Quadrant II – Transcript and Related Materials

Programme: Bachelor of Science (Second Year)

Subject: Physics

Course Code: PYS 101

Course Title: Network Analysis

Unit: 8 AC Bridges

Module Name: General AC bridges, Maxwell's bridge and Maxwell's L/C bridge.

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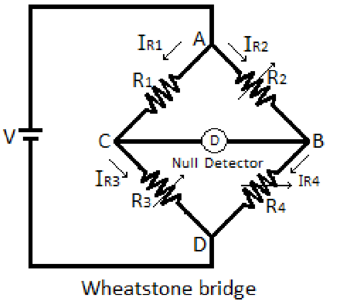
Notes.

Introduction.

Bridge is the name given to denote a class of measuring circuits.
DC Wheatstone's bridge is used to measure unknown resistance using null method or bridge balance technique, and change of resistance using bridge unbalanced technique, in this method it is very sensitive to a change in resistance and this change is converted to corresponding change in voltage.
AC bridge are used for making measurement of resistance, capacitance, inductance and circuit parameters directly derived from component values such as frequency and phase.
Bridge circuit merely compares the value of an unknown component to that of an known component (a standard), its measurement accuracy is high and is directly related to the accuracy of the bridge components

DC Wheatstone bridge.

DC Wheatstone bridge consists of two parallel resistor branches, with each branch containing two series resistors i.e each resistor in each of four bridge arms, A DC voltage source is connected across this resistance network to provide a source of current through the resistance network. A null detector is connected between the parallel branches to detect balanced condition. Figure shows a DC Wheatstone bridge.



Wheatstone bridge

The bridge is said to be balanced when the potential difference across the null detector is 0 volt and no current flows through the detector.
This condition occurs when the voltage between the two terminals of the detector are equal

$\Rightarrow V_{CD} = V_{BD}$

$\Rightarrow I_{AC} = I_{CD}$ or $I_{AB} = I_{BD}$

The balancing condition is given by the $\frac{R1}{R3} = \frac{R2}{R4}$

which can be written as $R_1R_4 = R_2R_3$

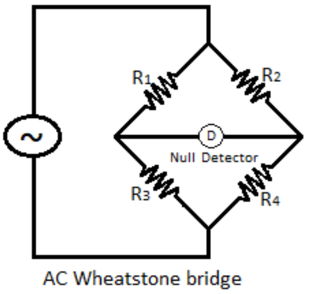
If three resistances are known, then fourth may be determined by the above equation. Some of the arms are made variable resistance. By varying the resistance, the potential values between terminals of detector are made equal. This is called balancing of the bridge.

General AC bridges.

The AC bridge are similar to D.C. Wheatstone bridge in way of connecting. Each of four arms of the bridge is taken as impedances, the bridge is excited by an ac source instead of dc source and the dc null detector is replaced by ac null detector.

AC bridge balance.

The impedances Z are vector complex quantities that possess phase angles. For bridge balance both the magnitude and phase angles of the impedance arms need to be adjusted i.e. must be balanced for both the reactance and the resistive component.



AC Wheatstone bridge

When bridge is balanced $V_{CD} = V_{BD}$

$V_{CD} = V\,Z_3 / (Z_1 + Z_3)$ (voltage divider relation)

$V_{BD} = V\,Z_2 / (Z_2 + Z_4)$

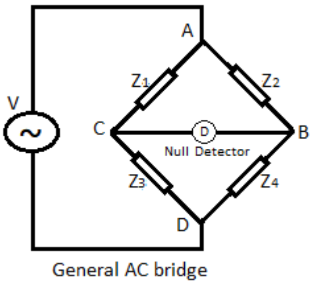
Substituting in bridge balance equation.

$V\,Z_3 / (Z_1 + Z_3) = V\,Z_2 / (Z_2 + Z_4)$

$Z_3 / (Z_1 + Z_3) = Z_2 / (Z_2 + Z_4)$

$(Z_1 + Z_3) / Z_3 = (Z_2 + Z_4) / Z_2$ $\frac{Z1}{Z3} = \frac{Z2}{Z4}$

$Z_1 Z_4 = Z_2 Z_3$



General AC bridge

Impedance $Z = Z\angle\theta$ (polar form) where Z represents the magnitude and θ represent the phase angle θ of the complex impedance,

Writing $Z_1Z_4 = Z_2Z_3$ as,

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

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

$\Rightarrow$2 conditions must be satisfied simultaneously to balance the AC bridge.

i) $Z_1 Z_4 = Z_2 Z_3$

ii) $\angle\theta_1+\angle\theta_4 = \angle\theta_2+\angle\theta_3$.

Note.

1. Balance in AC bridge will generally not to be perfect and we look for a minimum and not zero in detector voltage.
2. Since impedance Z depends on the frequency the balance will be frequency dependent

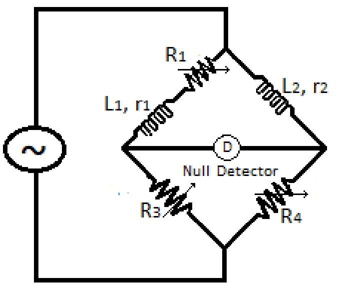
Measurement of Inductance (AC bridge circuit)

(Maxwell bridge**,** Hay bridge, Anderson bridge & Owen bridge)

Maxwell's Inductance bridge.

Measures the inductance by comparison with a standard self-inductance

$Z_1 Z_4 = Z_2 Z_3$ or $\frac{Z1}{Z3} = \frac{Z2}{Z4}$



Maxwell's Inductance bridge

Camparing the circuit with general AC bridge

$Z_1 = (R_1+r_1) + j\omega L_1$, $Z_2 = r_2 + j\omega L_2$

$Z_3 = R_3$ and $Z_4 = R_4$

$$\frac{(R_1+r_1)+j\omega L_1}{R_3} = \frac{r_2+j\omega L_2}{R_4}$$

$$\frac{(R_1+r_1)}{R_3} + \frac{j\omega L_1}{R_3} = \frac{r_2}{R_4} + \frac{j\omega L_2}{R_4}$$

Equating the real and Imaginary parts separately

$$\frac{(R_1+r_1)}{R_3} = \frac{r_2}{R_4}$$ Real parts

$$\therefore r_2 = \frac{(R_1+r_1)R_4}{R_3}$$ ac resistance of unknown inductor.

$$\frac{j\omega L_1}{R_3} = \frac{j\omega L_2}{R_4}$$ Imaginary parts

$$\therefore L_2 = \frac{L_1 R_4}{R_3}$$ unknown L_2 in terms of known L_1.

Disadvantage. The ratio R_4/ R_3 occurs in both equations The two balance conditions cannot be satisfied independently.

Maxwell's Inductance Capacitance or (L/C) bridge.

Measures an unknown inductance in terms of a standard capacitance.

The general equation of the bridge, $Z_1 Z_4 = Z_2 Z_3$ or $\frac{Z1}{Z2} = \frac{Z3}{Z4}$

Comparing with general AC bridge

$Z_1 = r_1 + j\omega L_1$, $Z_2 = R_2$, $Z_3 = R_3$ and $1/Z_4 = 1/R_4 + j\omega C$

$(r_1 + j\omega L_1)/ R_2 = R_3 (1/R_4 + j\omega C_4)$

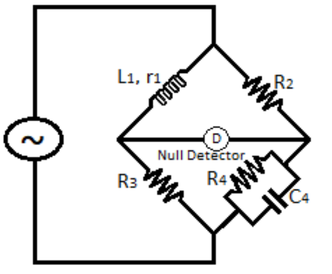
Equating the real and Imaginary parts separately

$r_1/ R_2 = R_3/R_4$ $r_1 = R_2R_3/R_4$ real part

$L_1 = C_4R_2R_3$ imaginary part

Inductance of unknown inductor in terms of known capacitor $C_{4.}$

$L = C R_2R_3$



Maxwell's L/C bridge

Advantages

1. Balance condition is independent of the excitation frequency.
2. The balance equation is independent of losses associated with inductance.
3. Useful for measurement of a wide range of inductance.

Disadvantages:

1. The bridge cannot be used to measure very low Q or High *Q* values, it is suitable measurements for $1 < Q < 10$.
2. The bridge balance equations are independent of frequency. But practically, the properties of coil under test vary with frequency which can cause error.