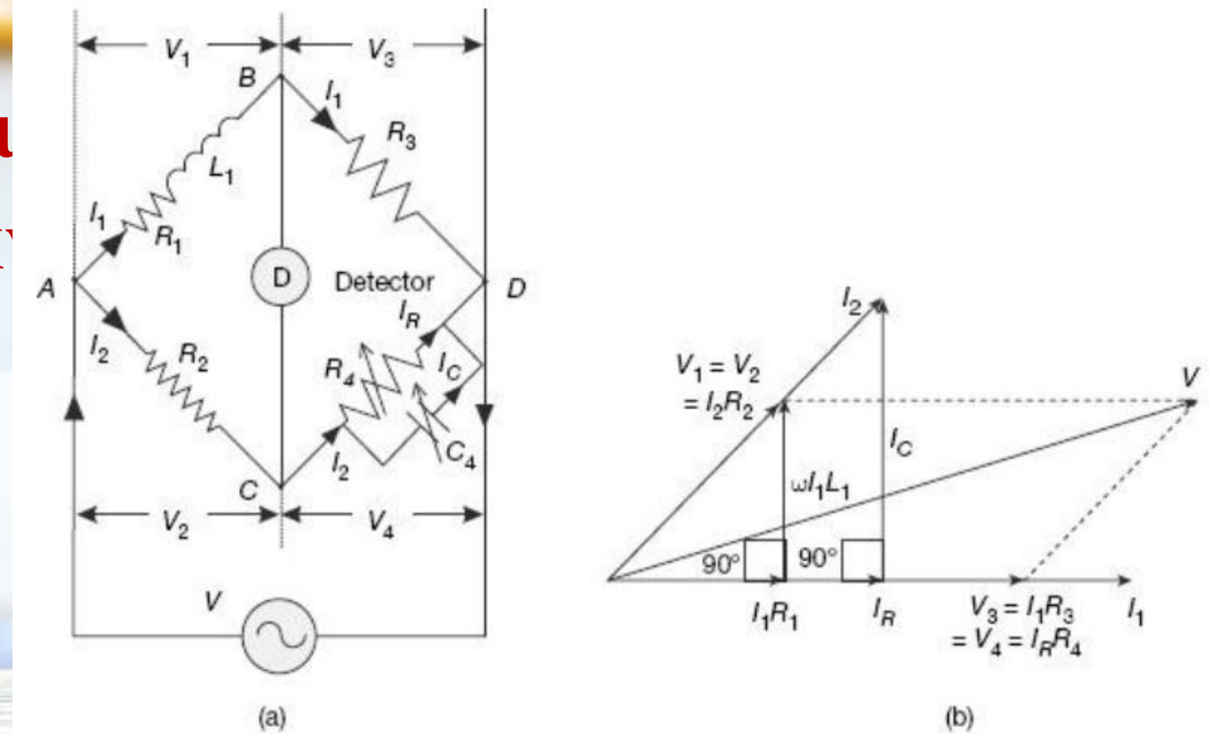


Under balance condition

Under balanced condition, no current flows through the detector. Under such condition, currents in the arms AB and BD are equal (I_1). Similarly, currents in the arms AC and CD are equal (I_2).

Under balanced condition, since nodes B and D are at the same potential, voltage drops across arm BD and CD are equal ($V_3 = V_4$); similarly, voltage drops across arms AB and AC are equal ($V_1 = V_2$).

Maxwell's Indu
Max

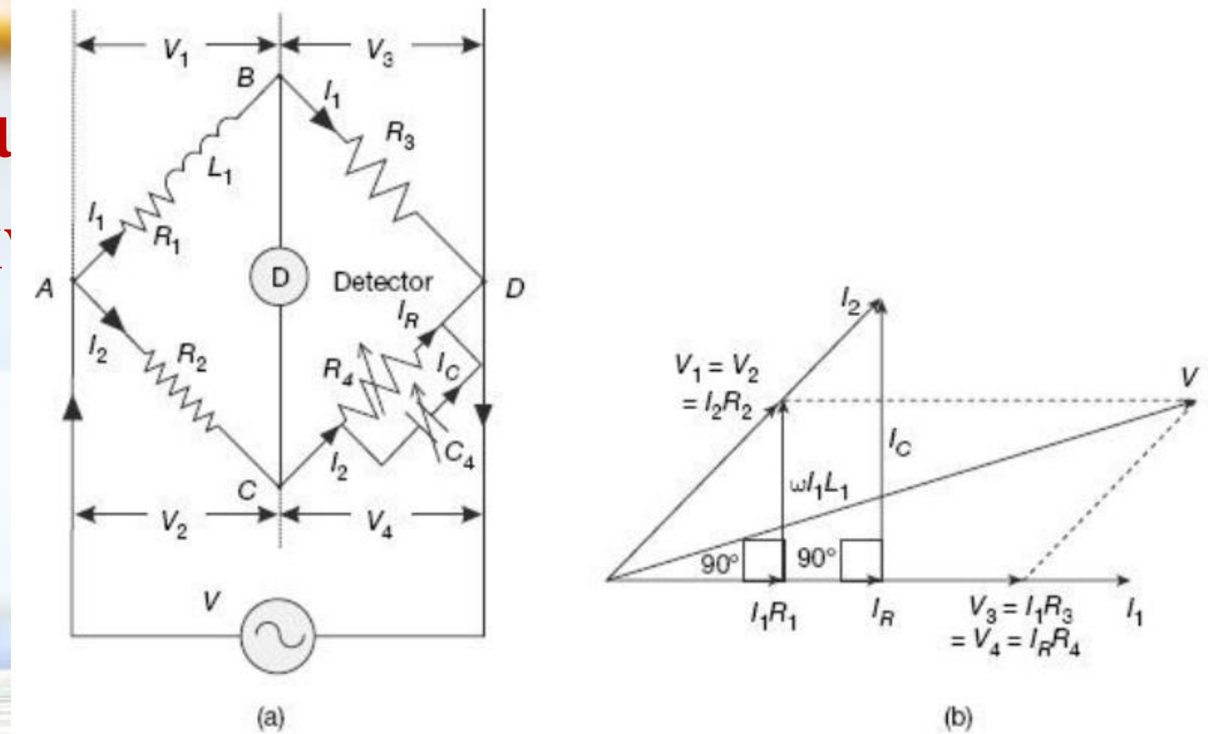


Under balance condition

As shown in the phasor diagram of, V_3 and V_4 being equal, they are overlapping both in magnitude and phase. The arm BD being purely resistive, current I_1through this arm will be in the same phase with the voltage drop V_3 across it. Similarly, the voltage drop V_4 across the arm CD, current I_R through the resistance R_4 in the same branch, and the resulting resistive voltage drop I_RR_4 are all in the same phase

Maxwell's Indu

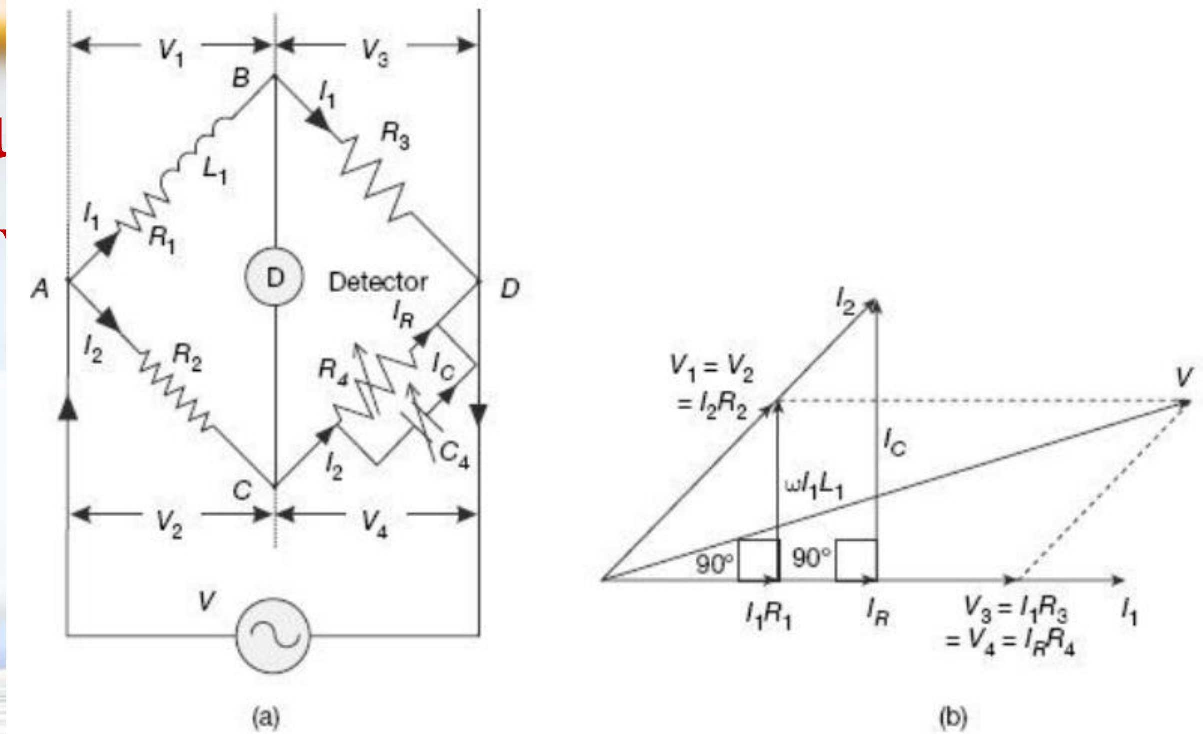
Max



Under balance condition

The resistive current I_R when added with the quadrature capacitive current I_C, results in the main current I_2 flowing in the arm CD. This current I_2 while flowing through the resistance R_2 in the arm AC, produces a voltage drop $V_2 = I_2R_2$, that is in same phase as I_2. Under balanced condition, voltage drops across arms AB and AC are equal, i.e., $V_1 = V_2$. This voltage drop across the arm AB is actually the phasor summation of voltage drop I_1R_1 across the resistance R_1 and the quadrature voltage drop wL_1I_1 across the unknown inductor L_1. Finally, phasor summation of V_1 and V_3 (or V_2 and V_4) results in the supply voltage V.

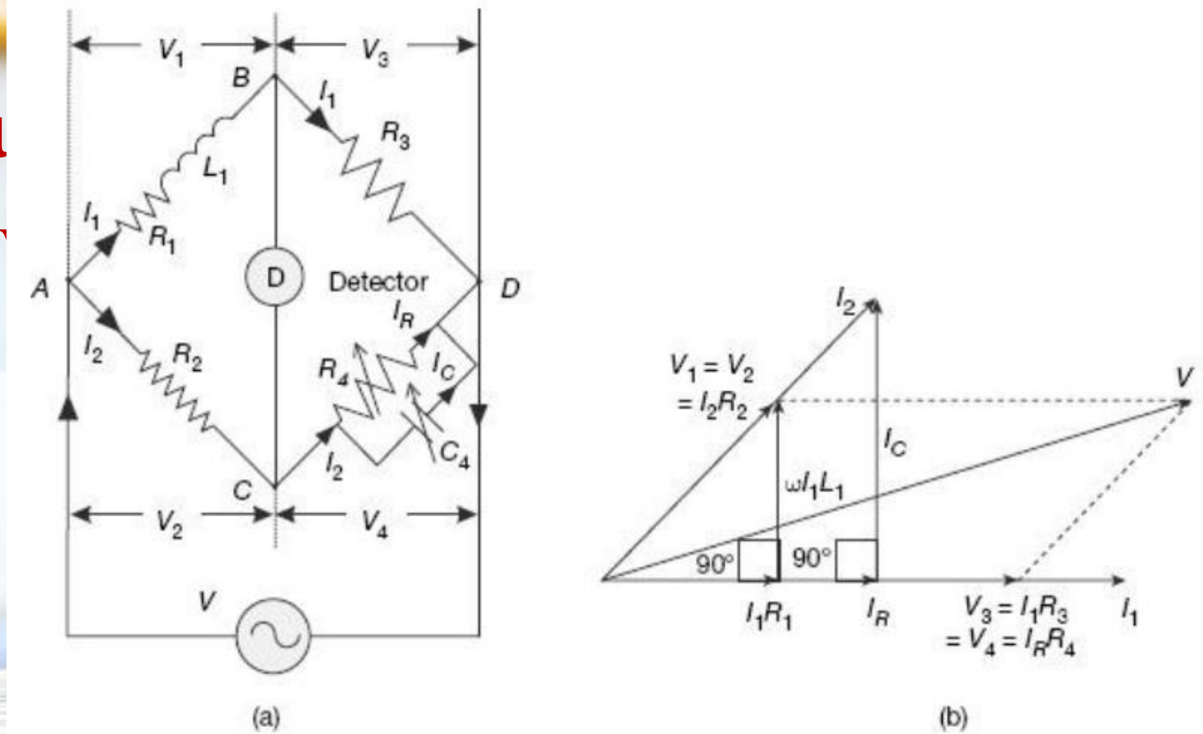
Maxwell's Indu
Max



Under balance condition

The resistive current I_R when added with the quadrature capacitive current I_C, results in the main current I_2 flowing in the arm CD. This current I_2 while flowing through the resistance R_2 in the arm AC, produces a voltage drop $V_2 = I_2R_2$, that is in same phase as I_2. Under balanced condition, voltage drops across arms AB and AC are equal, i.e., $V_1 = V_2$. This voltage drop across the arm AB is actually the phasor summation of voltage drop I_1R_1 across the resistance R_1 and the quadrature voltage drop wL_1I_1 across the unknown inductor L_1. Finally, phasor summation of V_1 and V_3 (or V_2 and V_4) results in the supply voltage V.

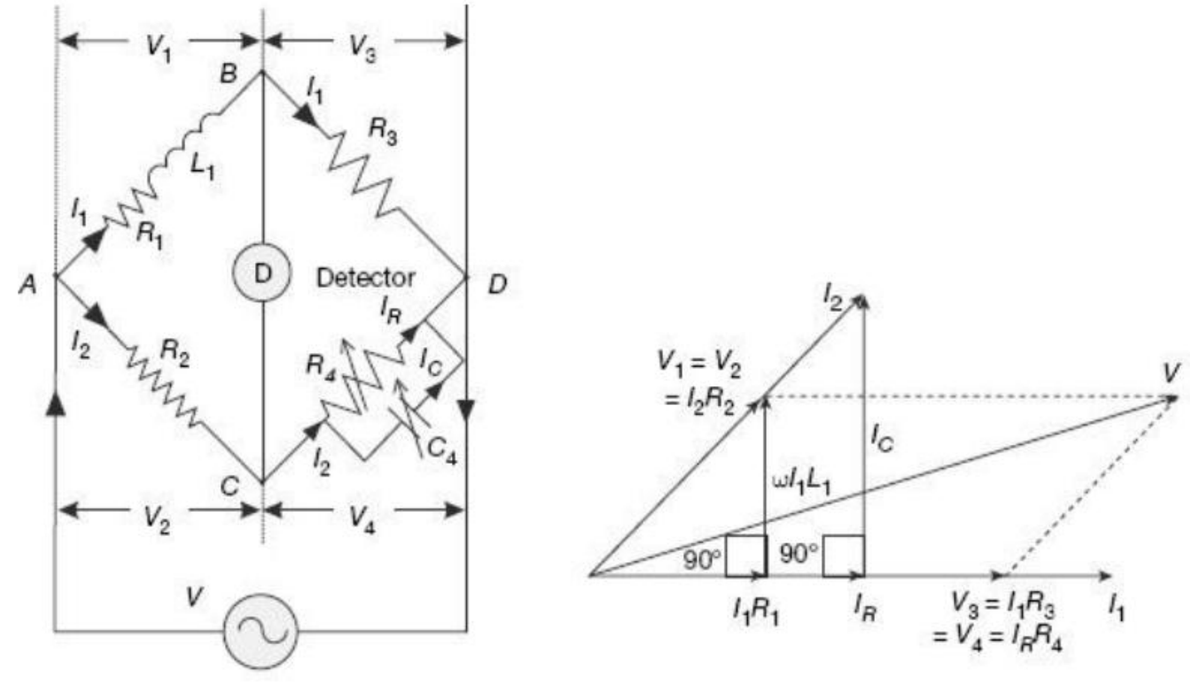
Maxwell's Indu
Max



Under balance condition

The resistive current I_R when added with the quadrature capacitive current I_C, results in the main current I_2 flowing in the arm CD. This current I_2 while flowing through the resistance R_2 in the arm AC, produces a voltage drop $V_2 = I_2R_2$, that is in same phase as I_2. Under balanced condition, voltage drops across arms AB and AC are equal, i.e., $V_1 = V_2$. This voltage drop across the arm AB is actually the phasor summation of voltage drop I_1R_1 across the resistance R_1 and the quadrature voltage drop wL_1I_1 across the unknown inductor L_1. Finally, phasor summation of V_1 and V_3 (or V_2 and V_4) results in the supply voltage V.

Maxwell's Indu
Max



(a) (b)

Under balance condition

$$\frac{R_1 + j\omega L_1}{R_3} = \frac{R_2}{\left(\dfrac{R_4}{1 + j\omega C_4 R_4}\right)}$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega C_4 R_2 R_3 R_4$$

$$R_1 R_4 = R_2 R_3$$

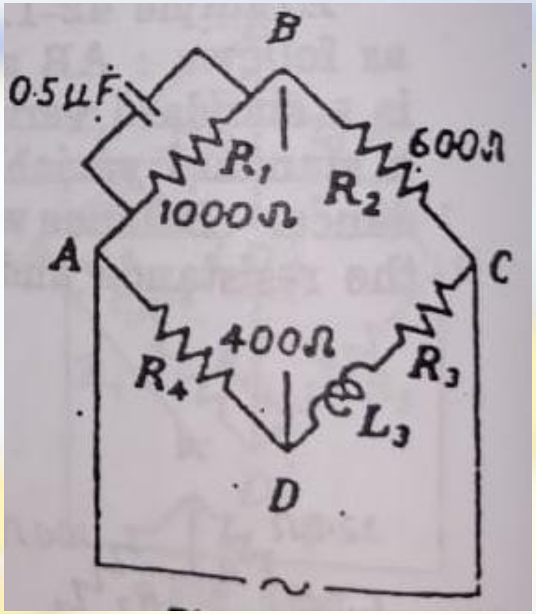
or, $$R_1 = R_2 \times \frac{R_3}{R_4}$$

and also, $$j\omega L_1 R_4 = j\omega C_4 R_2 R_3 R_4$$

or, $$L_1 = C_4 R_2 R_3$$

Maxwell's Inductance–Capacitance Bridge

Example 42-2. The arms of an a.c. Maxwell bridge are arranged as follows: AB is a non-inductive resistance of 1,000 Ω in parallel with a condenser of capacitance 0·5 μF. BC is a non-inductive resistance of 600 Ω, CD is an inductive impedance (unknown) and DA is a non-inductive resistance of 400 Ω. If balance is obtained under these conditions, find the values of the resistance and the inductance of the branch CD. *(Agra Univ. Third B.Sc. Engg.)*



Solution. The bridge is shown in Fig. 42-6.

Since $R_1 R_3 = R_2 R_4$

$\therefore \quad R_3 = R_2 R_4 / R_1$

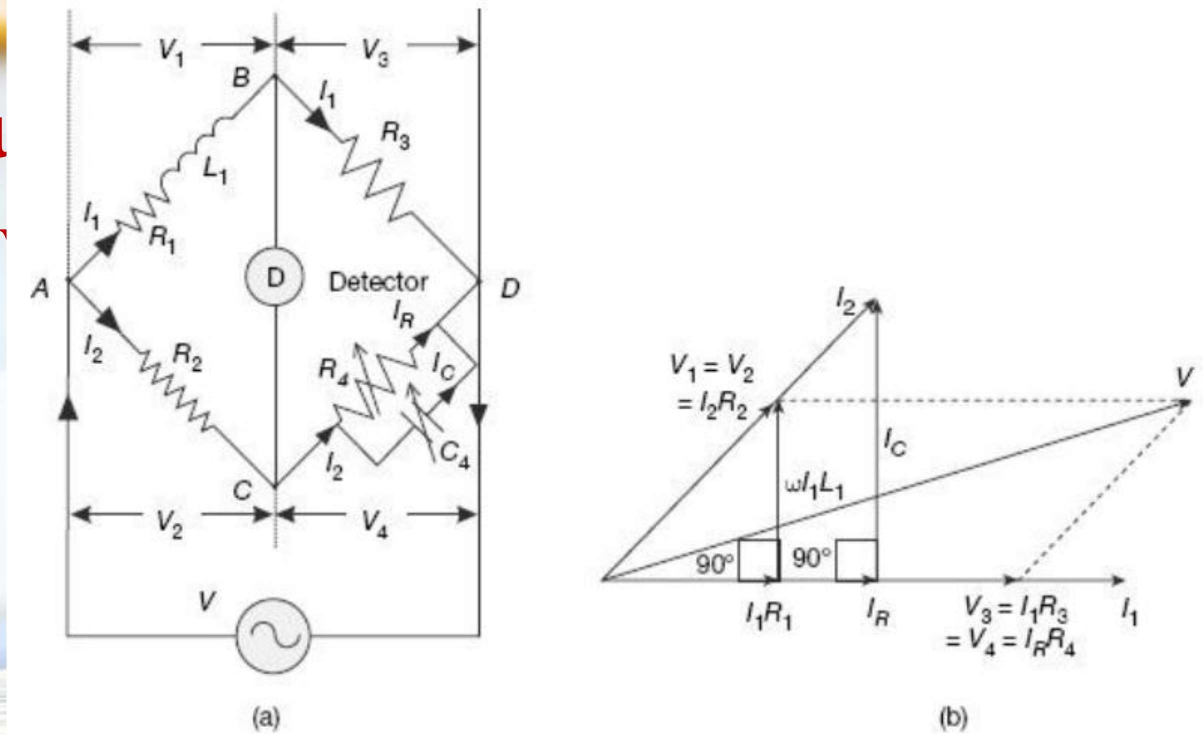
$= 600 \times 400/1000 = 240 \cdot \Omega$

Also $\quad L_3 = C R_2 R_4$

$= 0 \cdot 5 \times 10^{-6} \times 400 \times 600$

$= 12 \times 10^{-2}$ H $= 0 \cdot 12$ H

Maxwell’s Indu
Max

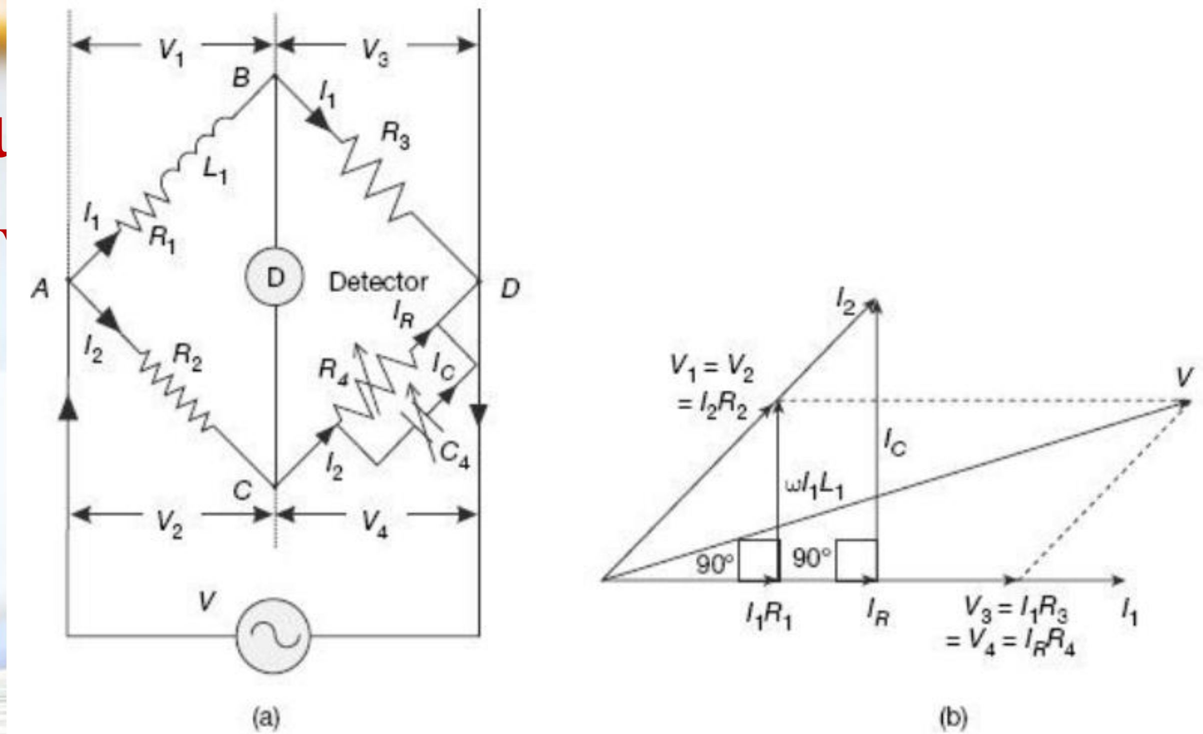


$$L_1 = C_4 R_2 R_3 \text{ and } R_1 = R_2 \times \frac{R_3}{R_4}$$

Advantages of Maxwell’s Bridge

1. The balance equations are independent of each other, thus the two variables C_4 and R_4 can be varied independently.
2. Final balance equations are independent of frequency.
3. The unknown quantities can be denoted by simple expressions involving known quantities.
4. Balance equation is independent of losses associated with the inductor.
5. A wide range of inductance at power and audio frequencies can be measured.

Maxwell's Indu
Max



$$L_1 = C_4 R_2 R_3 \text{ and } R_1 = R_2 \times \frac{R_3}{R_4}$$

Disadvantages of Maxwell's Bridge

1. The bridge, for its operation, requires a standard variable capacitor, which can be very expensive if high accuracies are asked. In such a case, fixed value capacitors are used and balance is achieved by varying R_4 and R_2.
2. This bridge is limited to measurement of low Q inductors ($1 < Q < 10$).
3. Maxwell's bridge is also unsuited for coils with very low value of Q (e.g., $Q < 1$). Such low Q inductors can be found in inductive resistors and RF coils. Maxwell's bridge finds difficult and laborious to obtain balance while measuring such low Q inductors.

Anderson's Bridge

Simple analysis method

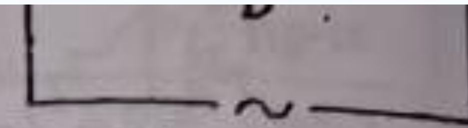


Fig. 42-6

42-4. Anderson Bridge

This is a very important and useful modification of the Maxwell-Wien bridge described in Art. 42-3. In this method, the unknown inductance is measured in terms of a known capacitance and resistance as shown in Fig. 42-7.

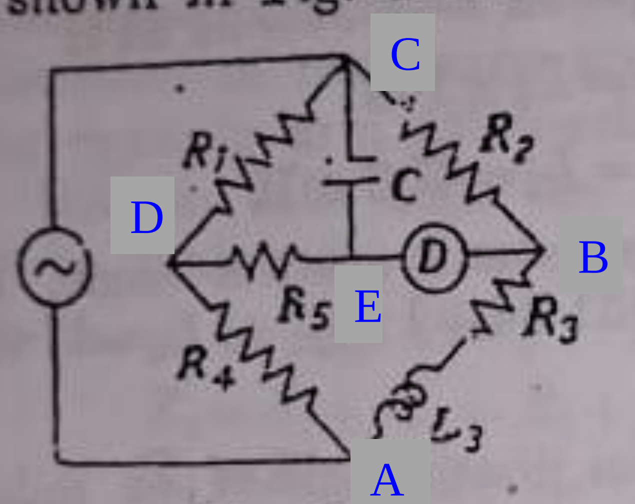
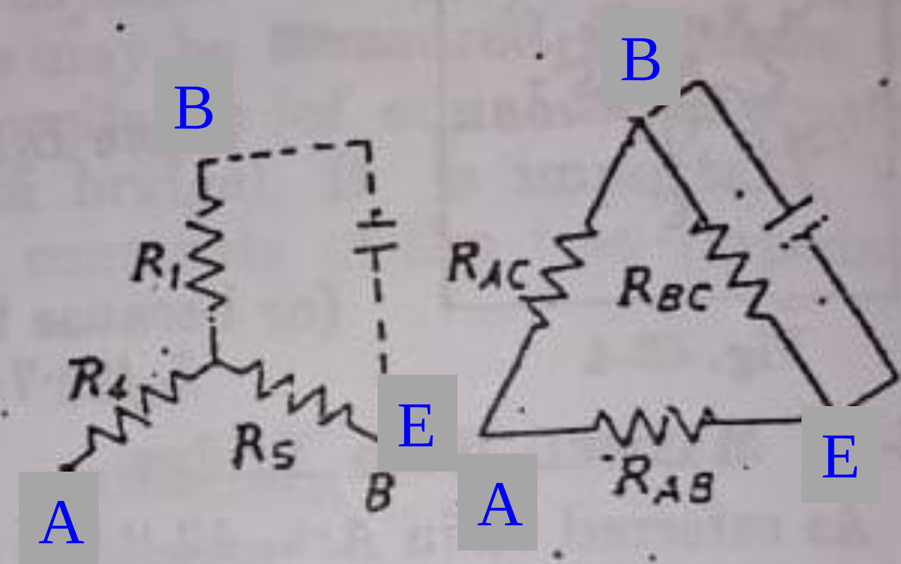


Fig. 42-7



(a) Fig. 42-8 (b)

inductance is measured in terms of
as shown in Fig. 42-7.

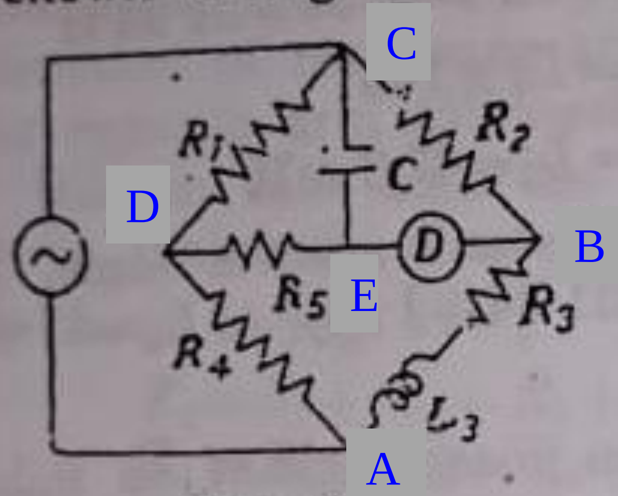
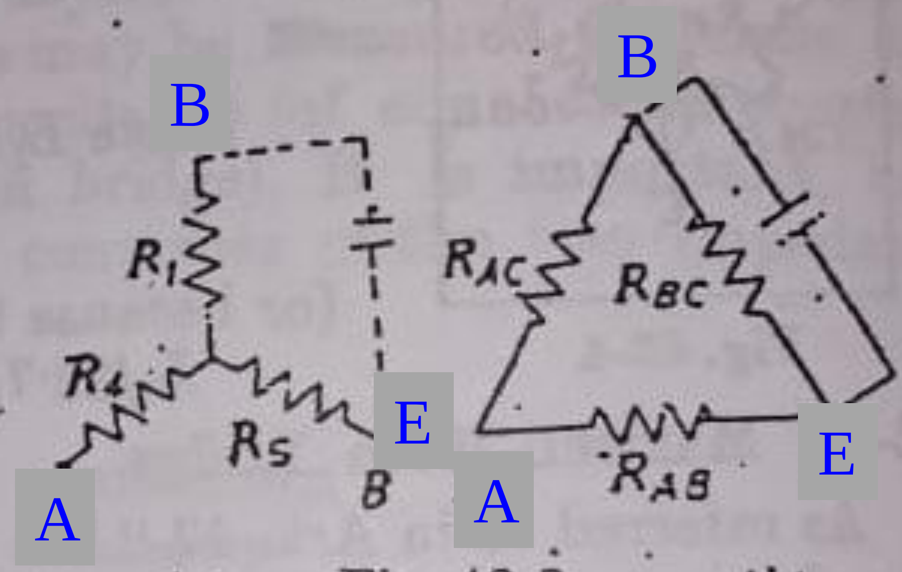
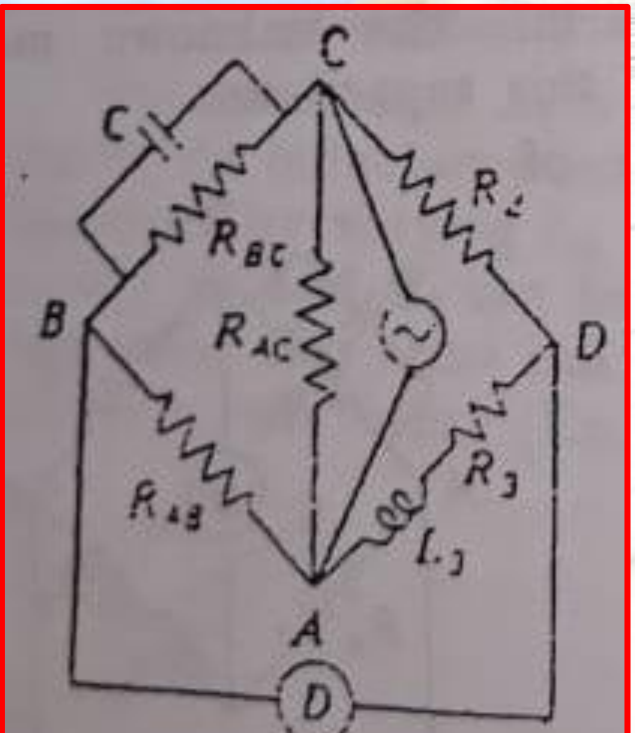


Fig. 42-7



(a) Fig. 42-8 (b)



$$R_{AB}=R_4\, R_5\left(\frac{1}{R_1}+\frac{1}{R_4}+\frac{1}{R_5}\right)$$

$$R_{BC}=R_1\, R_5\left(\frac{1}{R_1}+\frac{1}{R_4}+\frac{1}{R_5}\right)$$

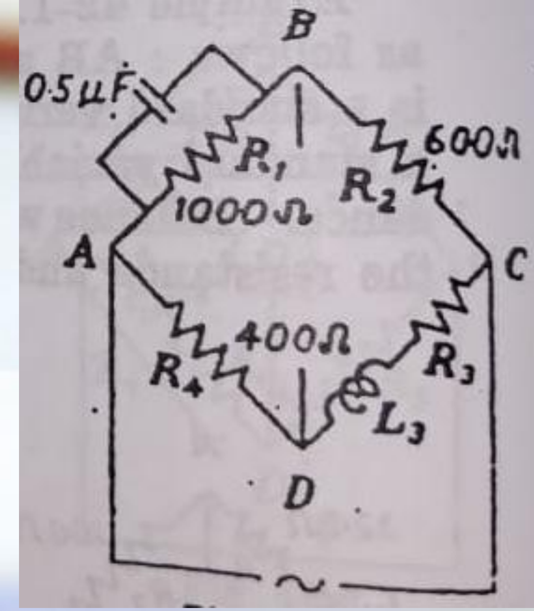
Similarly $R_{AC}=R_1\, R_4\left(\frac{1}{R_1}+\frac{1}{R_4}+\frac{1}{R_5}\right)$

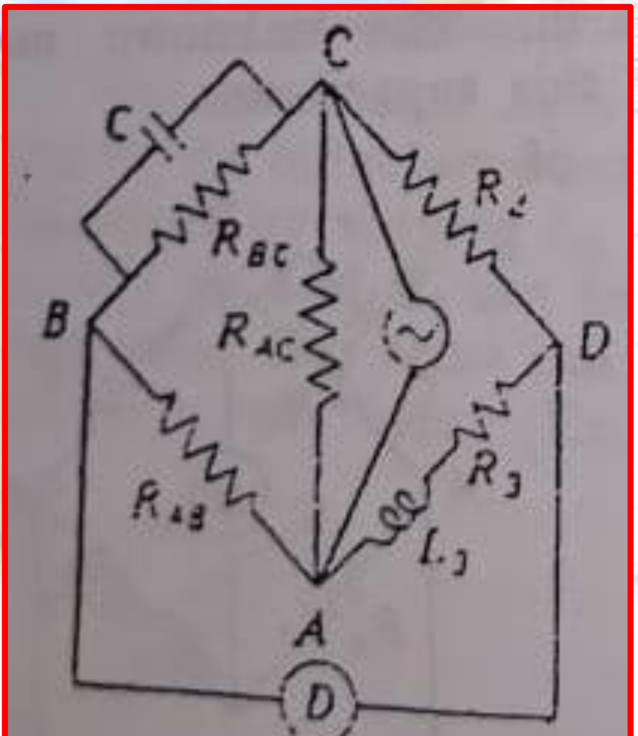
Hence, the Anderson bridge of Fig. 42-7 is reduced to an equivalent Maxwell-Wien bridge of Fig. 42-9*. Using the balance equations derived for the Maxwell-Wien bridge, we have

Maxwell's Wien Bridge

$$R_3 = R_2 R_4 / R_1$$

$$L_3 = C R_2 \, R_4$$





Anderson's Bridge

$$L = C R_3 \, . \, R_{AB}$$

$$L = C \; R_2 \; R_4 \; R_5 \left(\frac{1}{R_1} + \frac{1}{R_4} + \frac{1}{R_5} \right)$$

$$L = C \; R_2 \left[R_5 \left(1 + \frac{R_4}{R_1} \right) + R_4 \right]$$

$$R_{BC} \, . \, R_3 = R_2 \, . \, R_{AB}$$

$$R_1 \; R_5 \; R_3 \left(\frac{1}{R_1} + \frac{1}{R_4} + \frac{1}{R_5} \right)$$

$$= R_3 \; R_4 \; R_5 \left(\frac{1}{R_1} + \frac{1}{R_4} + \frac{1}{R_5} \right)$$

$$R_1 R_3 = R_2 R_4$$

Anderson's Bridge
(1)

Example 42-3. An alternating current bridge is arranged as follows :—

The arms AB and BC consist of non-inductive resistances of 100 Ω, the arms BE and CD of non-inductive variable resistances, the arm EC of a condenser of 1 μF capacity, the arm DA of an inductive impedance. The alternating current source is connected to A and C and the telephone receiver to E and D. A balance is obtained when the resistances of the arms CD and BE are 50 Ω and 2500 Ω respectively. Calculate the resistance and reactance of the arm DA.

(Elect. Measurement, Osmania Univ.)

Solution. The bridge circuit is shown in Fig. 42-10.

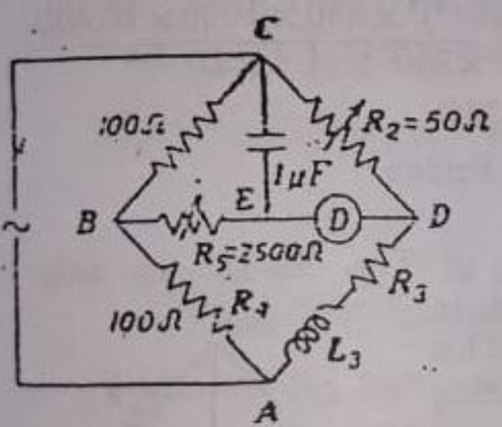


Fig. 42-10

Using the relations derived in Art. 42-4, we get

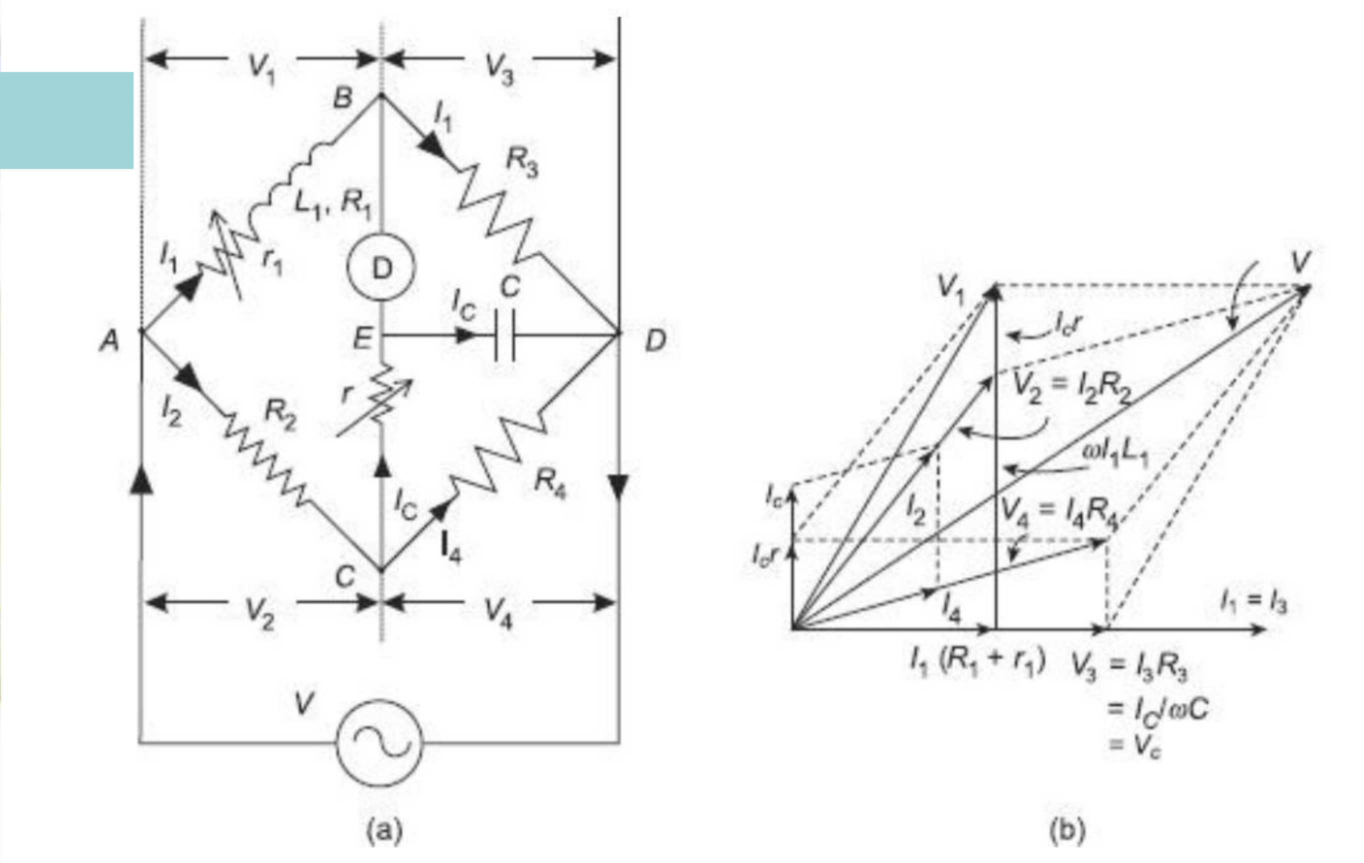
$$R_3 = R_2 R_4 / R_1$$
$$= 50 \times 100/100 = 50\ \Omega$$
$$L_3 = 1 \times 10^{-6} \times 50$$
$$\times \left[2500 \left(1 + \frac{100}{100} \right) + 100 \right]$$
$$= 5100 \times 50 \times 10^{-6}$$
$$= 0{\cdot}255\ \text{H}$$

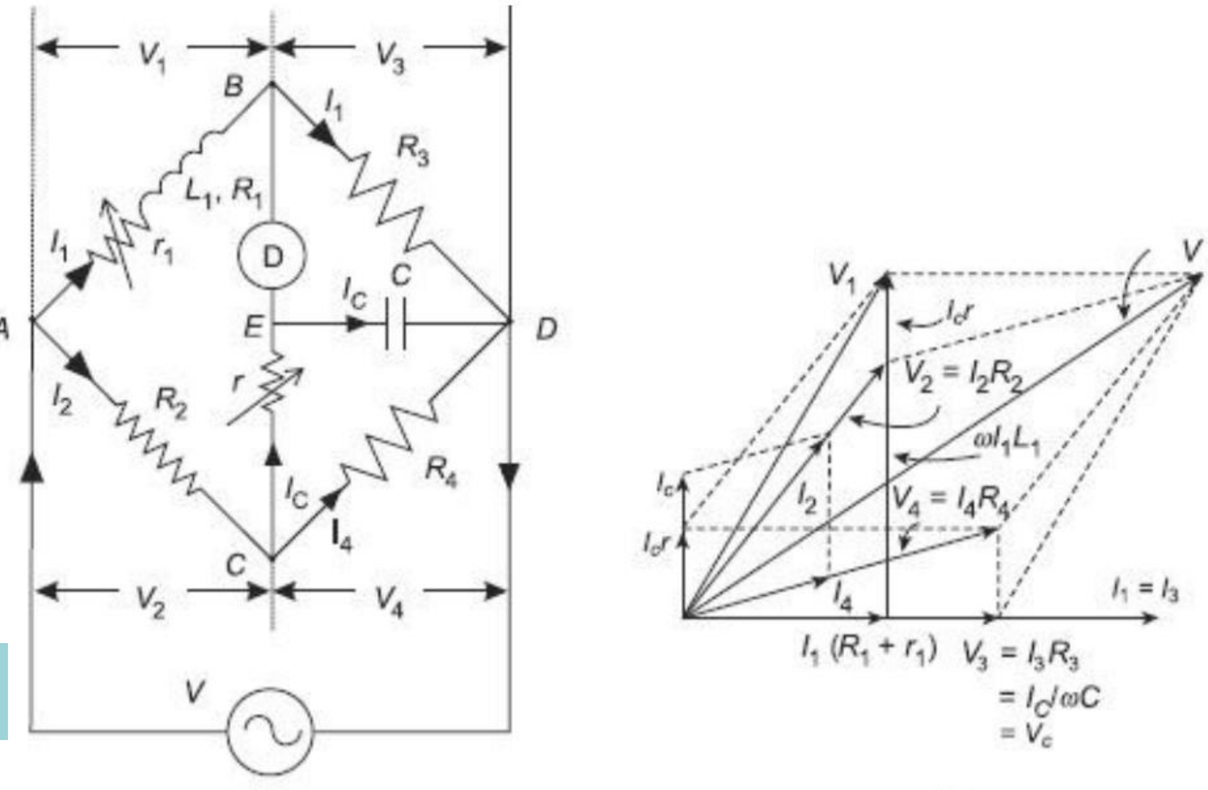
Anderson's Bridge

Detailed analysis method

This method is a modification of Maxwell's inductance–capacitance bridge, in which value of the unknown inductor is expressed in terms of a standard known capacitor. This method is applicable for precise measurement of inductances over a wide range of values

Bridge description



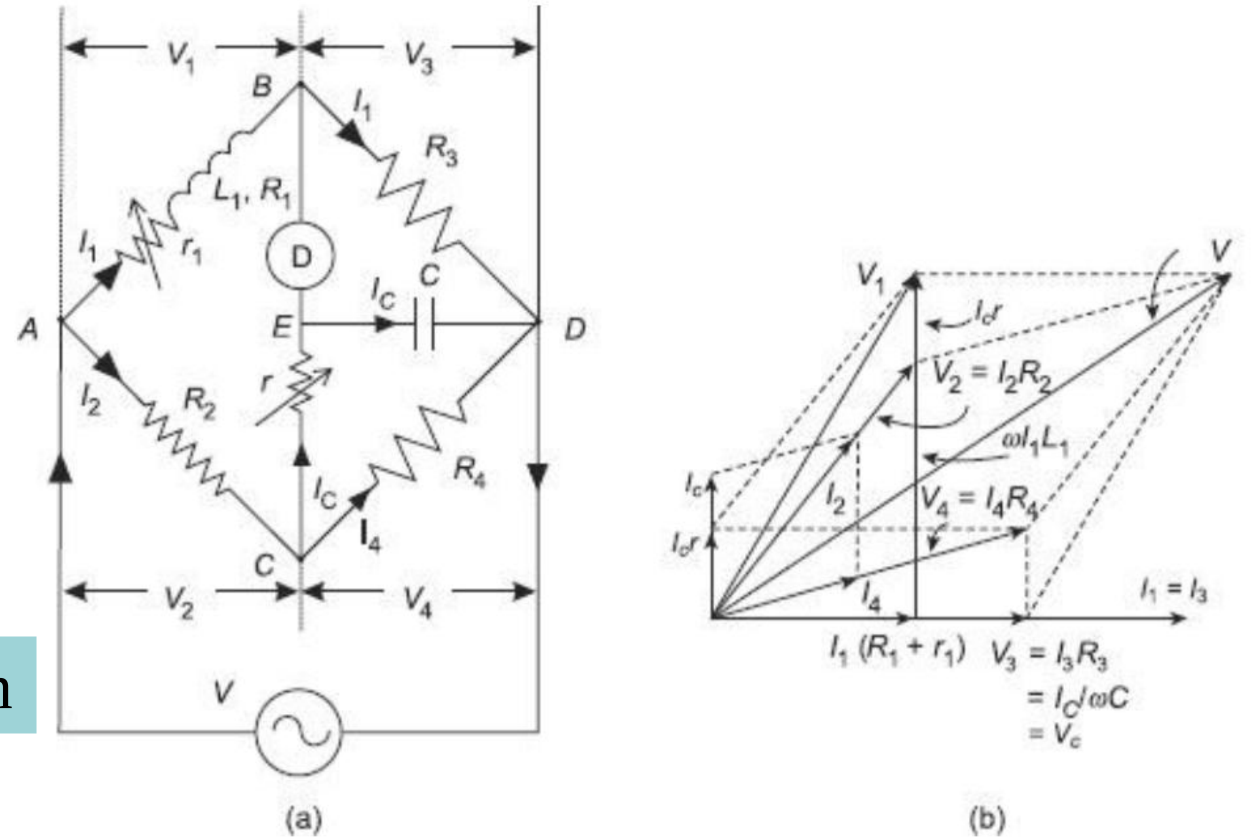


(a) (b)

Balance requirement

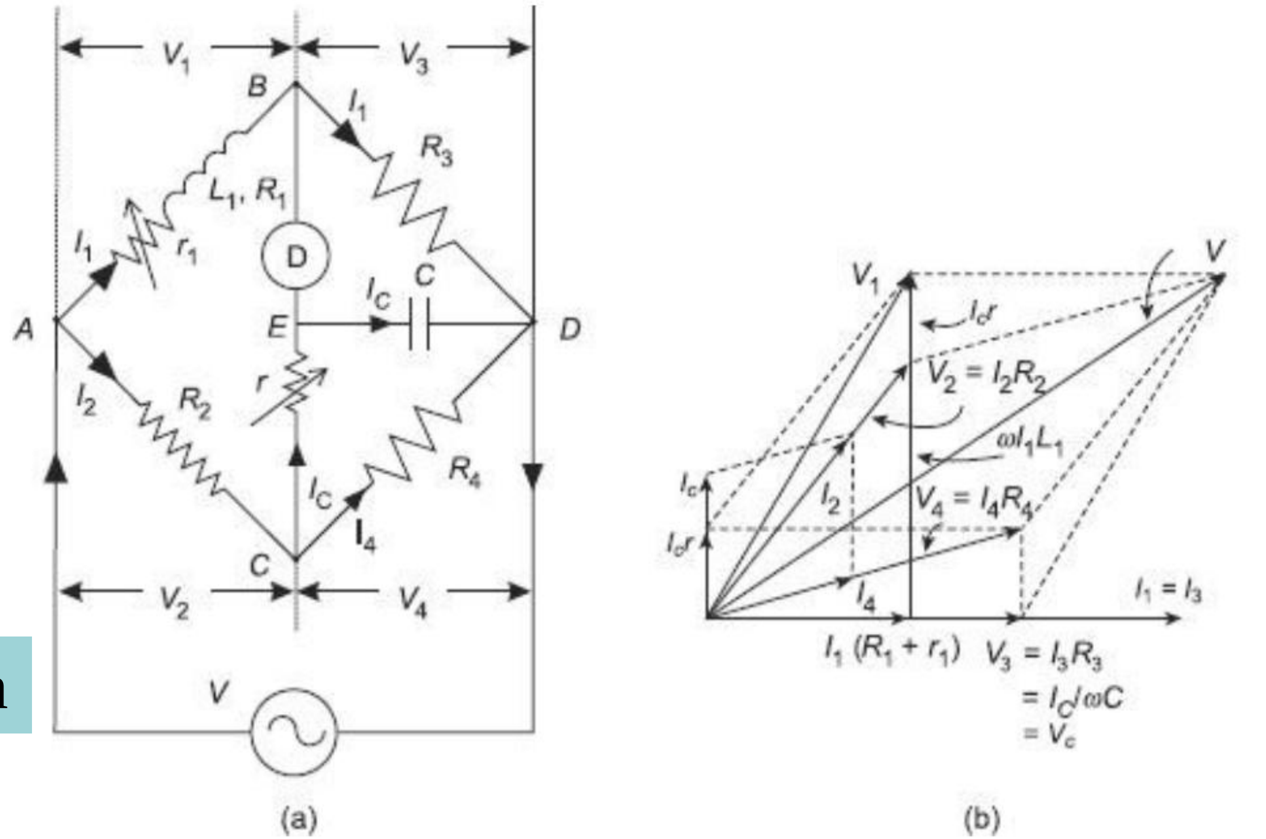
The unknown inductor L_1 of effective resistance R_1 in the branch AB is compared with the standard known capacitor C on arm ED. The bridge is balanced by varying r.

Under balance condition



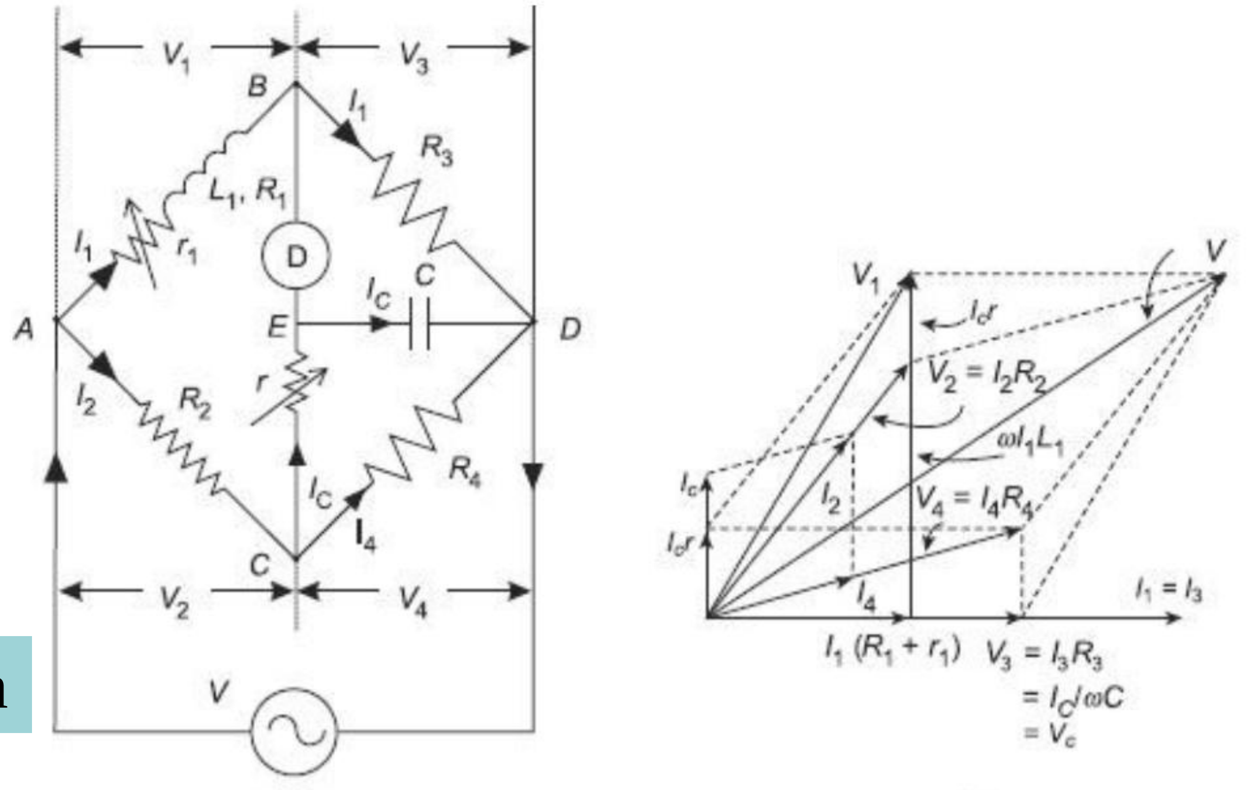
Under balanced condition, since no current flows through the detector, nodes B and E are at the same potential.

Under balance condition



As shown in the phasor diagram, I_1 and $V_3 = I_1R_3$ are in the same phase along the horizontal axis. Since under balance condition, voltage drops across arms BD and ED are equal, $V_3 = I_1R_3 = I_C/wC$ and all the three phasors are in the same phase.

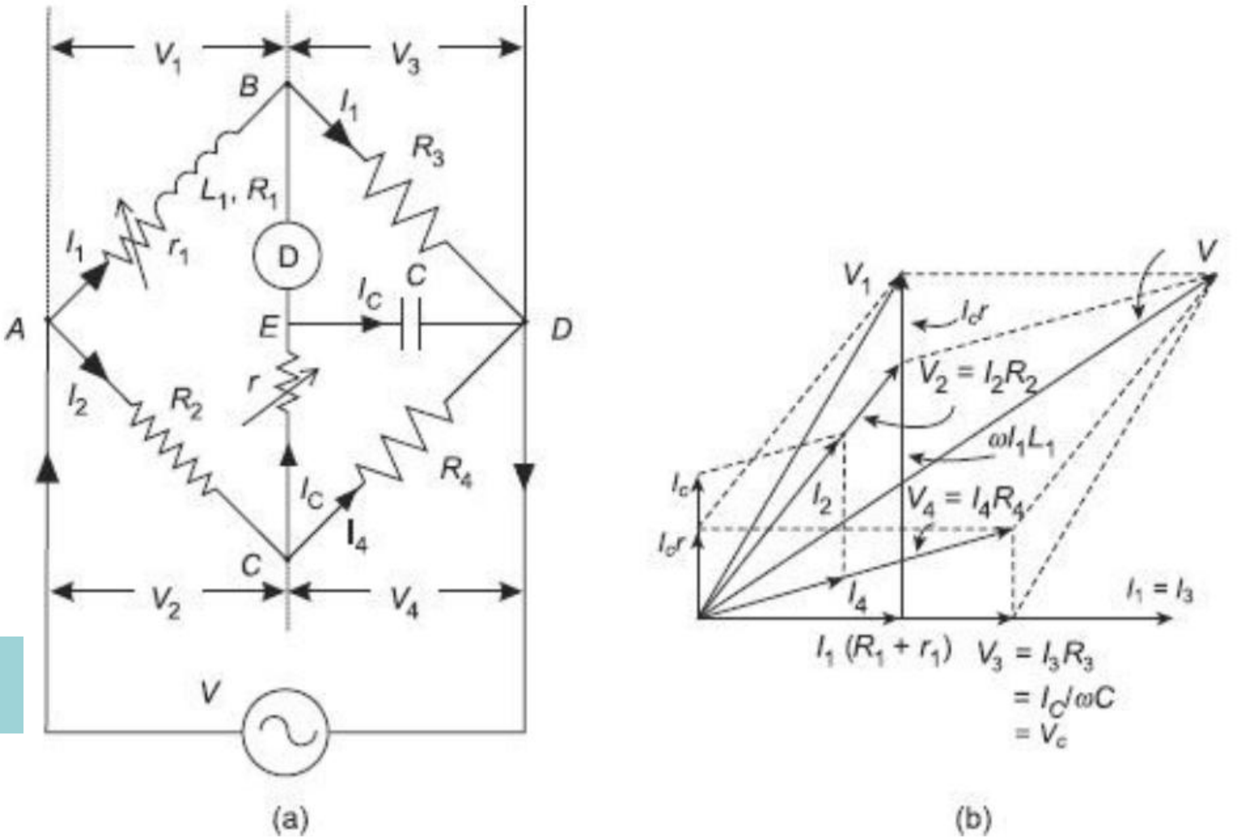
Under balance condition



(a) (b)

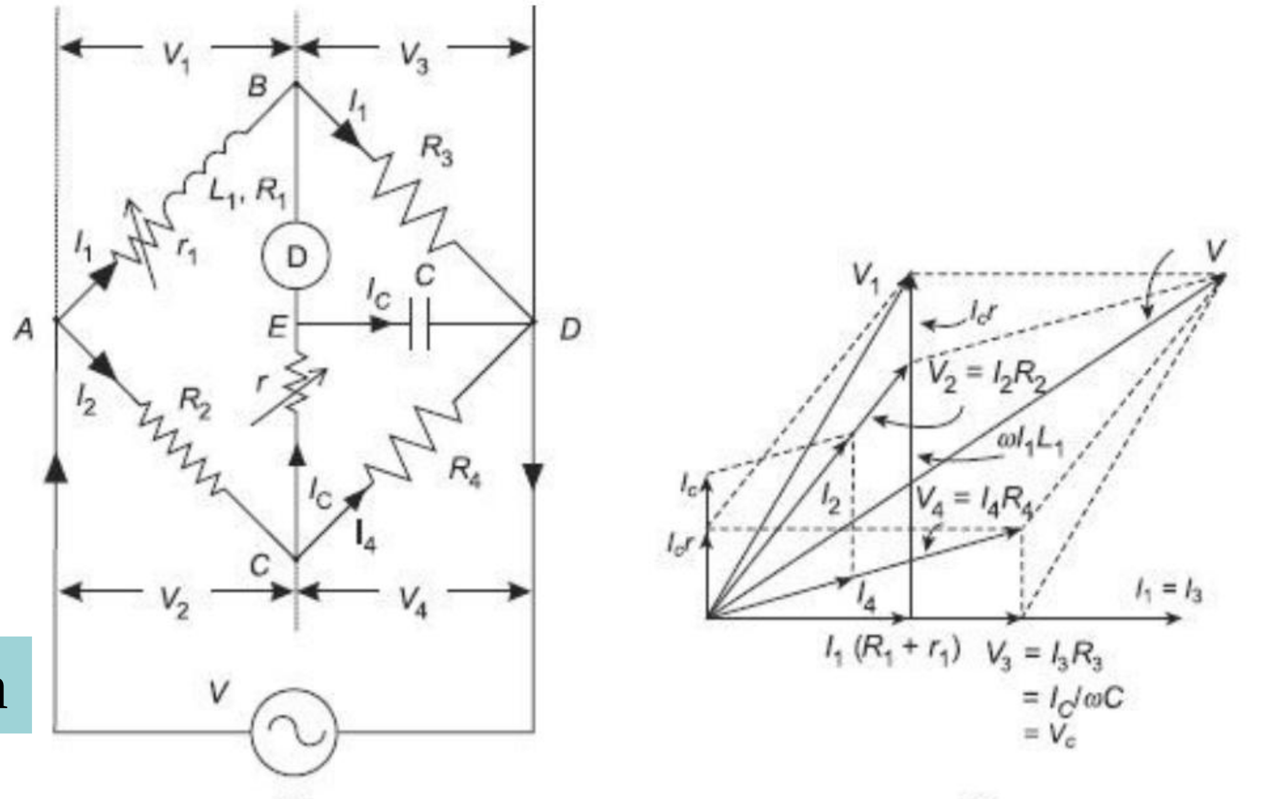
The same current I_1, when flowing through the arm AB produces a voltage drop $I_1(R_1 + r_1)$ which is once again, in phase with I_1. Since under balanced condition, no current flows through the detector, the same current I_C flows through the resistance r in arm CE and then through the capacitor C in the arm ED.

Under balance condition



Phasor summation of the voltage drops $I_C r$ in arm the CE and I_C /wC in the arm ED will be equal to the voltage drop V4 across the arm CD. V_4 being the voltage drop in the resistance R_4 on the arm CD, the current I_4 and V_4 will be in the same phase.

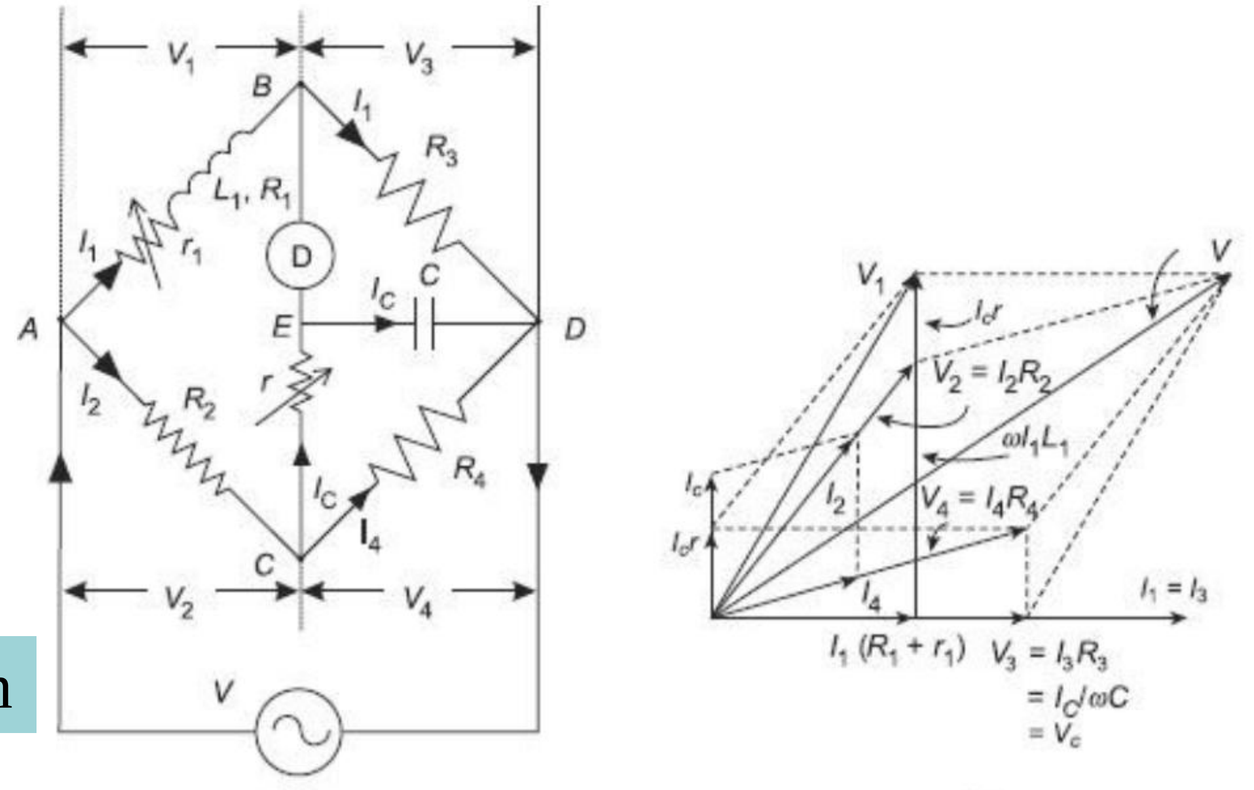
Under balance condition



(a) (b)

As can be seen from the Anderson's bridge circuit, and also plotted in the phasor diagram, phasor summation of the currents I_4 in the arm CD and the current I_C in the arm CE will give rise to the current I_2 in the arm AC. This current I_2, while passing through the resistance R_2 will give rise to a voltage drop $V_2 = I_2R_2$ across the arm AC that is in phase with the current I_2.

Under balance condition

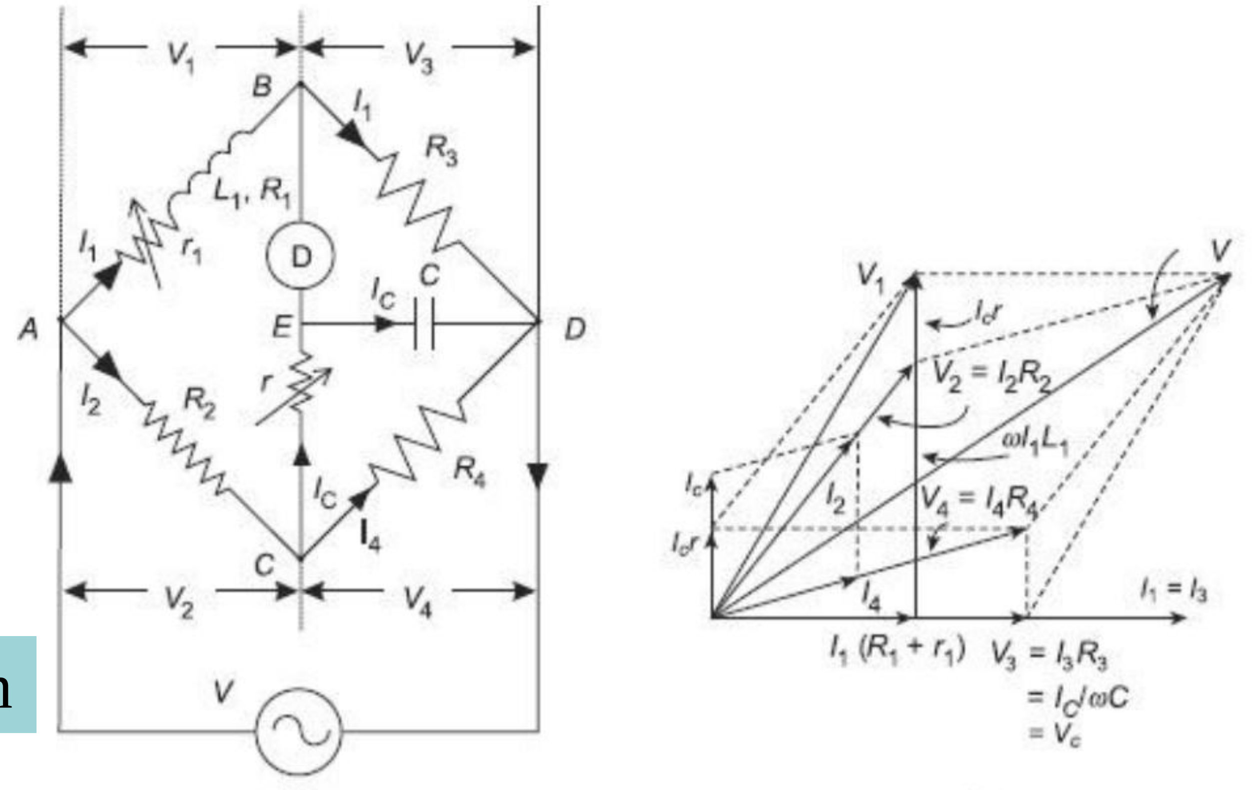


(a) (b)

Since, under balance, potentials at nodes B and E are the same, voltage drops between nodes A -B and between A -C -E will be equal.

Thus, phasor summation of the voltage drop $V_2 = I_2R_2$ in the arm AC and I_Cr in arm the CE will build up to the voltage V_1 across the arm AB. The voltage V_1 can also be obtained by adding the resistive voltage drop $I_1(R_1 + r_1)$ with the quadrature inductive voltage drop wL_1I_1 in the arm AB.

$$V_{AB} = V_{AC} + V_{CE}, \text{ or } I_1(r_1 + R_1 + j\omega L_1) = I_2R_2 + I_Cr$$



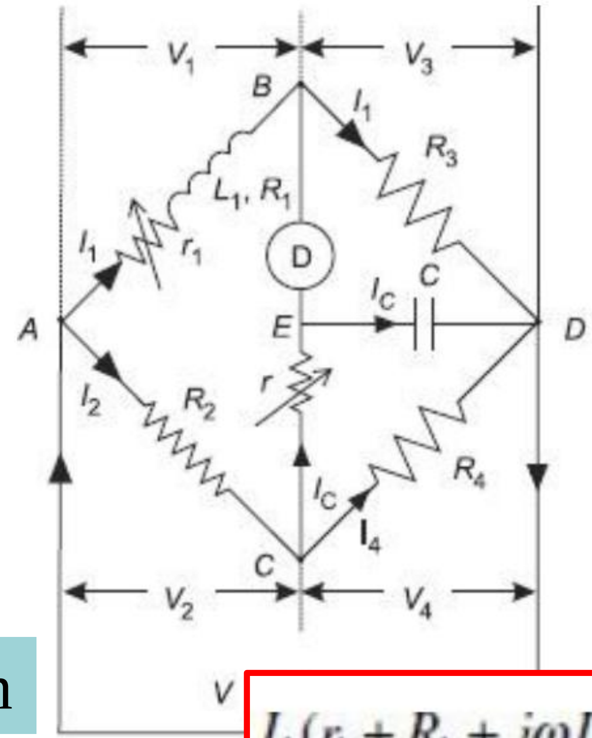
(a) (b)

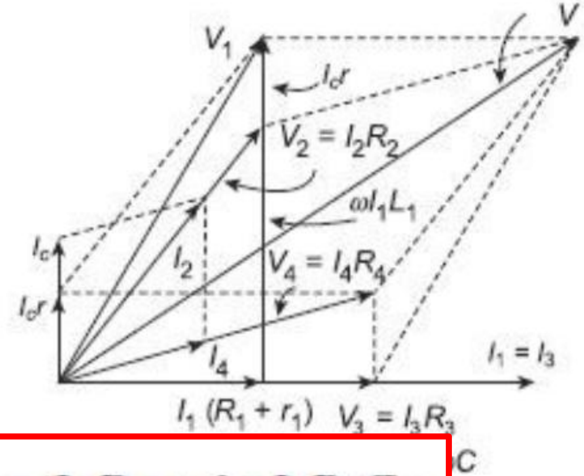
Under balance condition

At balance, $V_{BD} = V_{ED}$

$$I_1 R_3 = I_C \times \frac{1}{j\omega C}$$

$$V_{CD} = V_{CE} + V_{ED}, \text{or } I_C\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_C)R_4$$





Under balance condition

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + I_C r$$

$$I_1 R_3 = I_C \times \frac{1}{j\omega C}$$

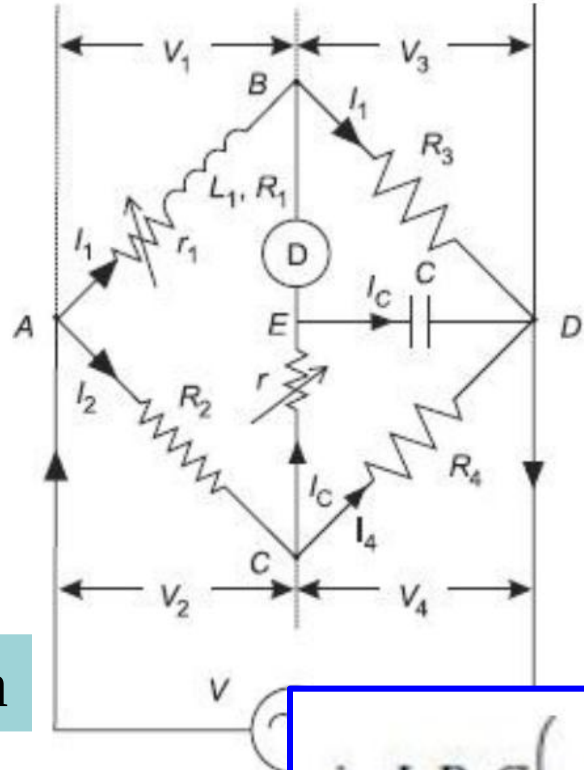
$$I_C\left(r + \frac{1}{j\omega C}\right) = (I_2 - I_C)R_4$$

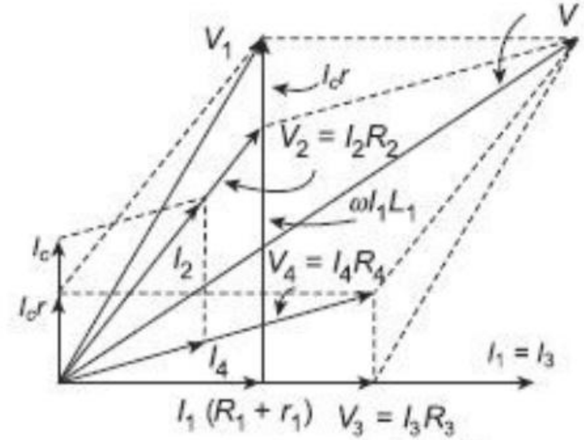
$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + j\omega I_1 R_3 C r$$

$$I_1(r_1 + R_1 + j\omega L_1 - j\omega R_3 C r) = I_2 R_2$$

$$j\omega I_1 R_3 C\left(r + \frac{1}{j\omega C}\right) = (I_2 - j\omega I_1 R_3 C)R_4$$

$$I_1(j\omega R_3 C r + R_3 + j\omega R_3 C R_4) = I_2 R_4$$





Under balance condition

$$I_1(r_1 + R_1 + j\omega L_1) = I_2 R_2 + j\omega I_1 R_3 C r$$

$$I_1(r_1 + R_1 + j\omega L_1 - j\omega R_3 C r) = I_2 R_2$$

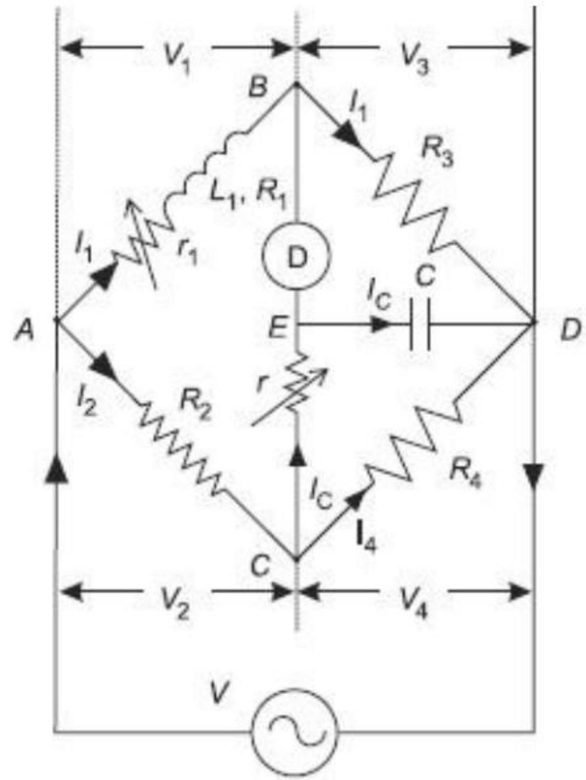
$$j\omega I_1 R_3 C\left(r + \frac{1}{j\omega C}\right) = (I_2 - j\omega I_1 R_3 C) R_4$$

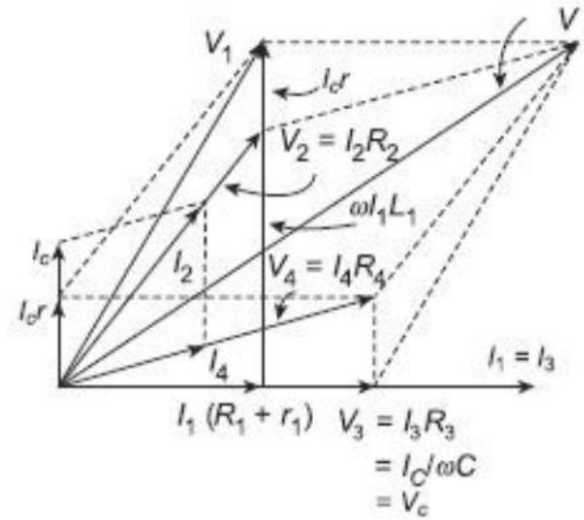
$$I_1(j\omega R_3 C r + R_3 + j\omega R_3 C R_4) = I_2 R_4$$

$$I_1(r_1 + R_1 + j\omega L_1 - j\omega R_3 C r) = I_1(j\omega R_3 C r + R_3 + j\omega R_3 C R_4)\frac{R_2}{R_4}$$

$$R_1 = \frac{R_2 R_3}{R_4} - r_1$$

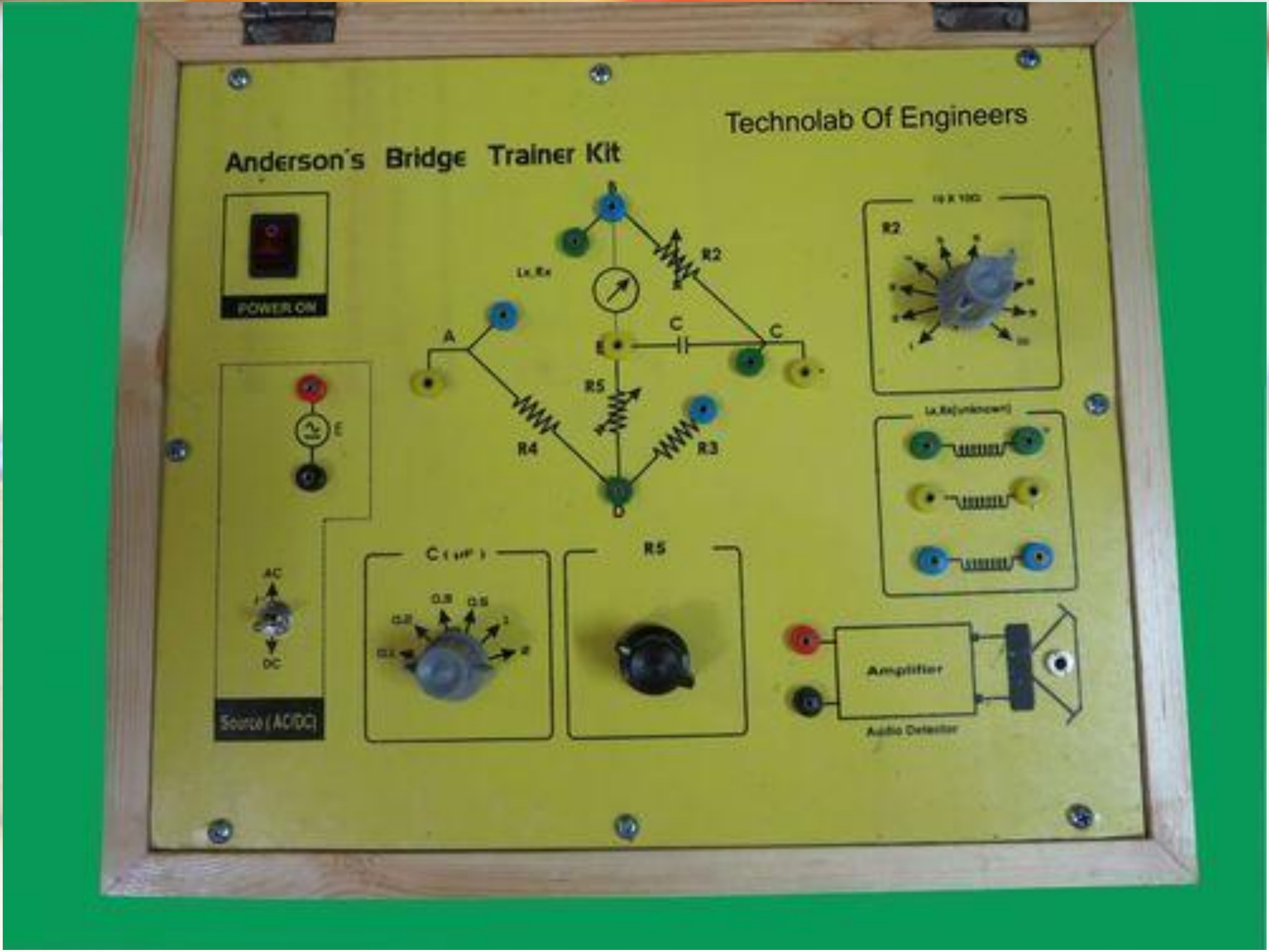
$$L_1 = C\frac{R_3}{R_4}\left[r(R_2 + R_4) + R_2 R_4\right]$$





Advantages and dis advantages

The advantage of Anderson’s bridge over Maxwell’s bride is that in this case a fixed value capacitor is used thereby greatly reducing the cost. This however, is at the expense of connection complexities and balance equations becoming tedious.



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Anderson's Bridge Trainer Kit
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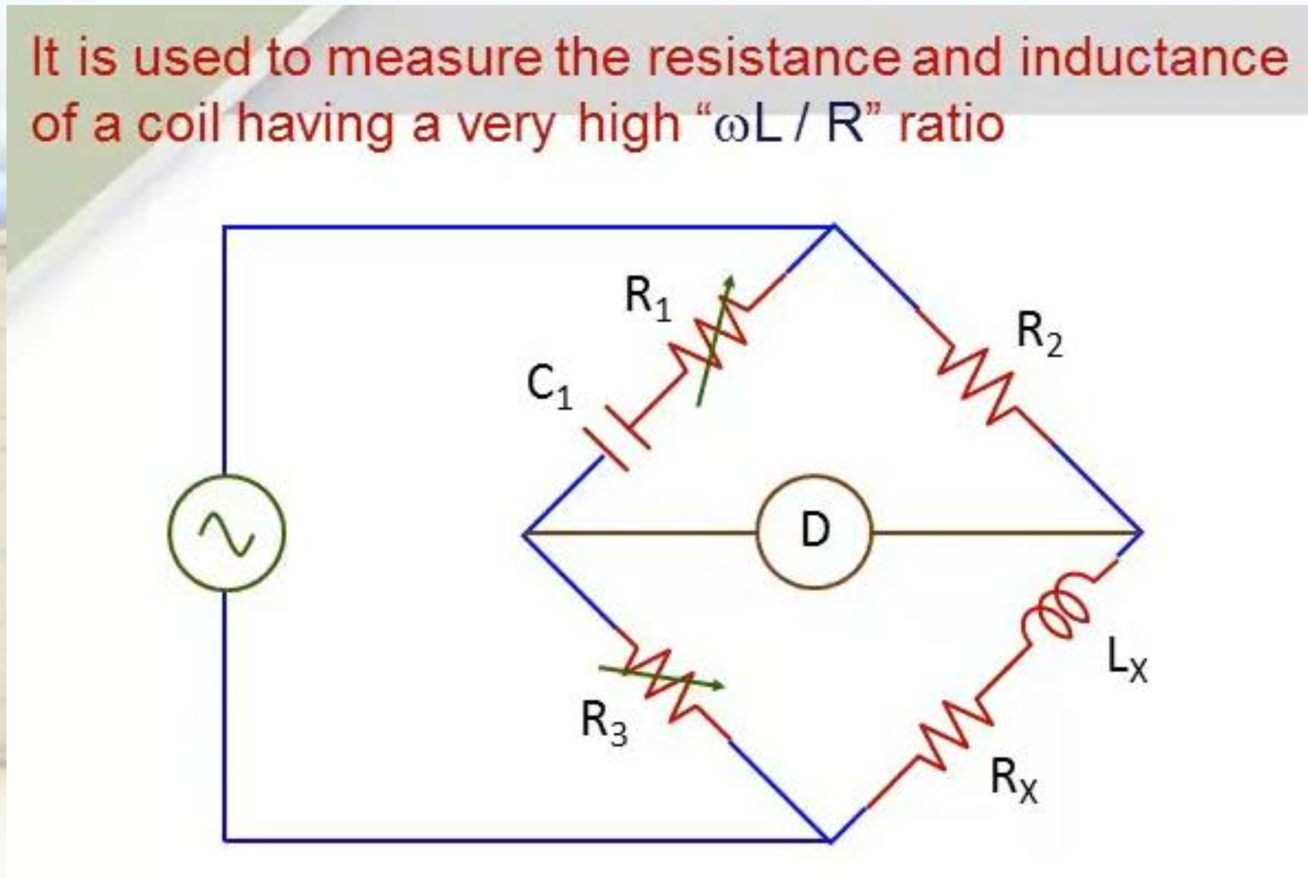
C
A
C
E
R5
R4
R3
D
Source (AC/DC)
AC
DC
C (uF)
R5
Amplifier
Audio Detector

-12V GND 12V 5V
L2
L1
R3
C
R1
Rx
R2
AUDIO OSCILLATOR
1KHz
1.5 KHz
AMP
GND
GHARA
DEVICE & SYSTEMS


ANDERSON BRIDGE
R
r
S
C
L
SUPPLY
DETECTOR
UNKNOWN
UNKNOWN INDUCTANCES
Digital
Null Detector

Hay’s Bridge

Hay’s bridge is a modification of Maxwell’s bridge. This method of measurement is particularly suited for high Q inductors (L>>>R)



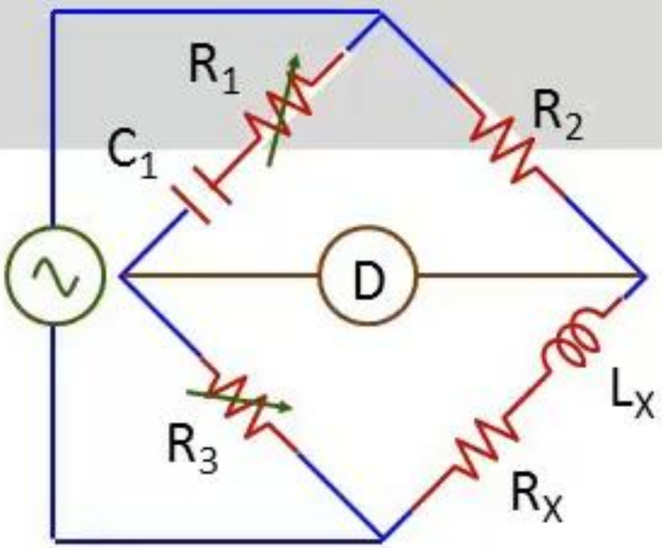
Hay's Bridge

Simple analysis method

$$Z_1 = R_1 - j\frac{1}{\omega C_1}$$

$$Z_2 = R_2 \qquad Z_3 = R_3$$

$$Z_4 = R_X + j\omega L_X$$



$$\left(R_1 - j\frac{1}{\omega C_1}\right)(R_X + j\omega L_X) = R_2\, R_3$$

$$R_1 R_X + L_X / C_1 = R_2\, R_3 \qquad R_1\, R_X\, C_1 + L_X = R_2\, R_3\, C_1$$

$$\omega\, L_X\, R_1 - R_X / \omega\, C_1 = 0 \qquad L_X = R_X / \omega^2\, C_1\, R_1$$

Hay's Bridge

Simple analysis method

$R_1 R_X C_1 + L_X = R_2 R_3 C_1$

$L_X = R_X / \omega^2 C_1 R_1$

$R_1 R_X C_1 + R_X / \omega^2 C_1 R_1 = R_2 R_3 C_1$

$$R_X = \frac{R_2 R_3 C_1}{R_1 C_1 + \dfrac{1}{\omega^2 C_1 R_1}}$$

$$R_X = \frac{\omega^2 C_1^2 R_1 R_2 R_3}{1 + \omega^2 C_1^2 R_1^2}$$

$$L_X = \frac{C_1 R_2 R_3}{1 + \omega^2 C_1^2 R_1^2}$$

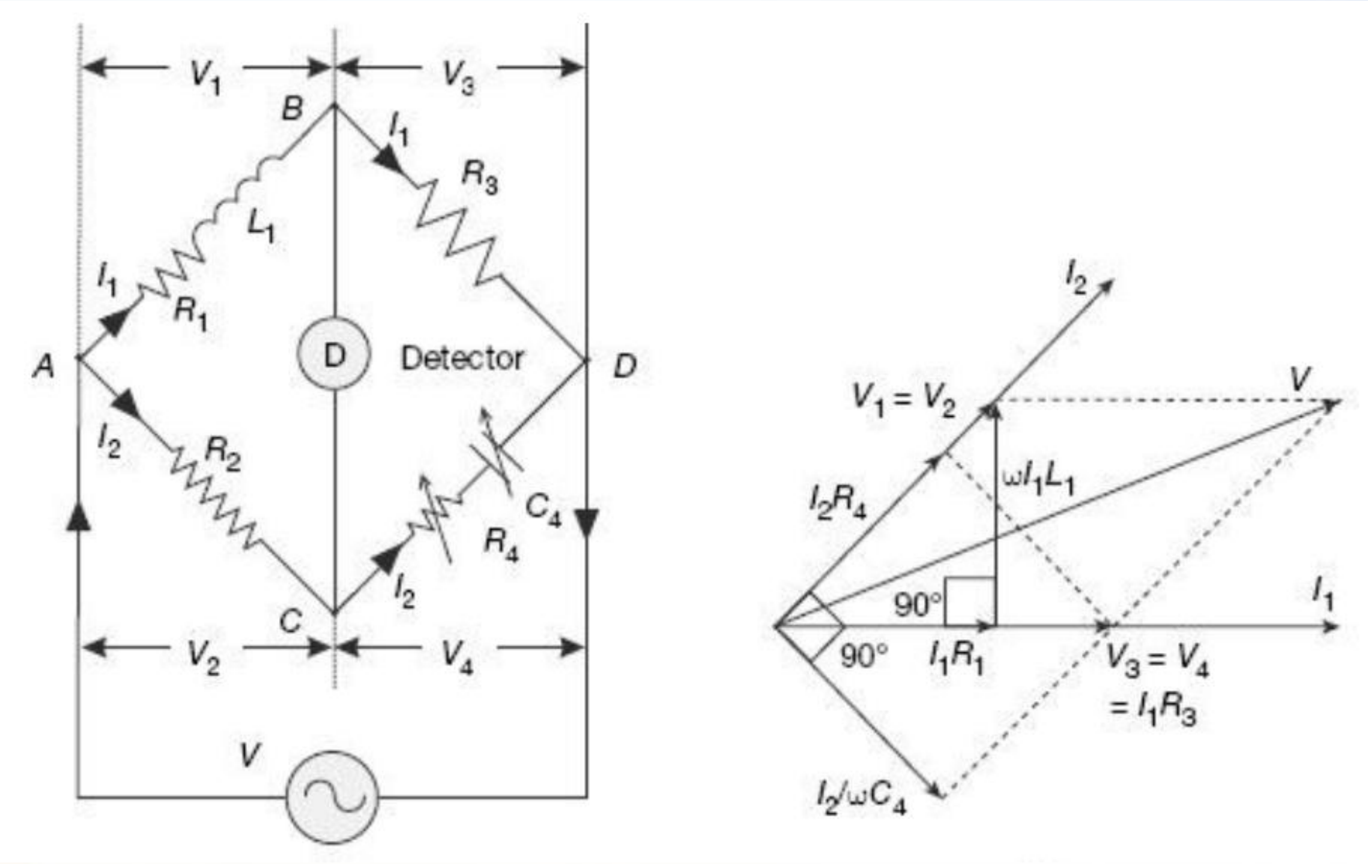
The bridge is frequency dependant

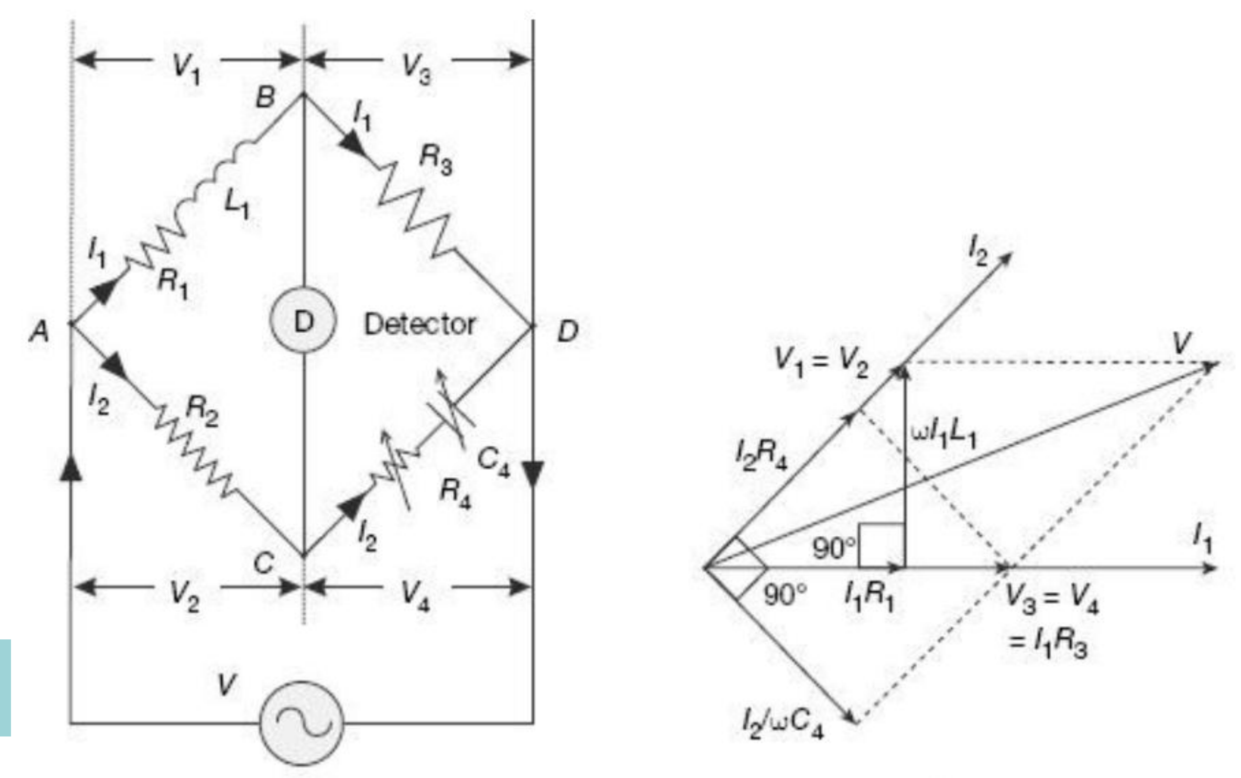
Hay's Bridge

Detailed analysis method

Hay's bridge is a modification of Maxwell's bridge. This method of measurement is particularly suited for high Q inductors (L>>>R)

Bridge description

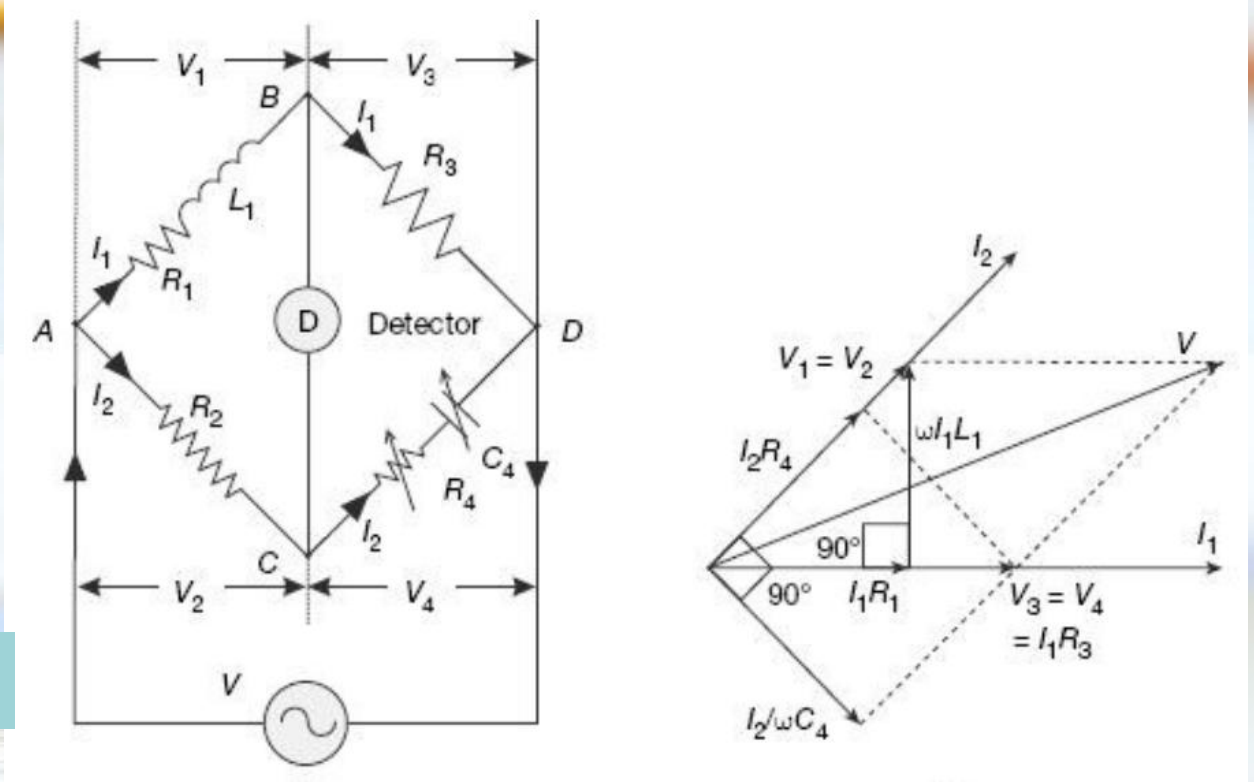




Balance requirement

The unknown inductor L_1 of effective resistance R_1 in the branch AB is compared with the standard known variable capacitor C_4 on arm CD. This bridge uses a resistance R_4 in series with the standard capacitor C_4 (unlike in Maxwell's bride where R_4 was in parallel with C_4). The other resistances R_2 and R_3 are known no-inductive resistors.

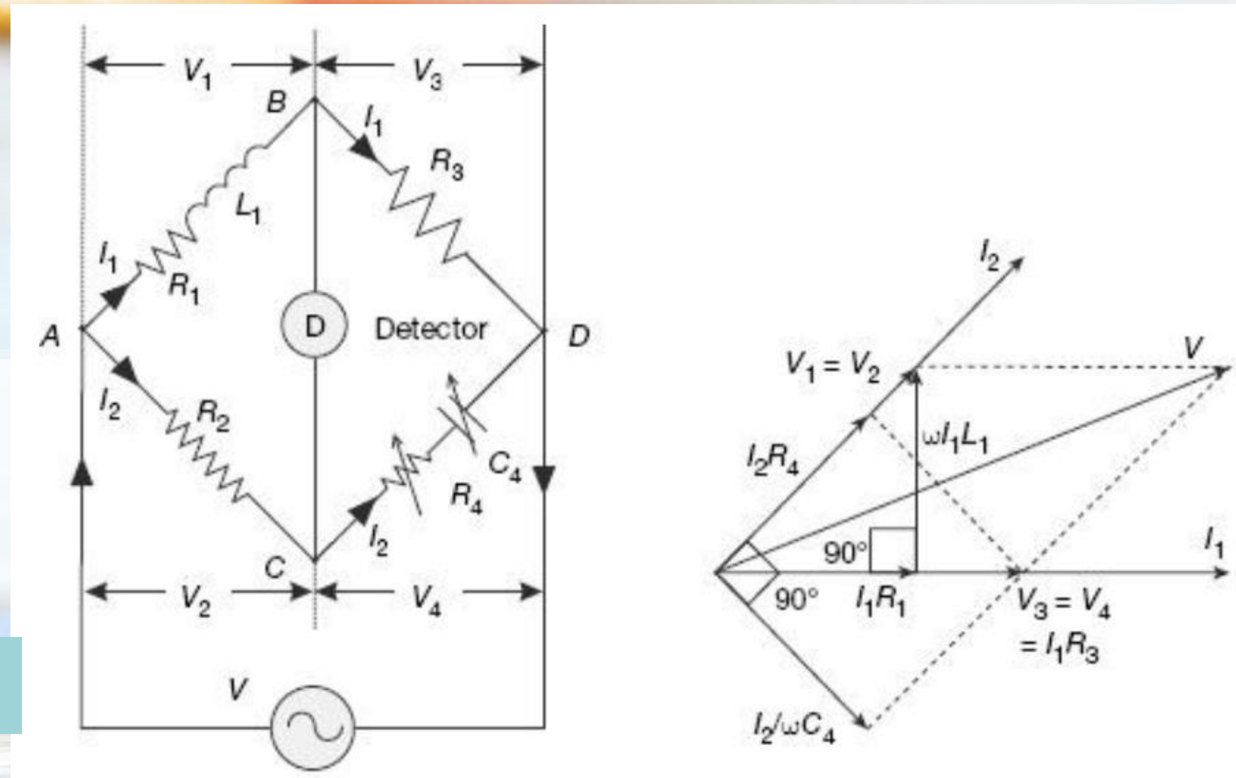
The bridge is balanced by varying C_4 and R_4 or varying R_4 and R_2



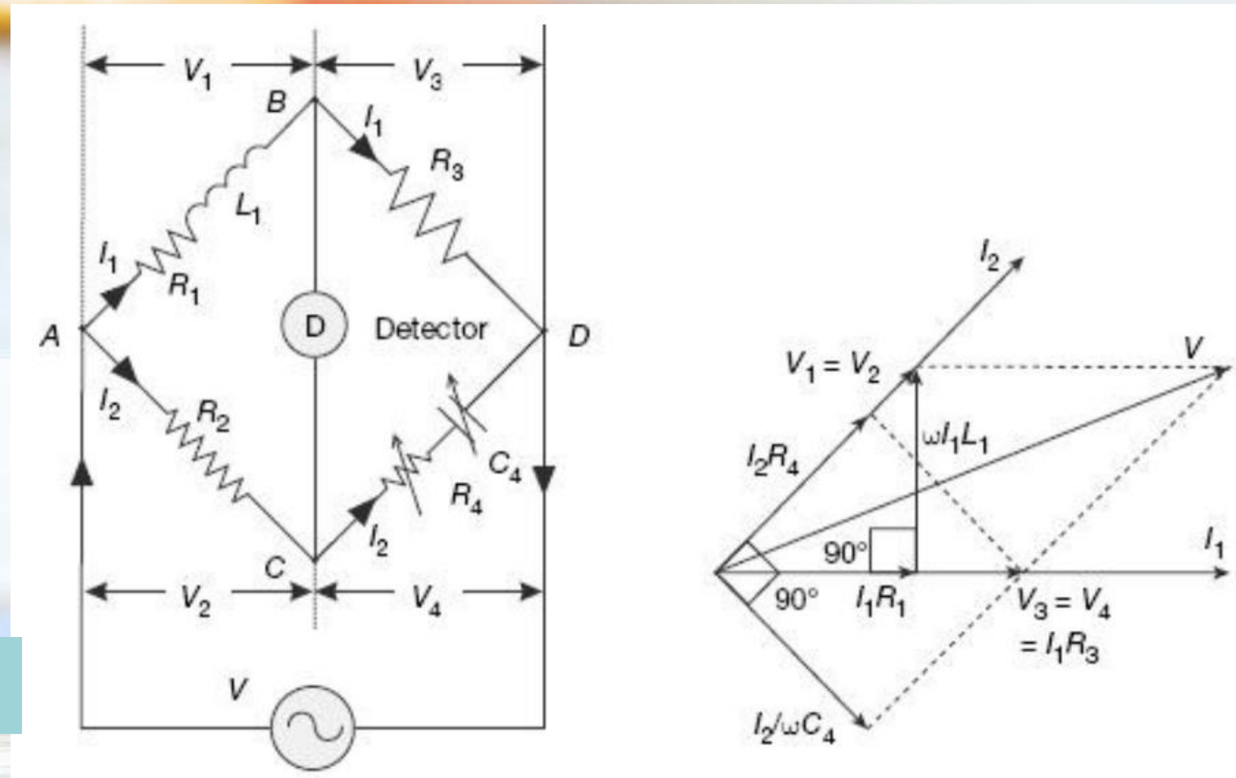
Under balance condition

Under balanced condition, since no current flows through the detector, nodes B and D are at the same potential, voltage drops across arm BD and CD are equal ($V_3 = V_4$); similarly, voltage drops across arms AB and AC are equal ($V_1 = V_2$).

Under balance condition



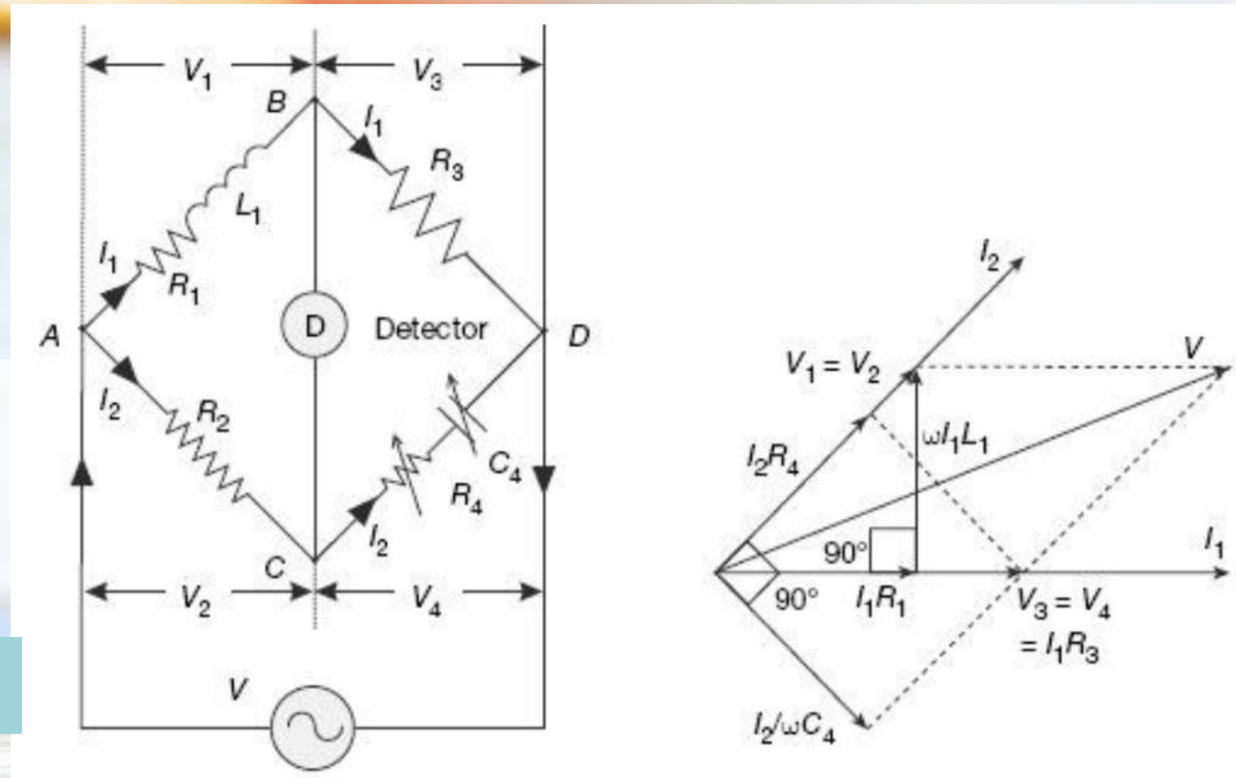
As shown in the phasor diagram, V_3 and V_4 being equal, they are overlapping both in magnitude and phase and are draw on along the horizontal axis. The arm BD being purely resistive, current I_1 through this arm will be in the same phase with the voltage drop $V_3 = I_1R_3$ across it. The same current I_1, while passing through the resistance R_1 in the arm AB, produces a voltage drop I_1R_1 that is once again, in the same phase as I_1. Total voltage drop V_1 across the arm AB is obtained by adding the two quadrature phasors I_1R_1 and wL_1I_1 representing resistive and inductive voltage drops in the same branch AB.



Under balance condition

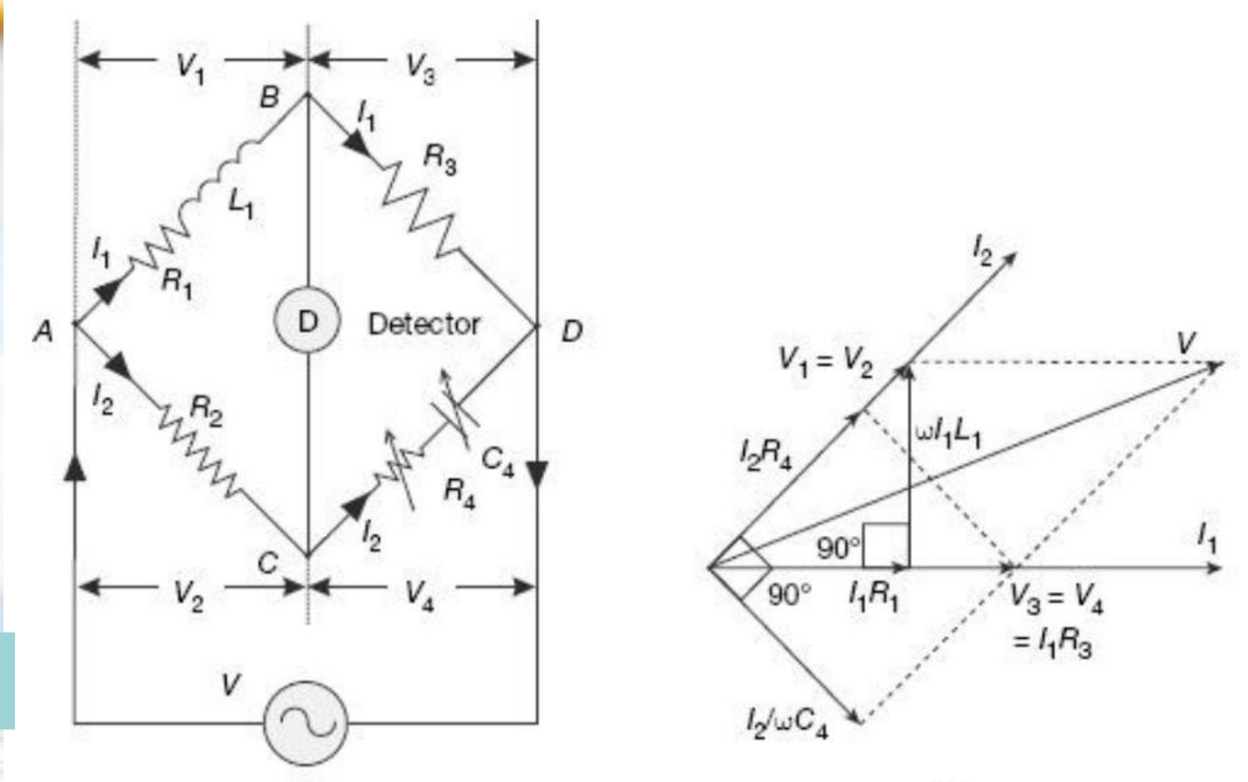
Since under balance condition, voltage drops across arms AB and AC are equal, i.e., ($V_1 = V_2$), the two voltages V_1 and V_2 are overlapping both in magnitude and phase. The branch AC being purely resistive, the branch current I_2 and branch voltage V_2 will be in the same phase.

voltage V.



Under balance condition

The same current I_2 flows through the arm CD and produces a voltage drop I_2R_4 across the resistance R_4. This resistive voltage drop I_2R_4, obviously is in the same phase as I_2. The capacitive voltage drop I_2/wC_4 in the capacitance C_4 present in the same arm AC will however, lag the current I_2 by 90°. Phasor summation of these two series voltage drops across R_4 and C_4 will give the total voltage drop V_4 across the arm CD. Finally, phasor summation of V_1 and V_3 (or V_2 and V_4) results in the supply voltage V.



Under balance condition

$$\left(R_1 + j\omega L_1\right)\left(R_4 - \frac{j}{\omega C_4}\right) = R_2 \; R_3$$

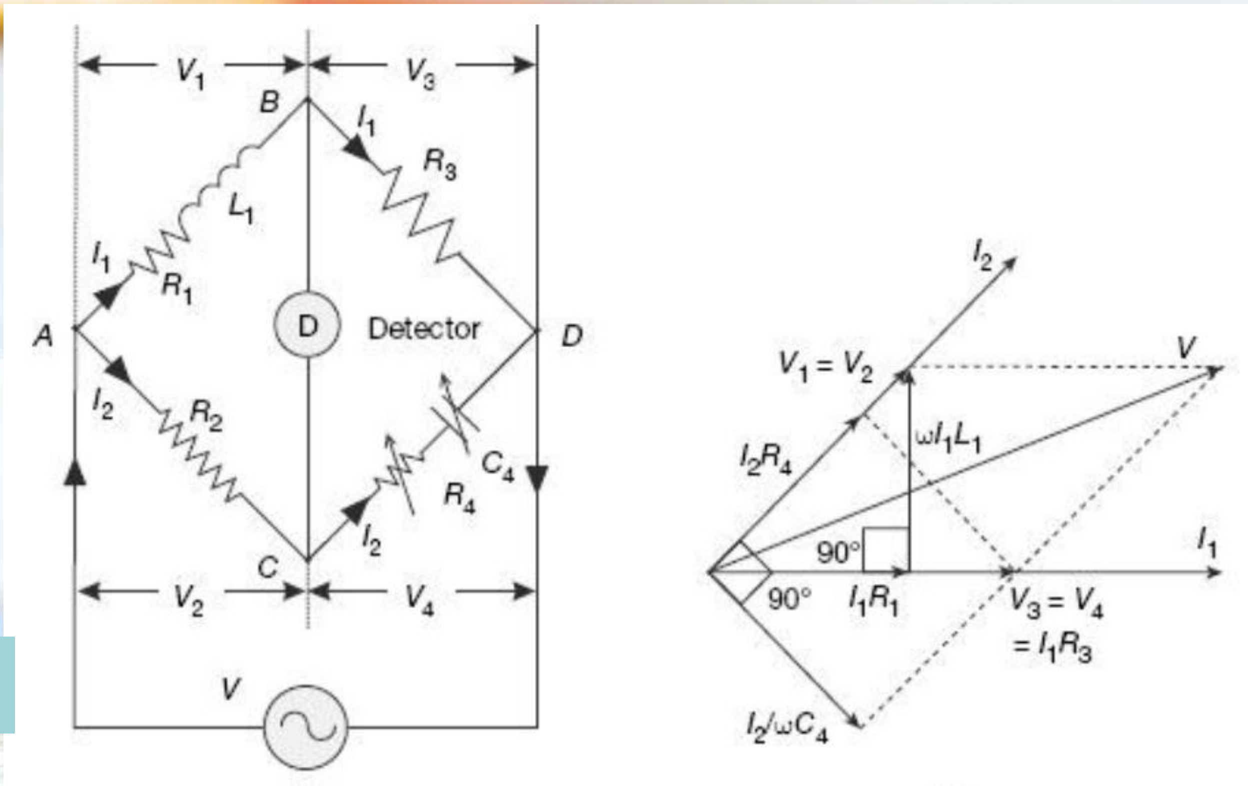
$$R_1R_4 + \frac{L_1}{C_4} + j\omega L_1 R_4 - \frac{jR_1}{\omega C_4} = R_2R_3$$

$$R_1R_4 + \frac{L_1}{C_4} = R_2R_3$$

$$\omega L_1 R_4 = \frac{R_1}{\omega C_4}$$

$$L_1 = \frac{R_2R_3C_4}{1+\omega^2 R_4{}^2 C_4{}^2}$$

$$R_1 = \frac{R_2R_3R_4\omega^2 C_4{}^2}{1+\omega^2 R_4{}^2 C_4{}^2}$$

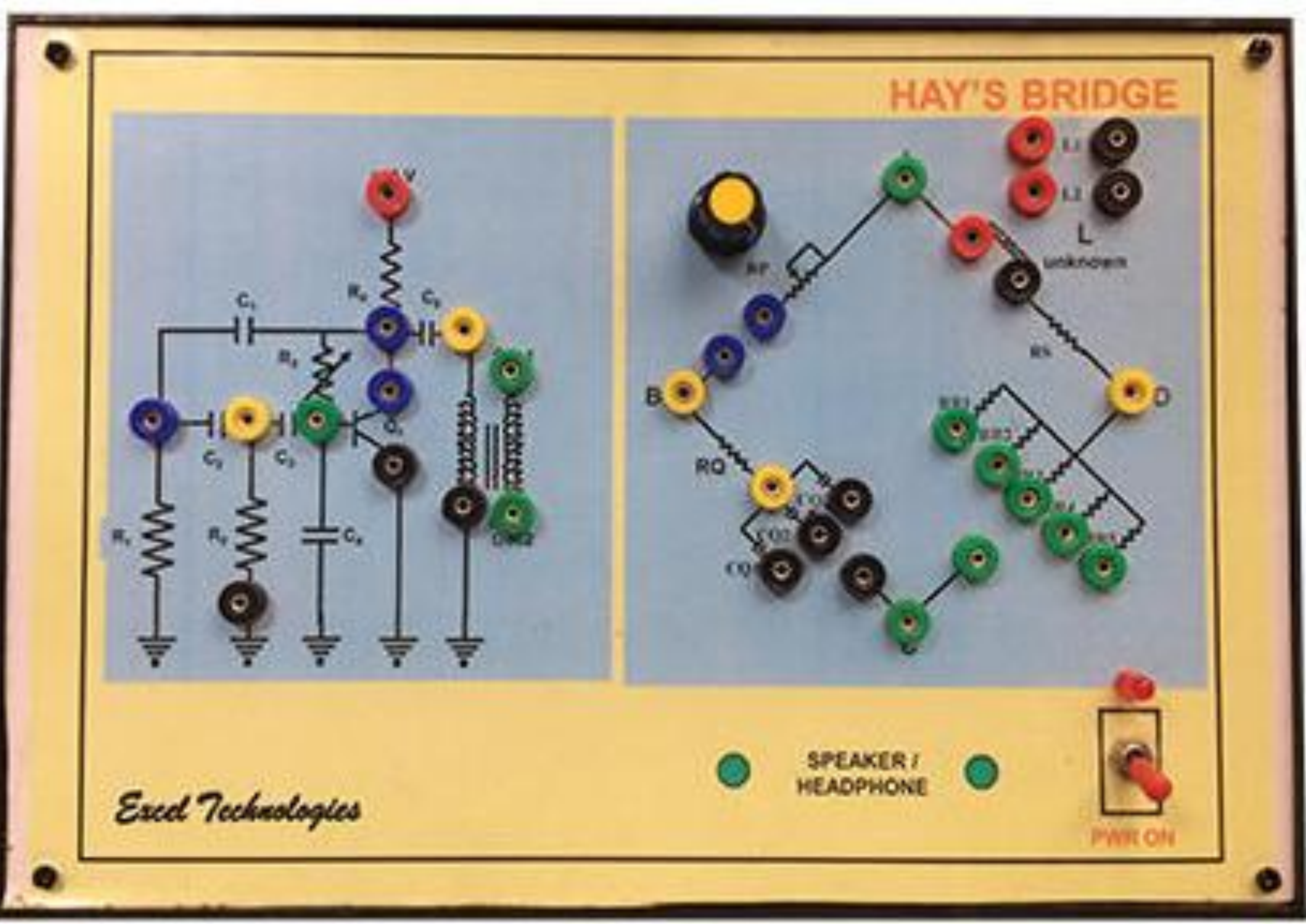


Under balance condition

$$L_1 = \frac{R_2 R_3 C_4}{1+\omega^2 R_4{}^2 C_4{}^2}$$

$$R_1 = \frac{R_2 R_3 R_4 \omega^2 C_4{}^2}{1+\omega^2 R_4{}^2 C_4{}^2}$$

The bridge is frequency dependent



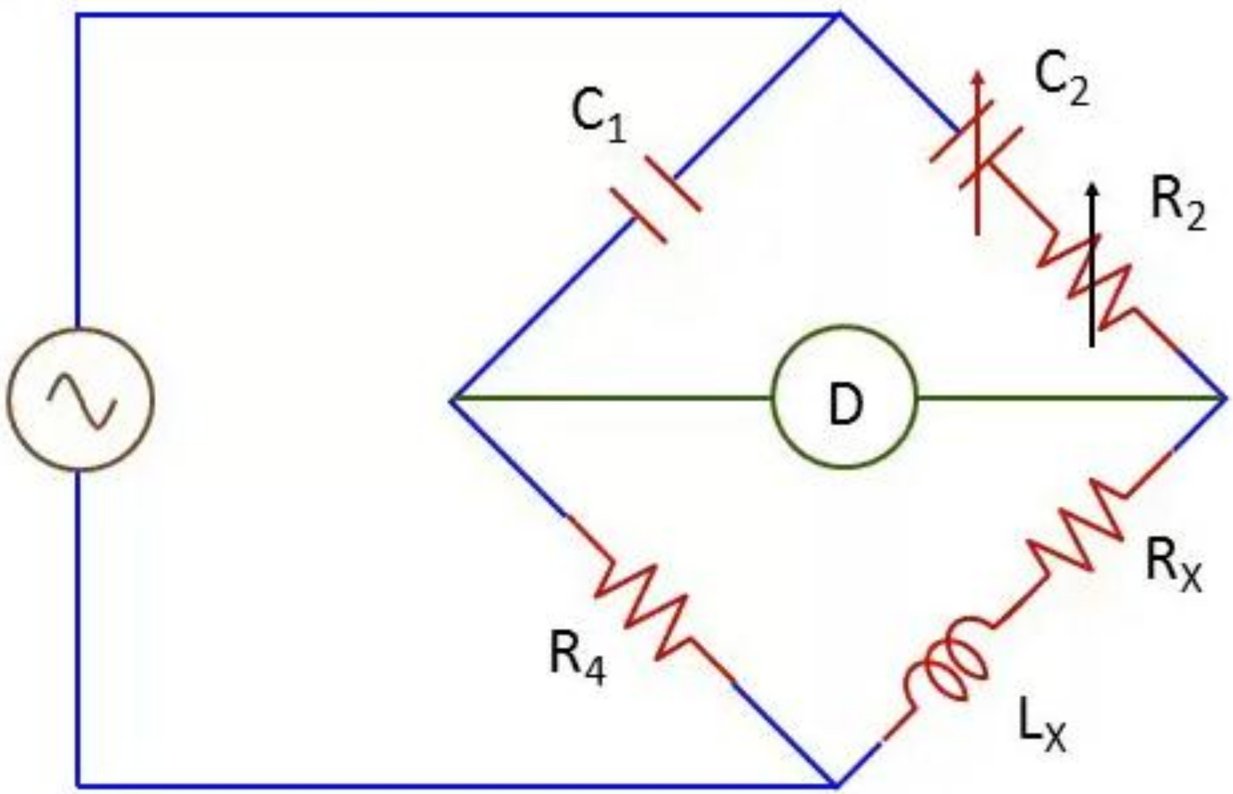
HAY'S BRIDGE
L
unknown
B
D
RQ
SPEAKER / HEADPHONE
Excel Technologies
PWR ON

Hay's Bridge


RAJAT
MEASUREMENT OF INDUCTANCE BY HAY'S BRIDGE
D
PREMIER TRADING CORP.

Owen's Bridge

It is used to measure the resistance and inductance of coils possessing a ***large*** value of inductance



Owen's Bridge

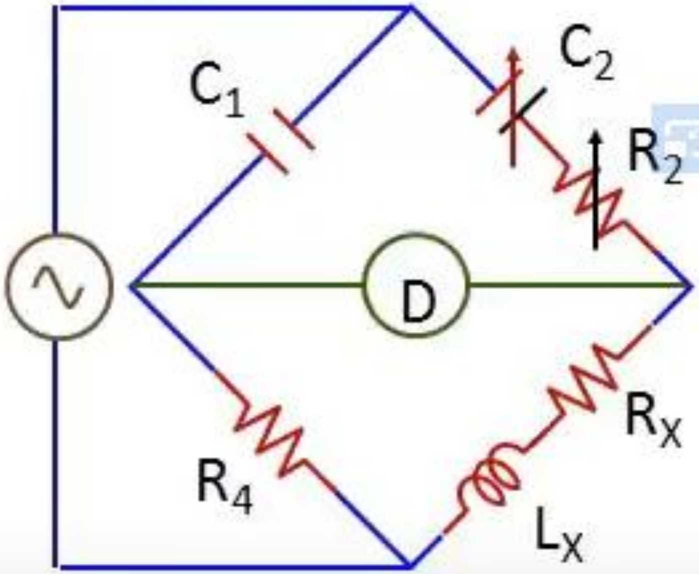
Simple analysis method

$$\frac{1}{j\omega C_1}(R_x + j\omega L_x) = (R_2 + \frac{1}{j\omega C_2})\ R_4$$

$$(R_x + j\omega L_x) = (j\omega C_1 R_2 + \frac{C_1}{C_2})R_4$$

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

$$L_x = C_1 R_2 R_4$$

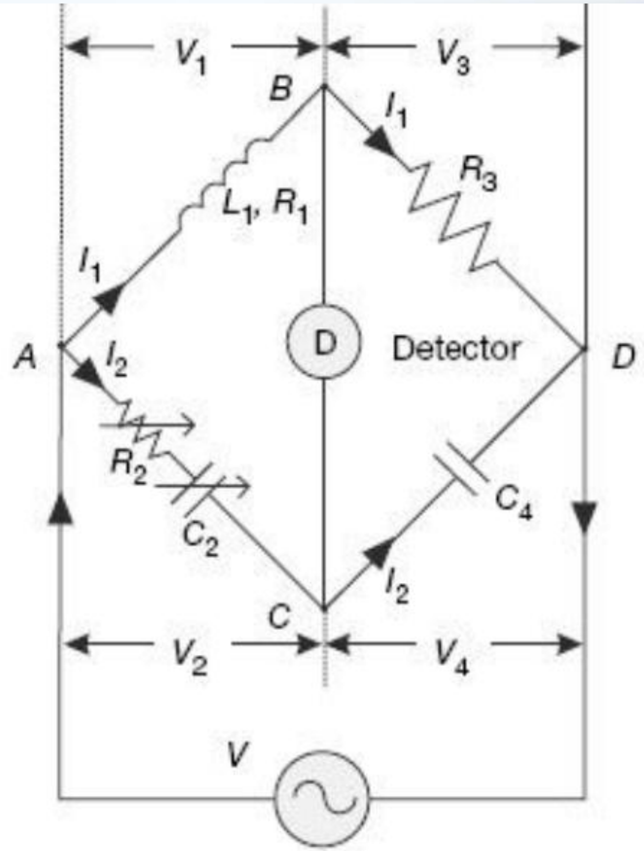


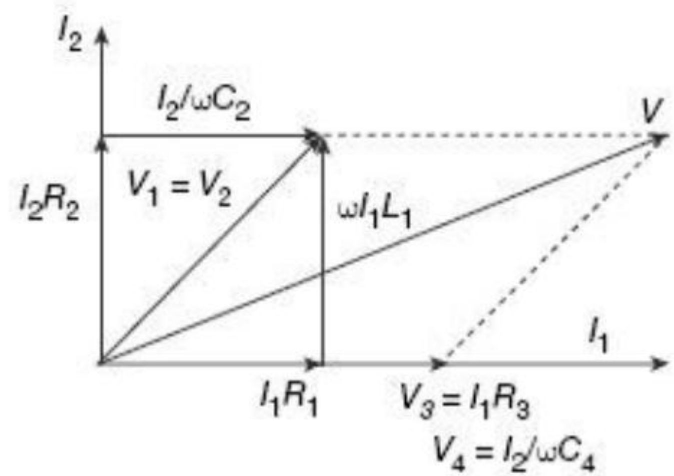
Owen’s Bridge

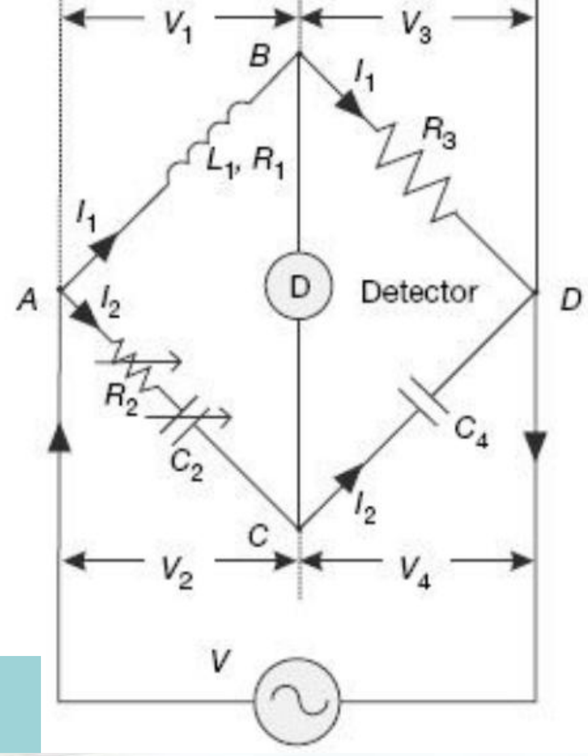
Detailed analysis method

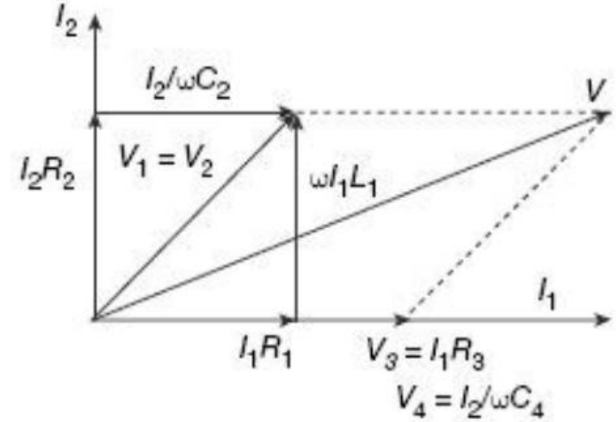
This bridge is used for measurement of unknown inductance in terms of known value capacitance. **This bridge has the advantages of being useful over a very wide range of inductances with capacitors of reasonable dimension**.

Bridge description



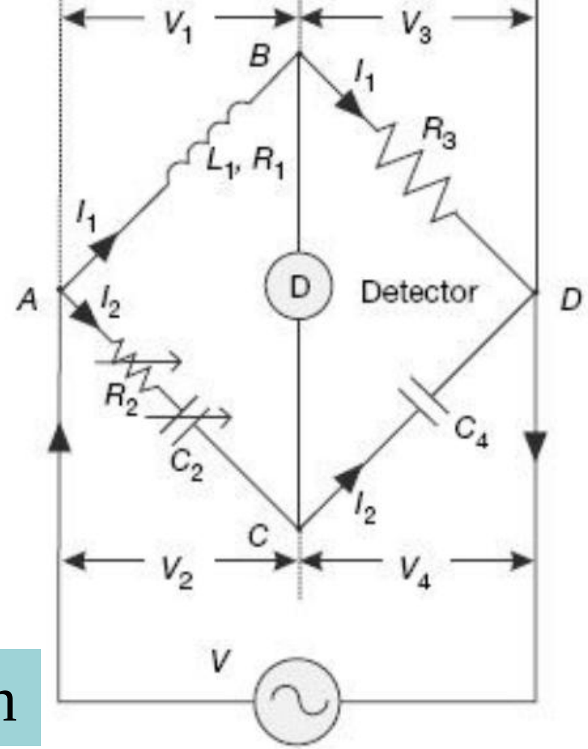


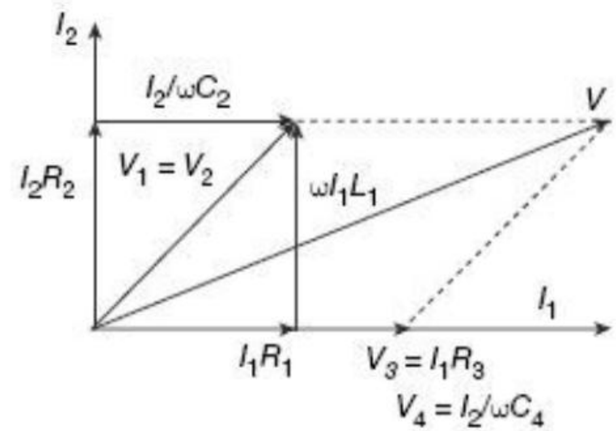




Balance requirement

The unknown inductor L_1 of effective resistance R_1 in the branch AB is compared with the standard known capacitor C_2 on arm AC. The bridge is balanced by varying R_2 and C_2 independently



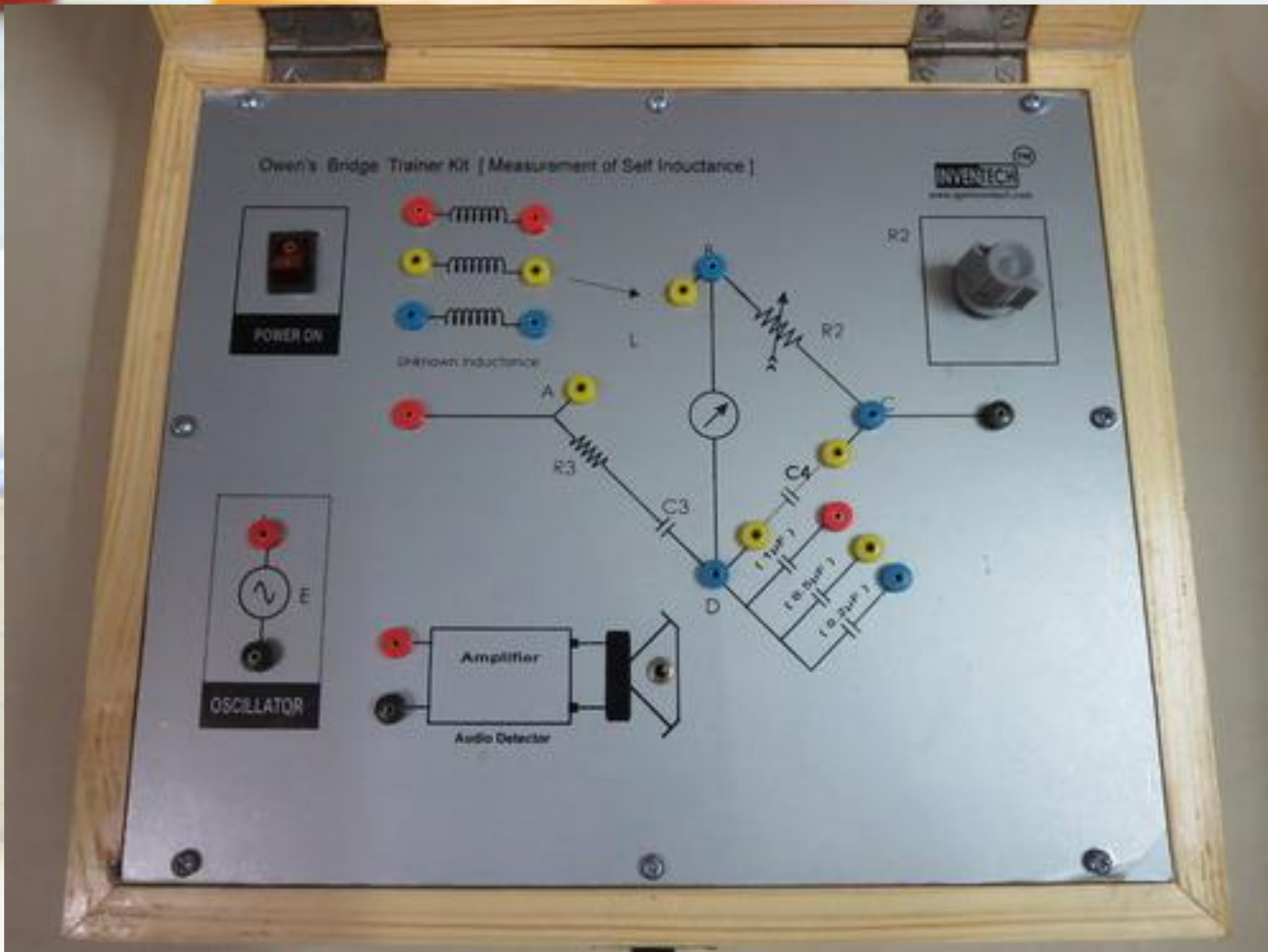


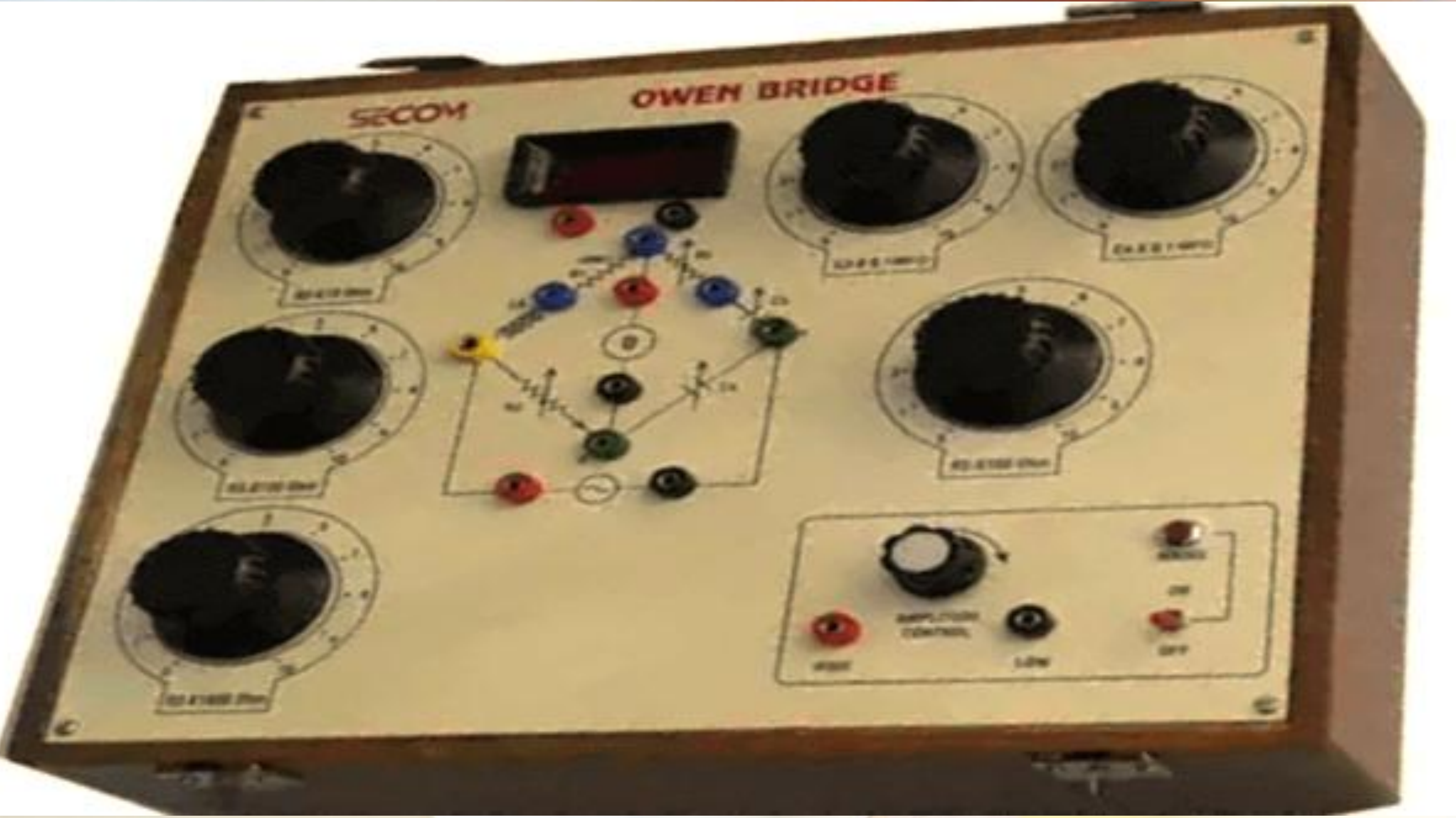
Under balance condition

$$R_1 = R_3 \frac{C_4}{C_2}$$

$$L_1 = R_2 R_3 C_4$$

Prove and verify with the aid of phasor diagram


Owen's Bridge Trainer Kit [Measurement of Self Inductance]
POWER ON
Unknown Inductance
R2
L
R2
A
C
R3
C3
C4
D
(1μF)
(0.5μF)
(0.2μF)
E
OSCILLATOR
Amplifier
Audio Detector


SECOM
OWEN BRIDGE

Thanks