

D.C & A.C Bridges

Bridge circuits are used very commonly as a variable conversion element in measurement systems and produce an output in the form of a voltage level that changes as the measured physical quantity changes. They provide an accurate method of measuring resistance, inductance and capacitance values, and enable the detection of very small changes in these quantities about a nominal value. They are of immense importance in measurement system technology because so many transducers measuring physical quantities have an output that is expressed as a change in resistance, inductance or capacitance. The displacement-measuring strain gauge, which has a varying resistance output, is but one example of this class of transducers. Normally, excitation of the bridge is by a d.c. voltage for resistance measurement and by an a.c. voltage for inductance or capacitance measurement. Both null and deflection types of bridge exist, and, in a like manner to instruments in general, null types are mainly employed for calibration purposes and deflection types are used within closed-loop automatic control schemes.

Null-type, d.c. bridge (Wheatstone bridge)

A null-type bridge with d.c. excitation, commonly known as a Wheatstone bridge, has the form shown in Figure 7.1. The four arms of the bridge consist of the unknown resistance R_u , two equal value resistors R_2 and R_3 and a variable resistor R_v (usually a decade resistance box). A d.c. voltage V_i is applied across the points AC and the resistance R_v is varied until the voltage measured across points BD is zero. This null point is usually measured with a high sensitivity galvanometer.

To analyse the Wheatstone bridge, define the current flowing in each arm to be $I_1 \dots I_4$ as shown in Figure 3.1. Normally, if a high impedance voltage-measuring instrument is used, the current I_m drawn by the measuring instrument will be very small and can be approximated to zero. If this assumption is made, then, for $I_m \approx 0$:

$$I_1 = I_3 \text{ and } I_2 = I_4$$

3.1

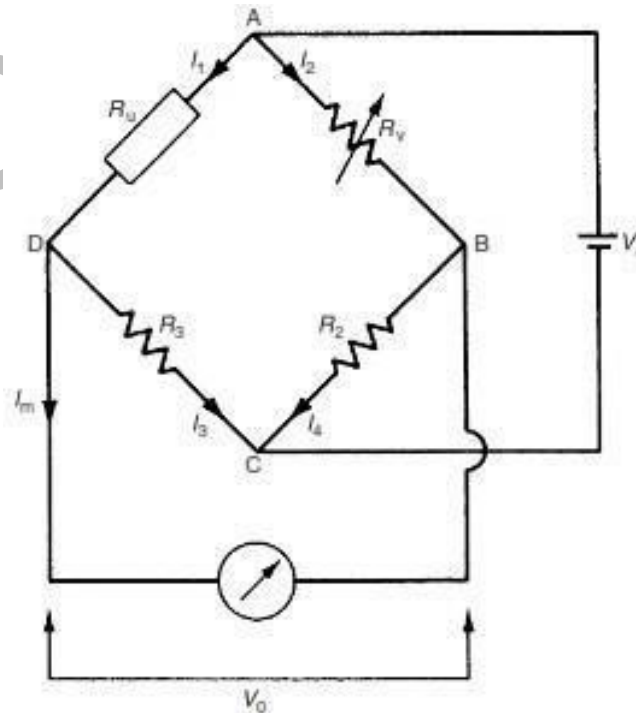
$$I_1 = I_3 \quad \text{and} \quad I_2 = I_4$$

Looking at path ADC, we have a voltage V_i applied across a resistance $R_u + R_3$ and by Ohm's law:

$$I_1 = \frac{V_i}{R_u + R_3}$$

Similarly for path ABC:

$$I_2 = \frac{V_i}{R_v + R_2}$$



Now we can calculate the voltage drop across AD and AB:

$$V_{AD} = I_1 R_v = \frac{V_i R_u}{R_u + R_3}; \quad V_{AB} = I_2 R_v = \frac{V_i R_v}{R_v + R_2}$$

By the principle of superposition,

$$V_0 = V_{BD} = V_{BA} + V_{AD} = -V_{AB} + V_{AD}$$

Thus:

$$V_0 = -\frac{V_i R_v}{R_v + R_2} + \frac{V_i R_u}{R_u + R_3}$$

At the null point $V_0 = 0$, so:

$$\frac{R_u}{R_u + R_3} = \frac{R_v}{R_v + R_2}$$

Inverting both sides:

$$\frac{R_u + R_3}{R_u} = \frac{R_v + R_2}{R_v} \quad \text{i.e.} \quad \frac{R_3}{R_u} = \frac{R_2}{R_v} \quad \text{or} \quad R_u = \frac{R_3 R_v}{R_2}$$

Thus, if $R_2 = R_3$, then $R_u = R_v$. As R_v is an accurately known value because it is derived from a variable decade resistance box, this means that R_u is also accurately known.

Deflection-type d.c. bridge

A deflection-type bridge with d.c. excitation is shown in Figure 3.2. This differs from the Wheatstone bridge mainly in that the variable resistance R_v is replaced by a fixed resistance R_1 of the same value as the nominal value of the unknown resistance R_u . As the resistance R_u changes, so the output voltage V_0 varies, and this relationship between V_0 and R_u must be calculated.

This relationship is simplified if we again assume that a high impedance voltage measuring instrument is used and the current drawn by it, I_m , can be approximated to zero. (The case when this assumption does not hold is covered later in this section.). The analysis is then exactly the same as for the preceding example of the Wheatstone bridge, except that R_v is replaced by R_1 . Thus, from equation (3.1),

$$V_0 = V_i * (R_u / R_u + R_3) - (R_1 / R_1 + R_2)$$

When R_u is at its nominal value, i.e. for $R_u \approx R_1$, it is clear that $V_0 \approx 0$ (since $R_2 \approx R_3$). For other values of R_u , V_0 has negative and positive values that vary in a non-linear way with R_u .

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D.C & A.C Potentiometers

An instrument that precisely measures an electromotive force (emf) or a voltage by opposing to it a known potential drop established by passing a definite current through a resistor of known characteristics. (A three-terminal resistive voltage divider is sometimes also called a potentiometer.) There are two ways of accomplishing this balance:

1. The current I may be held at a fixed value and the resistance R across which the IR drop is opposed to the unknown may be varied
2. current may be varied across a fixed resistance to achieve the needed IR drop.

The essential features of a general-purpose constant-current instrument are shown in the illustration. The value of the current is first fixed to match an IR drop to the emf of a reference standard cell. With the standard-cell dial set to read the emf of the reference cell, and the galvanometer (balance detector) in position $G1$, the resistance of the supply branch of the circuit is adjusted until the IR drop in 10 steps of the coarse dial plus the set portion of the standard-cell dial balances the known reference emf, indicated by a null reading of the galvanometer. This adjustment permits the potentiometer to be read directly in volts. Then, with the galvanometer in position $G2$, the coarse, intermediate, and slide-wire dials are adjusted until the galvanometer again reads null. If the potentiometer current has not changed, the emf of the unknown can be read directly from the dial settings. There is usually a switching arrangement so that the galvanometer can be quickly shifted between positions 1 and 2 to check that the current has not drifted from its set value.

Circuit diagram of a general-purpose constant-current potentiometer, showing essential features Potentiometer techniques may also be used for current measurement, the unknown current being sent through a known resistance and the IR drop opposed by balancing it at the voltage terminals of the potentiometer. Here, of course, internal heating and consequent resistance change of the current-carrying resistor (shunt) may be a critical factor in measurement accuracy; and the shunt design may require attention to dissipation of heat resulting from its I^2R power consumption.

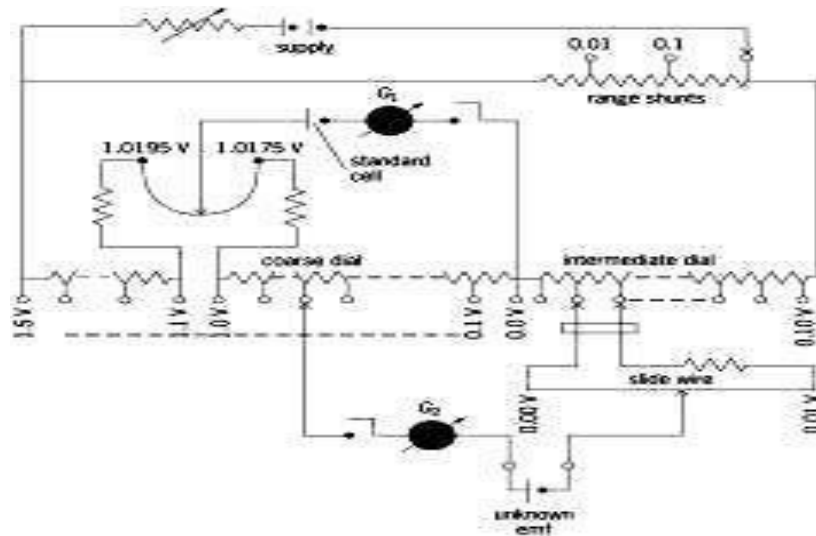


Fig 3.1 D.C & A.C Potentiometers

Potentiometer techniques have been extended to alternating-voltage measurements, but generally at a reduced accuracy level (usually 0.1% or so). Current is set on an ammeter which must have the same response on ac as on dc, where it may be calibrated with a potentiometer and shunt combination. Balance in opposing an unknown voltage is achieved in one of two ways: (1) a slide-wire and phase-adjustable supply; (2) separate in-phase and quadrature adjustments on slide wires supplied from sources that have a 90° phase difference. Such potentiometers have limited use in magnetic testing.

An instrument that precisely measures an electromotive force (emf) or a voltage by opposing it to a known potential drop established by passing a definite current through a resistor of known characteristics. (A three-terminal resistive voltage divider is sometimes also called a potentiometer.) There are two ways of accomplishing this balance: (1) the current I may be held at a fixed value and the resistance R across which the IR drop is opposed to the unknown may be varied; (2) current may be varied across a fixed resistance to achieve the needed IR drop.

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An electrical measuring device used in determining the electromotive force (emf) or voltage by means of the compensation method. When used with calibrated standard resistors, a potentiometer can be employed to measure current, power, and other electrical quantities; when used with the appropriate measuring transducer, it can be used to gauge various non-electrical quantities, such as temperature, pressure, and the composition of gases. Distinction is made between DC and AC potentiometers. In DC potentiometers, the voltage being measured is compared to the emf of a standard cell.

Since at the instant of compensation the current in the circuit of the voltage being measured equals zero, measurements can be made without reductions in this voltage. For this type of potentiometer, accuracy can exceed 0.01 percent. DC potentiometers are categorized as either high-resistance, with a slide-wire resistance ranging from The higher resistance class can measure up to 2 volts (V) and is used in testing highly accurate apparatus. The low-resistance class is used in measuring voltage up to 100 mV. To measure higher voltages, up to 600 V, and to test voltmeters, voltage dividers are connected to potentiometers. Here the voltage drop across one of the resistances of the voltage divider is compensated; this constitutes a known fraction of the total voltage being measured.

In AC potentiometers, the unknown voltage is compared with the voltage drop produced by a current of the same frequency across a known resistance. The voltage being measured is then adjusted both for amplitude and phase. The accuracy of AC potentiometers is of the order of 0.2 percent. In electronic automatic DC and AC potentiometers, the measurements of voltage are carried out automatically. In this case, the compensation of the unknown voltage is achieved with the aid of a servomechanism that moves the slide along the resistor, or rheostat. The servomechanism is actuated by the imbalance of the two voltages, that is, by the difference between the compensating voltage and the voltage that is being compensated. In electronic automatic potentiometers, the results of measurements are read on dial indicators, traced on recorder charts or received as numerical data. The last method makes it possible to input the data directly into a computer. In addition to measurement, electronic automatic potentiometers are also capable of regulating various parameters of industrial processes. In this case, the slide of the rheostat is set in a position that predetermines, for instance, the temperature of the object to be regulated. The voltage imbalance of the potentiometer drives the servomechanism, which then increases or decreases the electric heating or regulates the fuel supply.

A voltage divider with a uniform variation of resistance, a device that allows some fraction of a given voltage to be applied to an electric circuit. In the simplest case, the device consists of a conductor of high resistance equipped with a sliding contact. Such dividers are used in electrical engineering, radio engineering, and measurement technology. They can also be utilized in analog computers and in automation systems, where, for example, they function as sensors for linear or angular displacement

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FINAL INSPECTION PRIOR TO ENERGIZATION

After the Package Compact Substation has been found to be in good condition and the protective equipment is operational, the substation may be connected to the network. However, it is recommended that the transformer to be left to settle for 1 or 2 days after installation so those air bubbles in the oil have time to dissolve before connecting the voltage.

Before energizing the unit, a complete electrical inspection should be made. The following checklist should be used as a minimum requirement.

Electrical Inspection

All external connections have been made properly (phasing of connections to terminals, etc.).

All connections are tight and secure.

All accessory circuits are operational. Check the transformer protective equipment and test the function of their electrical circuits: Thermometers (alarms, tripping)

Pressure relay (tripping) Oil level indicator

Ensure that all fuses are inserted and in the correct position all tap connections are properly positioned. The neutral and ground connections have been properly made.

Mechanical Inspection

All shipping members have been removed.

There is no obstructions in or near the openings for ventilation. No tools or other articles are left inside the enclosures.

All protective covers are in place or closed and bolted tight.

MAINTENANCE AND PERIODIC INSPECTION

In order to assure a long lifetime and correct and reliable operation of equipment delivered for this facility it is of utmost importance to perform maintenance regularly. Following general rules should always be considered before starting maintenance activity.

1. Authority from responsible engineer shall always be obtained before starting any maintenance.
2. Follow safety procedure established in carrying out the work.

Realize that no set of safety *or maintenance instructions* will ever be written that can adequately cover all accident possibilities.

Therefore "**SAFETY**" as dictated by actual current conditions, always takes precedence over any previously prepared safety or maintenance instructions. Assume nothing. Take the precautions that you personally deem necessary in addition to those included in standard practice.

- Be familiar with the drawings and previous test records before starting activity.
- Scrutinize maintenance instructions given for the equipment to be maintained.

Maintenance information is given in the Operation and Maintenance Manual for each type of equipment.

The main dangers of such process are:

- Inaccessible lubrication points (greased for life) cannot be lubricated and may seize up.
- Areas not lubricated may be subject to corrosion.
- The high-pressure spray may damage equipment.
- Especially protective coatings may be removed.

Bolt Tightness

All connections should be tight and secure. Bolts and nuts on bus bar and terminal lugs should be torqued and marked properly.

Inspection and Testing

The need for preventive maintenance will vary on operating conditions. Where heavy dust conditions exist, an accumulation of dust on the equipment may affect the operation of unit substation and its protective apparatus.

When normal maintenance inspection and cleaning of bus connections, relays, lug connections, and other part of the distribution system is being made, it is advisable to operate and check circuit breaker or switch-disconnect or operation.

Routine Field Testing

Routine field testing of the electrical equipment is intended to enable maintenance personnel to determine, without laboratory conditions or complicated equipment, that a particular electrical equipment is able to perform its basic circuit functions.

The following constitutes a guide to tests that might be performed during routine maintenance.

1. Insulation Resistance Test

Extreme atmospheres and conditions may reduce the dielectric with stand ability of any insulating material. An instrument commonly known as "megger" is used to perform this test.

The voltage recommended for this test should be at least 50 percent greater than the circuit rating; however, a minimum of 500 volts is permissible. Tests should be made between phases of opposite polarity as well as from current carrying parts of the circuit protective device to ground. Also, a test should be made between the line-and-load terminals with the circuit protective device in the "OFF" position.

Resistance values below one mega ohm are considered unsafe and should be investigated for possible contamination on the surfaces

NOTE: For individual circuit protective device's resistance readings, load and line conductors should be disconnected. If not disconnected, the test measurements will also include the characteristics of the attached circuits. A temperature and humidity reading are recommended and recorded during the testing period.

Insulation resistivity is markedly effected by temperature and humidity conditions. Based condition of one (1) mega ohm per kV assumes a 20°C wet bulb reading. The following table shall be used to adjust readings to the 20°C constant.

2. Connection Test

Connections to the circuit protective device should be inspected to determine that a proper electrical joint is present. If overheating in these connections is evident by discoloration or signs of arcing, the connections should be removed and the connecting surfaces clean before re-connections. It is essential that electrical connections be made properly to prevent and reduce overheating.

3. Mechanical Operation

During routine tests, mechanical operation of the circuit protective devices or disconnects should be checked by turning it "ON" and "OFF" at least three times.

INTERFERENCE AND SCREENING

Interference is one of the most serious as well as most common problems in audio electronics. We encounter interference when it produces effects like noise, hiss, hum or cross-talk. If a radio engineer faces such problems, good theoretical knowledge as well as experience is required to overcome them.

However, it should be considered, that interference is always present. All technical remedies only aim at reducing the effect of interference to such a degree, that it is neither audible nor disturbing. This is mainly achieved by different ways of screening. This paper will explain the technical background of interference and provides some common rules and hints which may help you to reduce the problems.

TYPES OF INTERFERENCE.

Theoretically, the effects and mechanism of a single interference can well be calculated. But in practice, the complex coupling systems between pieces of equipment prevent precise prediction of interference. The following picture shows the different types of interference coupling. The different types of interference between the components of an electric system. If we consider all possible coupling paths in the diagram above we will find 10 different paths. This means a variety of 1024 different combinations. It should be noted, that not only the number of paths, but also their intensity is important.

SYMMETRICAL AND ASYMMETRICAL INTERFERENCE.

Having a closer look at the interference of cable, we find that hf-interference currents cause measurable levels on signal (audio) lines and on supply lines. A ground-free interference source would produce signals on a cable which spread along the line. These voltages and currents can be called symmetrical interference. In practice this rarely occurs.

Through interference, asymmetrical signals are produced in respect to the ground. The asymmetrical interference current flows along the two wires of the symmetrical line to the sink and via the ground back to the source. These interference signals are cancelled at the symmetrical input.

GALVANIC COUPLING OF INTERFERENCE.

Galvanic coupling of interference occurs if the source and the sink of interference are coupled by a conductive path. As can be seen from the equivalent circuit diagram, the source impedance of the interference consists of the resistance RC and the inductance LC of the conductor, which are common to the two parts of the circuit. From these elements the interference source voltage can be calculated.

CAPACITIVE COUPLING OF INTERFERENCE.

The capacitive coupling of interference occurs due to any capacitance between the source and sink of interference.

Principle of capacitive coupling of interference.

The current in the interference sink can be calculated as the interference voltage in the sink is proportional to its impedance. Systems of high impedance are therefore more sensitive to interference than those of low impedance. The coupled interference current depends on the rate of change of the interference and on the coupling capacitance CC .

INDUCTIVE COUPLING OF INTERFERENCE.

Inductive coupling of interference occurs if the interference sink is in the magnetic field of the interference source (e.g. coils, cables, etc.)

Principle of the inductive coupling of interference.

GROUNDING (OR EARTHING).

This is one of the simplest but most efficient methods to reduce interference.

Grounding can be used for three different purposes:

1. Protection Ground

Provides protection for the operators from dangerous voltages.

Widely used on mains-operated equipment.

2. Function Ground

The ground is used as a conductive path for signals.

Example: in asymmetrical cables screen, which is one conductor for the signal, is connected to the ground.

3. Screening Ground

Used to provide a neutral electrical path for the interference, to prevent that the interfering voltages or currents from entering the circuit. In this chapter we will only consider the third aspect. Grounding of equipment is often required for the cases 1 or 2 anyhow, so that the screening ground is available "free of charge". Sometimes the grounding potential, provided by the mains connection, is much "polluted". This means that the ground potential itself already carries an interfering signal. This is especially likely if there are big power consumers in the neighborhood or even in the same building. Using such a ground might do more harm than good. The quality of the ground line can be tested by measuring it with a storage scope against some other ground connection, e.g. a metal waterpipe or some metal parts of the construction.

A.C bridges

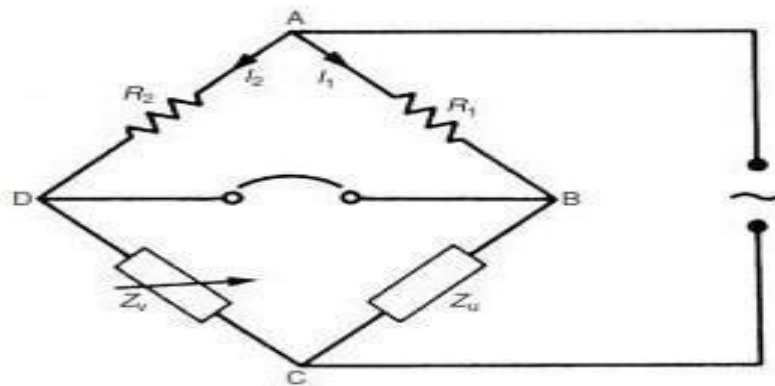
Bridges with a.c. excitation are used to measure unknown impedances. As for d.c. bridges, both null and deflection types exist, with null types being generally reserved for calibration duties.

Null-type Impedance Bridge

A typical null-type impedance bridge is shown in Figure 3.3. The null point can be conveniently detected by monitoring the output with a pair of headphones connected via an operational amplifier across the points BD. This is a much cheaper method of null detection than the application of an expensive galvanometer that is required for a d.c. Wheatstone bridge

$$I_1 R_1 = I_2 R_2; \quad I_1 Z_u = I_2 Z_v$$

$$Z_u = \frac{Z_v R_1}{R_2}$$



If Z_u is capacitive, i.e. $Z_u = \frac{1}{j\omega C_u}$, then Z_v must consist of a variable capacitance box, which is readily available. If Z_u is inductive, then $Z_u = R_u + j\omega L_u$.

Notice that the expression for Z_u as an inductive impedance has a resistive term in it because it is impossible to realize a pure inductor. An inductor coil always has a resistive component, though this is made as small as possible by designing the coil to have a high Q factor (Q factor is the ratio inductance/resistance). Therefore, Z_v must consist of a variable-resistance box and a variable-inductance box. However, the latter are not readily available because it is difficult and hence expensive to manufacture a set of fixed value

inductors to make up a variable-inductance box. For this reason, an alternative kind of null-type bridge circuit, known as the *Maxwell Bridge*, is commonly used to measure unknown inductances.

Maxwell Bridge Definition

A Maxwell bridge (in long form, a Maxwell-Wien bridge) is a type of Wheatstone bridge used to measure an unknown inductance (usually of low Q value) in terms of calibrated resistance and capacitance. It is a real product bridge.

The maxwell bridge is used to measure unknown inductance in terms of calibrated resistance and capacitance. Calibration-grade inductors are more difficult to manufacture than capacitors of similar precision, and so the use of a simple "symmetrical" inductance bridge is not always practical.

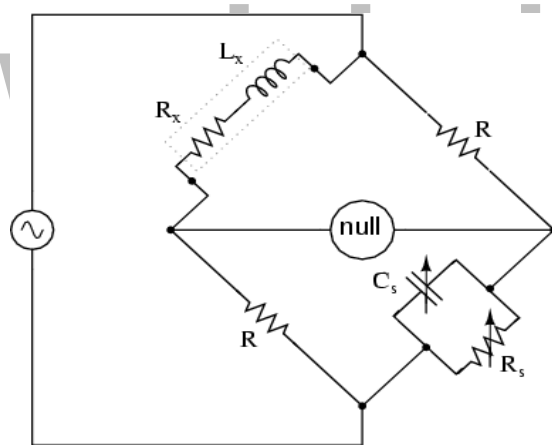


Figure 3.4. Maxwell Bridge

Explanation

- With reference to the picture, in a typical application R_1 and R_4 are known fixed entities, and R_2 and C_2 are known variable entities.
- R_2 and C_2 are adjusted until the bridge is balanced. R_3 and L_3 can then be calculated based on the values of the other components:
- As shown in Figure, one arm of the Maxwell bridge consists of a capacitor in parallel with a resistor (C_1 and R_2) and another arm consists of an inductor L_1 in

series with a resistor (L1 and R4). The other two arms just consist of a resistor each (R1 and R3).

- The values of R1 and R3 are known, and R2 and C1 are both adjustable. The unknown values are those of L1 and R4.
- Like other bridge circuits, the measuring ability of a Maxwell Bridge depends on 'Balancing' the circuit.
- Balancing the circuit in Figure 1 means adjusting C1 and R2 until the current through the bridge between points A and B becomes zero. This happens when the voltages at points A and B are equal.
- Mathematically,
- $Z1 = R2 + 1 / (2\pi f C1)$; while $Z2 = R4 + 2\pi f L1$. $(R2 + 1 / (2\pi f C1)) / R1 = R3 / [R4 + 2\pi f L1]$;
- Or $R1R3 = [R2 + 1 / (2\pi f C1)] [R4 + 2\pi f L1]$
- To avoid the difficulties associated with determining the precise value of a variable capacitance, sometimes a fixed-value capacitor will be installed and more than one resistor will be made variable.
- The additional complexity of using a Maxwell bridge over simpler bridge types is warranted in circumstances where either the mutual inductance between the load and the known bridge entities, or stray electromagnetic interference, distorts the measurement results.
- The capacitive reactance in the bridge will exactly oppose the inductive reactance of the load when the bridge is balanced, allowing the load's resistance and reactance to be reliably determined.

Advantages:

- The frequency does not appear
- Wide range of inductance

Disadvantages:

- Limited measurement
- It requires variable standard capacitor

SCHERING BRIDGE:

A **Schering Bridge** is a bridge circuit used for measuring an unknown electrical capacitance and its dissipation factor. The dissipation factor of a capacitor is the ratio of its resistance to its capacitive reactance. The Schering Bridge is basically a four-arm alternating-current (AC) bridge circuit whose measurement depends on balancing the loads on its arms. Figure 1 below shows a diagram of the Schering Bridge.

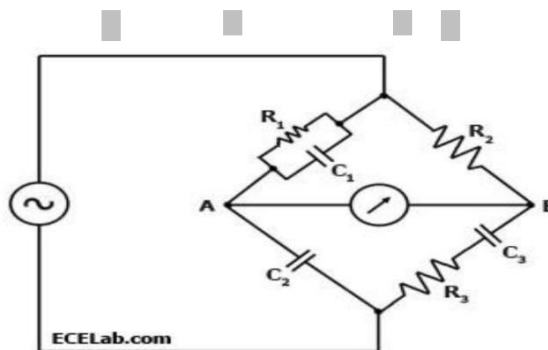


Figure 3.5 Schering Bridge

Explanation

- In the Schering Bridge above, the resistance values of resistors R_1 and R_2 are known, while the resistance value of resistor R_3 is unknown.
- The capacitance values of C_1 and C_2 are also known, while the capacitance of C_3 is the value being measured.
- To measure R_3 and C_3 , the values of C_2 and R_2 are fixed, while the values of R_1 and C_1 are adjusted until the current through the ammeter between points A and B becomes zero.
- This happens when the voltages at points A and B are equal, in which case

the bridge is said to be 'balanced'.

- When the bridge is balanced, $Z_1/C_2 = R_2/Z_3$, where Z_1 is the impedance of R_1 in parallel with C_1 and Z_3 is the impedance of R_3 in series with C_3 .
- When the bridge is balanced, $Z_1/C_2 = R_2/Z_3$, where Z_1 is the impedance of R_1 in parallel with C_1 and Z_3 is the impedance of R_3 in series with C_3 .

$$Z_1 = R_1/[2\pi f C_1((1/2\pi f C_1) + R_1)] = R_1/(1 + 2\pi f C_1 R_1)$$

$$\text{while } Z_3 = 1/2\pi f C_3 + R_3. \quad 2\pi f C_2 R_1 / (1 + 2\pi f C_1 R_1) = R_2 / (1/2\pi f C_3$$

$$+ R_3); \text{ or } 2\pi f C_2 (1/2\pi f C_3 + R_3) = (R_2/R_1)$$

$$(1 + 2\pi f C_1 R_1); \text{ or } C_2/C_3 + 2\pi f C_2 R_3 =$$

$$R_2/R_1 + 2\pi f C_1 R_2.$$

- When the bridge is balanced, the negative and positive reactive components are equal and cancel out, so

$$2\pi f C_2 R_3 = 2\pi f C_1 R_2 \text{ or } R_3 = C_1 R_2 / C_2.$$

- Similarly, when the bridge is balanced, the purely resistive components are equal, so

$$C_2/C_3 = R_2/R_1 \text{ or } C_3 = R_1 C_2 / R_2.$$

- Note that the balancing of a Schering Bridge is independent of frequency

Advantages:

- Balance equation is independent of frequency

Used for measuring the insulating properties of electrical cables and equipment's

HAY BRIDGE:

A Hay Bridge is an AC bridge circuit used for measuring an unknown inductance by balancing the loads of its four arms, one of which contains the unknown inductance. One of the arms of a Hay Bridge has a capacitor of known characteristics, which is the principal component used for determining the unknown inductance value. Figure 1 below shows a diagram of the Hay Bridge.

Explanation

- As shown in Figure 1, one arm of the Hay bridge consists of a capacitor in series with a resistor (C_1 and R_2) and another arm consists of an inductor L_1 in series with a resistor (L_1 and R_4).

The other two arms simply contain a resistor each (R_1 and R_3). The values of R_1 and R_3 are known, and R_2 and C_1 are both adjustable. The unknown values are those of L_1 and R_4 . Like other bridge circuits, the measuring ability of a Hay Bridge depends on 'balancing' the circuit.

- Balancing the circuit in Figure 1 means adjusting R_2 and C_1 until the current through the ammeter between points A and B becomes zero. This happens when the voltages at points A and B are equal.

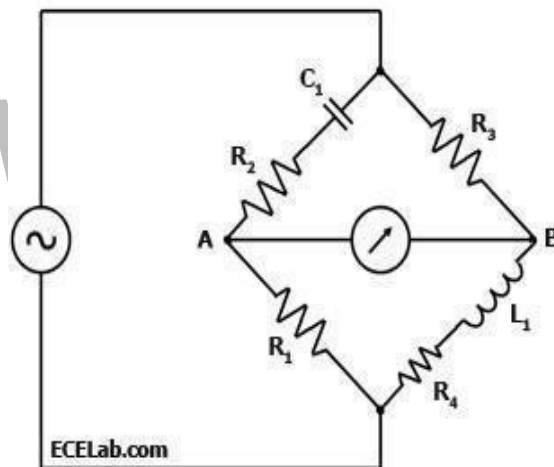


Figure 3.6 Hay Bridge

- When the Hay Bridge is balanced, it follows that $Z_1/R_1 = R_3/Z_2$ wherein Z_1 is the impedance of the arm containing C_1 and R_2 while Z_2 is the impedance of the arm containing L_1 and R_4 .

$$\begin{aligned} \text{Thus, } Z_1 &= R_2 + 1/(2\pi fC) \text{ while } Z_2 = R_4 \\ &+ 2\pi fL_1. [R_2 + 1/(2\pi fC_1)] / R_1 = R_3 / \\ &[R_4 + 2\pi fL_1]; \text{ or } [R_4 + 2\pi fL_1] = R_3R_1 / \\ &[R_2 + 1/(2\pi fC_1)]; \text{ or } R_3R_1 = R_2R_4 + \\ &2\pi fL_1R_2 + R_4/2\pi fC_1 + L_1/C_1. \end{aligned}$$

- When the bridge is balanced, the reactive components are equal, so $2\pi f L_1 R_2 = R_4 / 2\pi f C_1$, or $R_4 = (2\pi f)^2 L_1 R_2 C_1$.

- Substituting R_4 , one comes up with the following equation:

$$R_3 R_1 = (R_2 + 1/2\pi f C_1) ((2\pi f)^2 L_1 R_2 C_1) + 2\pi f L_1 R_2$$

$$+ L_1 / C_1; \text{ Or } L_1 = R_3 R_1 C_1 / (2\pi f)^2 R_2^2 C_1^2 +$$

$$4\pi f C_1 R_2 + 1);$$

$$L_1 = R_3 R_1 C_1 / [1 + (2\pi f R_2 C_1)^2]$$

- After dropping the reactive components of the equation since the bridge is

Thus, the equations for L_1 and R_4 for the Hay Bridge in Figure 1 when it is balanced are:

$$L_1 = R_3 R_1 C_1 / [1 + (2\pi f R_2 C_1)^2]; \text{ and}$$

$$R_4 = (2\pi f C_1)^2 R_2 R_3 R_1 / [1 + (2\pi f R_2 C_1)^2]$$

- Simple expression

Disadvantages:

- It is not suited for measurement of coil

WIEN BRIDGE:

A Wien bridge oscillator is a type of electronic oscillator that generates sine waves. It can generate a large range of frequencies. The circuit is based on an electrical network originally developed by Max Wien in 1891. Wien did not have a means of developing electronic gain so a workable oscillator could not be realized. The modern circuit is derived from William Hewlett's 1939 Stanford University master's degree thesis. Hewlett, along with David Packard co-founded Hewlett-Packard. Their first product was the HP 200A, a precision sine wave oscillator based on the Wien bridge. The 200A was one of the first instruments to produce such low distortion.

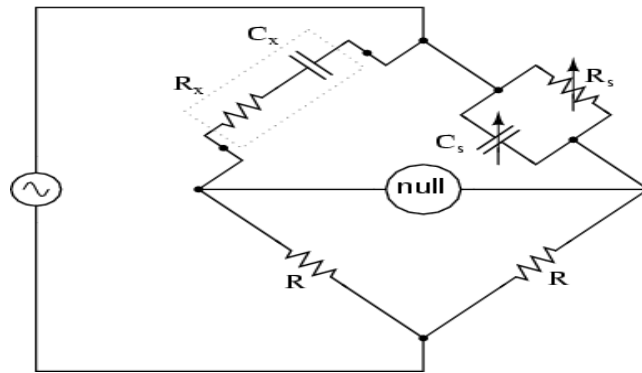


Figure 3.7 Wein bridge

Amplitude stabilization:

- The key to Hewlett's low distortion oscillator is effective amplitude stabilization. The amplitude of electronic oscillators tends to increase until clipping or other gain limitation is reached. This leads to high harmonic distortion, which is often undesirable.
- Hewlett used an incandescent bulb as a positive temperature coefficient (PTC) thermistor in the oscillator feedback path to limit the gain.
- The resistance of light bulbs and similar heating elements increases as their temperature increases.
- If the oscillation frequency is significantly higher than the thermal time constant of the heating element, the radiated power is proportional to the oscillator power.
- Since heating elements are close to black body radiators, they follow the Stefan-Boltzmann law.
- The radiated power is proportional to T^4 , so resistance increases at a greater rate than amplitude.
- If the gain is inversely proportional to the oscillation amplitude, the oscillator gain stage reaches a steady state and operates as a near ideal class A amplifier, achieving very low distortion at the frequency of interest.

- At lower frequencies the time period of the oscillator approaches the thermal time constant of the thermistor element and the output distortion starts to rise significantly.
- Light bulbs have their disadvantages when used as gain control elements in Wien bridge oscillators, most notably a very high sensitivity to vibration due to the bulb's micro phonic nature amplitude modulating the oscillator output, and a limitation in high frequency response due to the inductive nature of the coiled filament.
- Modern Distortion as low as 0.0008% (-100 dB) can be achieved with only modest improvements to Hewlett's original circuit.
- Wien bridge oscillators that use thermistors also exhibit "amplitude bounce" when the oscillator frequency is changed. This is due to the low damping factor and long time constant of the crude control loop, and disturbances cause the output amplitude to exhibit a decaying sinusoidal response.
- This can be used as a rough figure of merit, as the greater the amplitude bounce after a disturbance, the lower the output distortion under steady state conditions.

Analysis:

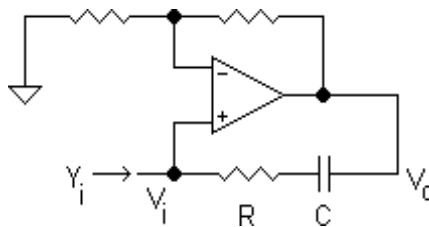


Figure 3.8 Input analysis

Input admittance analysis

- If a voltage source is applied directly to the input of an ideal amplifier with feedback, the input current will be:

Where v_{in} is the input voltage, v_{out} is the output voltage, and Z_f is the feedback impedance.

If the voltage gain of the amplifier is defined as:

- And the input admittance is defined as: Input admittance can be rewritten as:
- If A_v is greater than 1, the input admittance is a negative resistance in parallel with an inductance.
- If a resistor is placed in parallel with the amplifier input, it will cancel some of the negative resistance. If the net resistance is negative, amplitude will grow until clipping occurs.
- If a resistance is added in parallel with exactly the value of R , the net resistance will be infinite and the circuit can sustain stable oscillation at any amplitude allowed by the amplifier.

Advantages:

- Frequency sensitive
- Supply voltage is purely sinusoidal

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RECEIVING / INSPECTION / STORAGE

The Package Compact Substation is shipped from the factory ready for installation on site. It has been submitted to all normal routine tests before being shipped, and it is not required to do any voltage testing before putting it into service, provided the substation has not sustained any damage during transportation.

Immediately upon receipt of the Package Compact Substation, examine them to determine if any damage or loss was sustained during transit. If abuse or rough handling is evident, file a damage claim with carrier and promptly notify the nearest ABB office. ABB ELECTRICAL INDUSTRIES CO. LTD. is not responsible for damage of goods after delivery to the carrier; however, we will lend assistance if notified of claims.

PERSONNEL SAFETY

The first and most important requirements are the protection against contact with live parts during normal service as well as maintenance or modifications.

This is the reason why all live parts have been metal enclosed, so that when the parts are live and the Package Compact Substation doors are open, no one can be able to touch them. Also, it is safe in case any short-circuiting or sparking occurs at the bus bars.

VENTILATION

Transformer compartment has been provided with sand trap louvers, to prevent ingress of sand and that proper air circulation should take place.

EARTHING

Proper earthing bus bar has been provided.

HANDLING

Lifting lugs has been provided on top of four corners of the housing for lifting the DPS by crane and chains as a single unit, otherwise this can be done by a forklift of

Sufficient capacity, but the lifting fork must be positioned under the transformer portion.

INSTALLATIONS

A clean, flat surface capable of supporting the Package Compact Substation unit weight is the only requirement for a foundation. It is, however, important that adequate accessibility, ventilation and ease of inspection of the unit must be provided. In all installation work, the safety regulations for electrical installations have to be observed.

Each Package Compact Substation must be permanently grounded or earthed by connecting an effective recognized ground or earth as prescribed by the latest applicable edition of IEC or ANSI requirements. The Package Compact Substation is designed to operate with a solidly grounded neutral system. The neutral connections should be solidly and permanently grounded.

Tap connections

All units have taps located in the High Voltage winding. The tap arrangement is shown on the nameplate of the transformer. These taps are provided to furnish rated output voltage when the input voltage differs from the rated voltage.

To change tap connections, do the following steps:

1. De-energized the unit, short-circuit both the high and low voltage connections and ground both sides.
2. Unlock the tap changer handle, and then move the taps changer handle to the desired tap, then locked the tap changer handle.
3. Remove safety shorts and ground connections from the high voltage and low voltage buses.

After ensuring that no tools or hardware was left in the enclosure, and the enclosures are closed properly, you may then re-energize the Package Compact Substation. Make sure that the tap connections are proper for the required voltage as listed on the nameplate. The transformer is normally shipped with the tap changer for the rated voltage.

Cable connections

When making outside cable connections, conductors suitable for at least 85°C should be used. All connections should be made without placing undue stress on the terminals. Conductors should be securely fastened in place and adequately supported with allowances for expansion and contraction.

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TRANSFORMER RATIO BRIDGES & SELF-BALANCING BRIDGES

TRANSFORMER RATIO BRIDGES

INTRODUCTION

The product to which this manual refers should be installed, commissioned, operated and maintained under the supervision of a competent *Electrical Engineer* in accordance with relevant statutory requirements and good engineering practice, including Codes of Practice where applicable, and properly used within the terms of the specification.

The instructions in this manual should familiarize qualified personal with the proper procedures to keep all new unit(s) in proper operating condition. These instructions for installation, operation and maintenance of Package Compact Substation should be read carefully and used as a guide during installation and initial operation.

These instructions do not propose to cover all details or variations in equipment, nor to provide for every contingency to be met in connection with installation, operation, or maintenance. Should further information be desired, or particular problems arise which are not covered, please contact the nearest ABB office.

We would in particular stress the importance of care in:

- Site selection and design, embodying features that provide adequate ventilation, protection and security and which have taken account of appropriate fire, moisture and explosion hazards.
- Jointing.
Earthing
- Selection and setting of electrical protection in primary and secondary, against overload, overvoltage and short-circuit.
- Carrying out regular inspection and electrical and mechanical maintenance.

The Package Compact Substation(s) covered by these instructions have been repeatedly inspected and tested to meet all applicable standards of IEC, to ensure you of a first-rate quality product, which should give many years of satisfactory performance.

The specific ratings of each Package Compact Substation are shown on the drawings. File these instructions in a readily accessible place together with drawings and

descriptive data of the Package Compact Substation. These instructions will be a guide to proper maintenance of the equipment and prolong its life and usefulness

GENERAL:

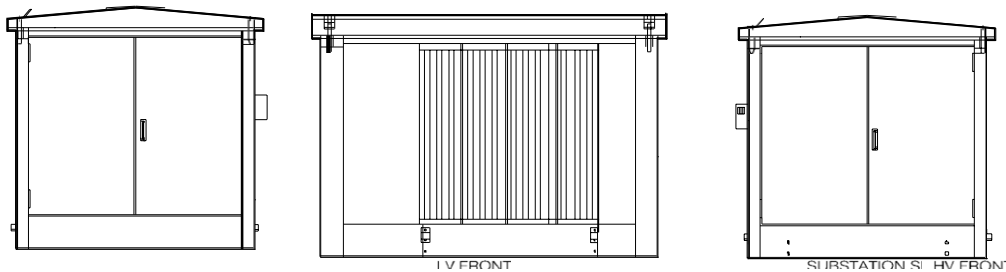


Figure 3.9 TRANSFORMER RATIO BRIDGES

The Package Compact Substations are completely self-contained, mounted on an integral base, factory assembled in a totally enclosed, aesthetically and acceptable cladding, vandal-proof, vermin-proof and weather-proof housing ready for installation into position on a concrete base pad or pier. The base frame is of welded structural steel and been hot-dipped galvanized after fabrication to assure affective corrosion resistance in service. Housing of the Package Compact Substation is made of special material called ALUZINK, a sheet steel with a metallic alloy coating. The alloy consists of 55% aluminum and 43.4% zinc. This provides optimum corrosion protection. The housing has three compartments, separated with ALUZINK sheet. The transformer compartment is completely separated from the medium voltage and low voltage compartments.