Wheatstone Bridge

EECE105L

Dr. Rama Komaragiri

Bridge Circuits

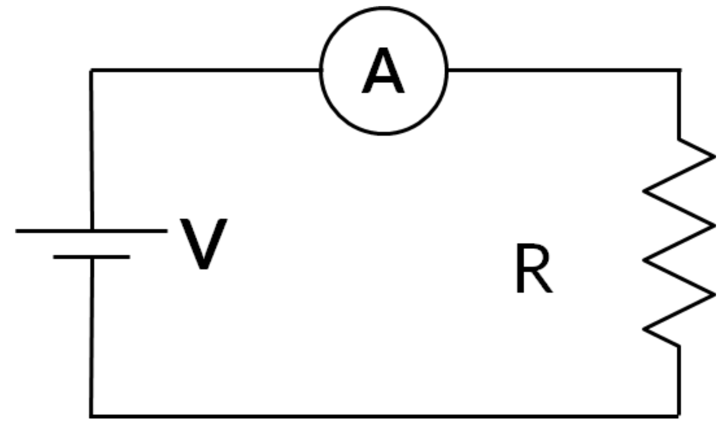
Introduction

Bridge Circuits - Introduction

- Bridge circuit is an electrical circuit in which two circuit branches are bridged by a third branch
- The two circuit branches are parallel to each other
- The third branch connected between the first two branches at some intermediate point along them
- Bridge circuits are used for making comparison measurements
  - widely used to measure resistance, inductance, capacitance
- Bridge circuits operate on a principle called a null-detection or null-indication
- Very accurate method as the null-indication is independent of the the indicating device or any characteristics of it.

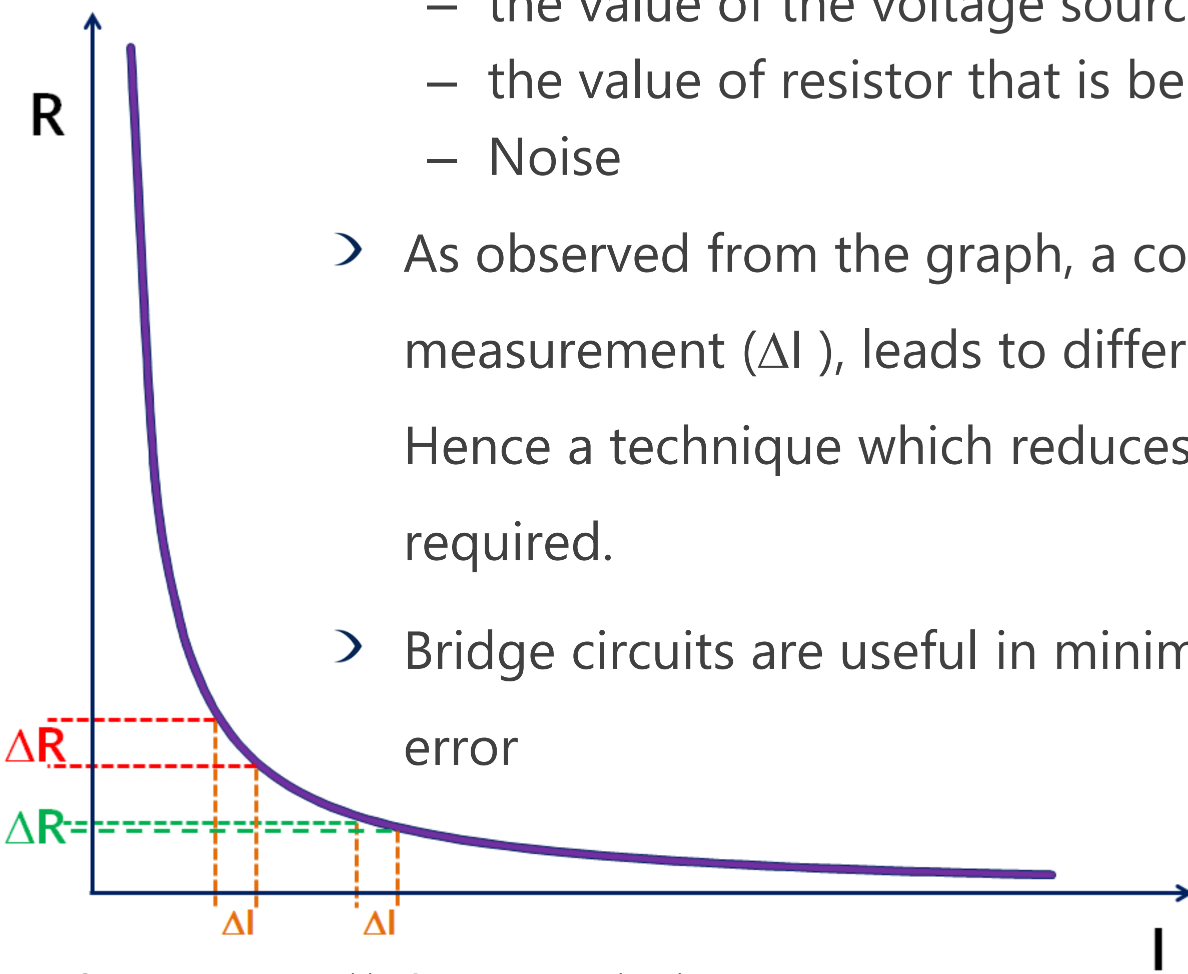
- Consider shown which is used to measure resistance:
  - A constant voltage V is connected to resistance in series and current flow through the resistance is measured
  - The resistance is given by

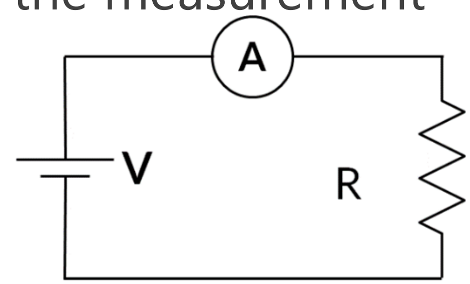
$$R = \frac{V}{I}$$



- As the applied voltage is constant, the value of current depends on the value of resistance that is being measured
  - If R is large, I is small
  - If R is small, I is large

- As a result, the error in the measurement mainly depends on
  - the value of the voltage source
  - the value of resistor that is being measured
  - Noise
- As observed from the graph, a constant error in current measurement (ΔI), leads to different errors in measurement. Hence a technique which reduces error in measurement is required.
- Bridge circuits are useful in minimising the measurement error



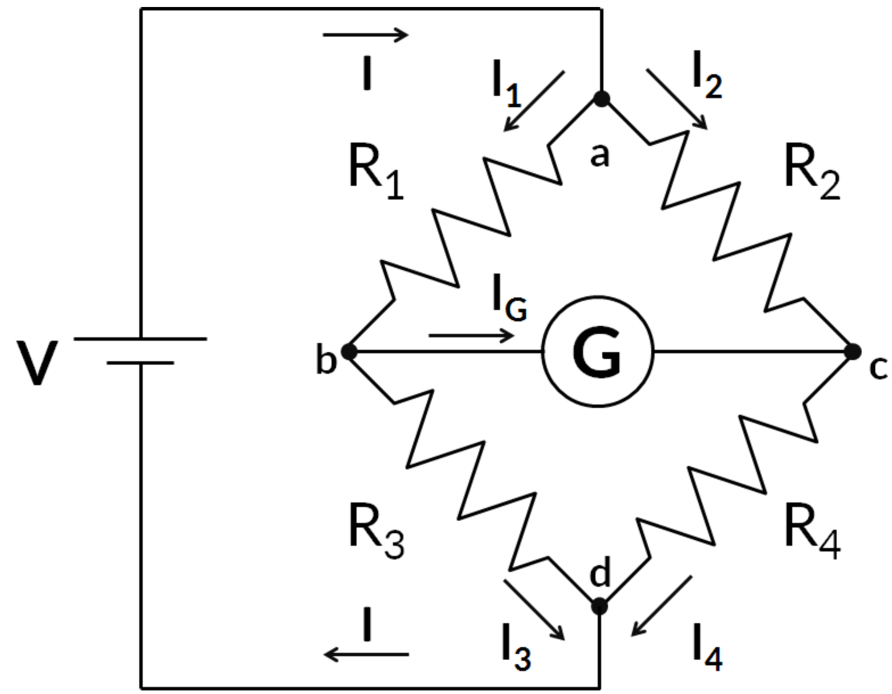


© Dr. Rama Komaragiri, ECED, Bennett University

Wheatstone Bridge

Wheatstone Bridge - Construction

- Wheatstone bridge consists of two parallel resistance branches
  - First branch consists resistors R_1 and R_3
  - Second branch consists resistor R_2 and R_4



- A DC voltage source connected across the resistance network works as a current source for the resistive network.
- A null detector (for e.g. galvanometer) is connected between the parallel branches to detect the balance condition.

Wheatstone Bridge - Working

- Writing KCL at node **a**,

$$I = I_1 + I_2$$

- Writing KCL at node **b**,

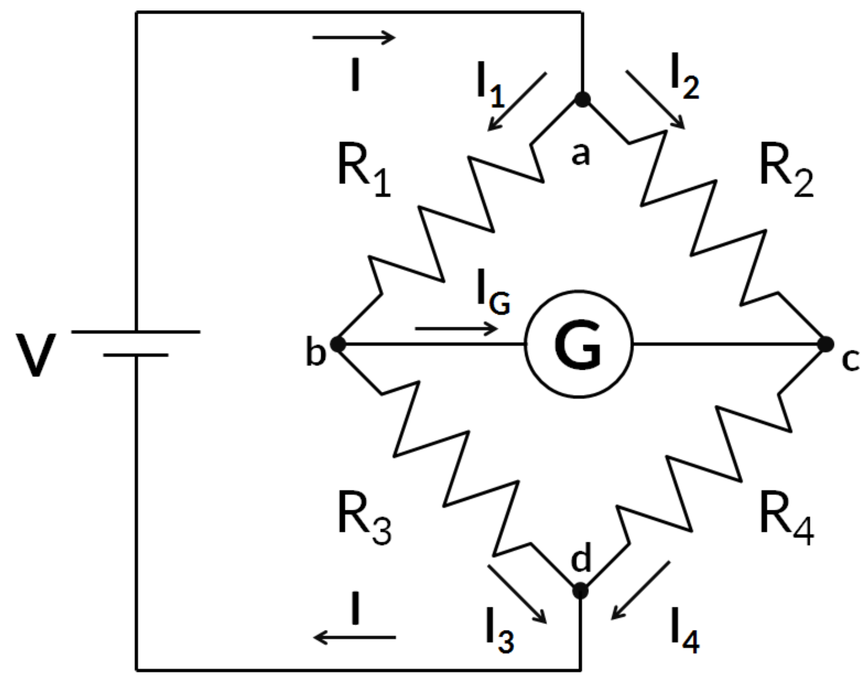
$$I_1 = I_3 + I_G$$

- Writing KCL at node **c**,

$$I_4 = I_2 + I_G$$

- Writing KCL at node **d**,

$$I = I_3 + I_4$$



Wheatstone Bridge - Working

- Writing KCVL for the loop *abd*,

$$I_1R_1 + V_G = I_2R_2$$

- Writing KVL for the loop **bdc**,

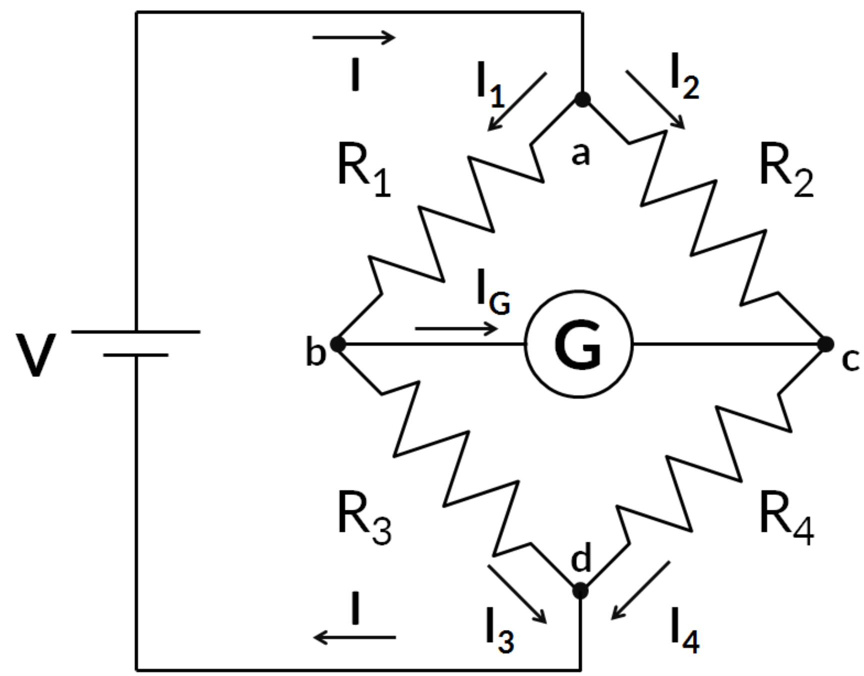
$$I_3R_3 = I_4R_4 + V_G$$

- When the bridge is balanced,

$$V_b = V_c \Rightarrow I_G = 0$$

- Thus

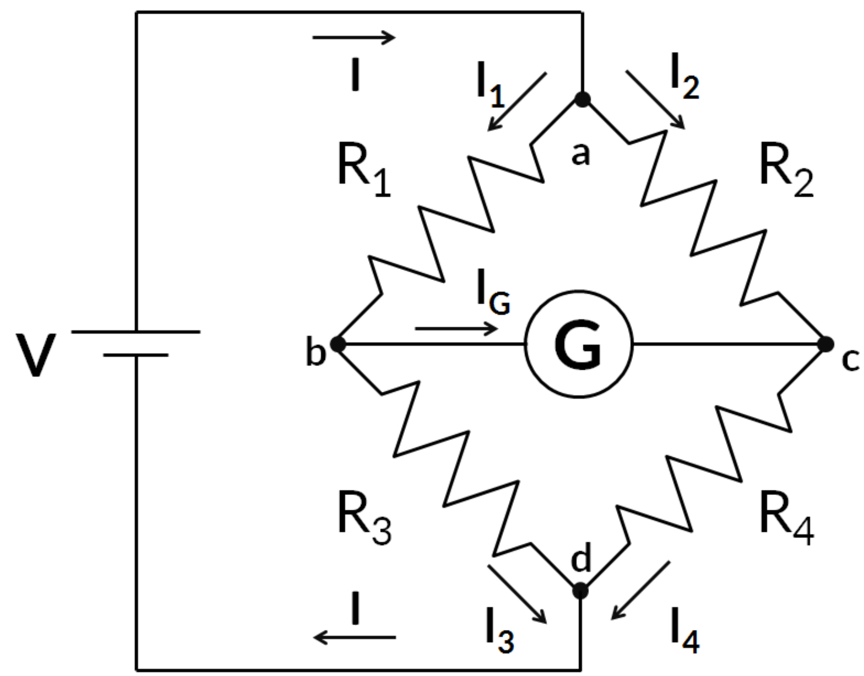
$$\frac{I_1}{I_2} = \frac{R_2}{R_1} \, and \, \frac{I_3}{I_4} = \frac{R_4}{R_3}; I_1 = I_3 \, and \, I_2 = I_4$$



Wheatstone Bridge - Working

- Re-writing, $$\boxed{\frac{R_3}{R_1} = \frac{R_4}{R_2}}$$

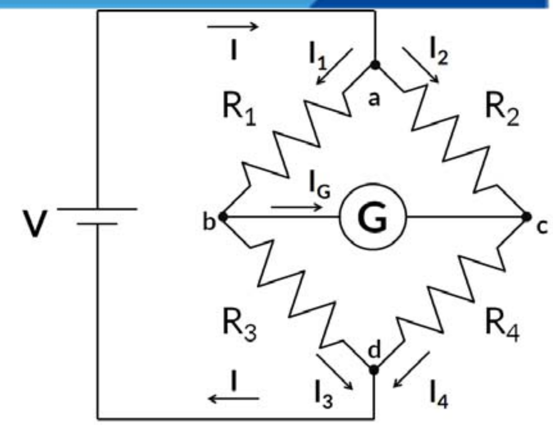
- Wheatstone bridge circuit is used to determine unknown resistance value.

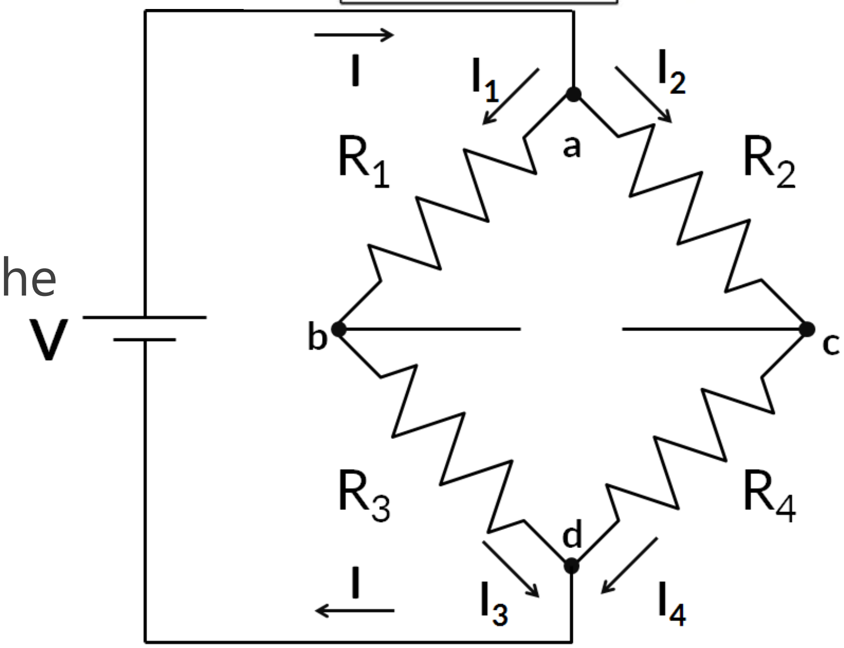


Wheatstone Bridge – Unbalanced

- When the bridge is not balanced, a current will flow through the galvanometer and $V_{\mathbf{bc}} \neq 0$
- The current that flows through galvanometer can be determined by using Thevenin's theorem
- Thevenin's resistance (R_{TH}) between the nodes **b** and **c** is given by

$$R_{Th} = R_{bc} = \left(R_1 // R_3\right) + \left(R_2 // R_4\right)$$
$$= \frac{R_1 R_3}{R_1 + R_3} + \frac{R_2 R_4}{R_2 + R_4}$$





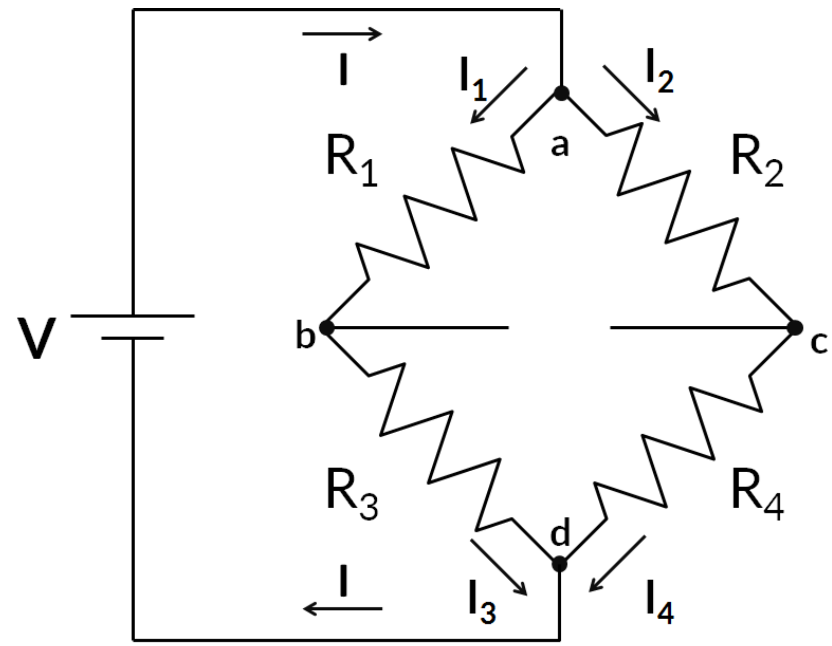
Wheatstone Bridge – Unbalanced

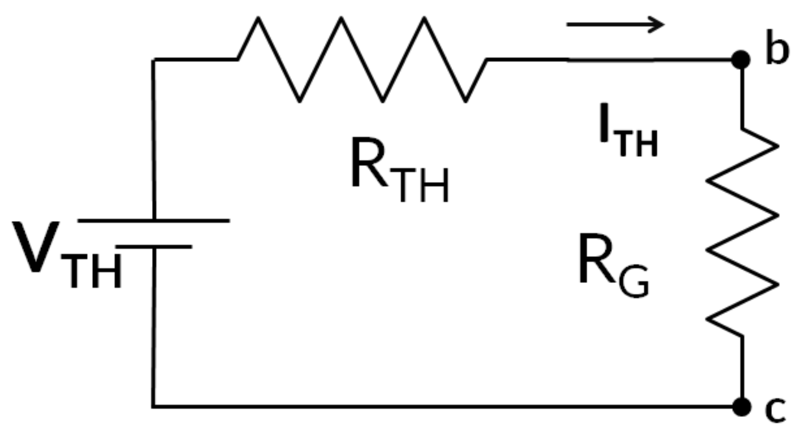
- Thevenin's voltage (V_{TH}) between the nodes **b** and **c** is given by

$$\boxed{V_{TH} = V_b - V_c = V\frac{R_3}{R_1 + R_3} - V\frac{R_4}{R_2 + R_4}}$$

- Current through galvanometer (I_G) is given by

$$\boxed{I_G = \frac{V_{TH}}{R_{TH} + R_G}}$$





Other Bridges

- The Kelvin Bridge is the modified version of the Wheatstone Bridge.
- Kelvin bridge enables to measure resistances in the range of 1 $\mu\Omega$ to 1Ω with a high degree of accuracy.

© Dr. Rama Komaragiri, ECED, Bennett University