**EE 2010 Circuit Analysis**

**Session # 16: Precision through differences: Wheatstone Bridge Notes**

These notes are drawn from *Alexander and Sadiku*, 2013, *O'Malley*, 2011, WIKIPEDIA, and other sources. They are intended to offer a summary of topics to guide you in focused studies. You should augment this handout with notes taken in class, reading textbook(s), and working additional example problems.

**Learning Objective:** In this module, we consider a technique used to measure small differences when an absolute reference may be unavailable. The resulting circuit configuration is known as the *Wheatstone Bridge*.

**The Wheatstone bridge** (or resistance bridge) circuit is used in applications where a precision measurement is desired. The guiding principle being the relative precision of observing a zero (or null) is higher than that of measuring some non-zero value. Any technique, including the Wheatstone configuration, relies on at least one (usually three) precision elements.

Consider the circuit below:

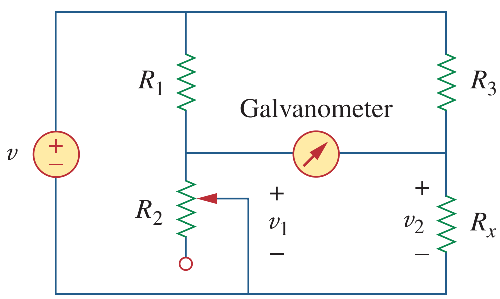


**Figure 4.63**
The Wheatstone bridge; $R_x$ is the resistance to be measured.

The variable resistance is adjusted until no current flows through the galvanometer, which is essentially a d'Arsonval movement operating as a sensitive current-indicating device, like an ammeter, in the $\mu A$ range. When a null occurs (no current flow), it follows that $v_1 = v_2$. Hence, we have the equivalent ratios:

$$v_1 = v_2 \quad \Longrightarrow \quad \frac{R_1}{R_2} = \frac{R_3}{R_x}$$

and any algebraic equivalent.

The estimated value of $R_x$ is only as precise as the precision of the other circuit elements: resistors $R_1$ and $R_3$, and precision variable resistor $R_2$.

**Homework:** None (You may look at Chapter 4 # 90, 91)

(a) Find $i$ when $R = 4\ \Omega$.

(b) Determine the maximum power from the box.

| $R(\Omega)$ | $V$(V) | $i$(A) |
|---|---|---|
| 2 | 3 | 1.5 |
| 8 | 8 | 1.0 |
| 14 | 10.5 | 0.75 |

**4.87** A transducer is modeled with a current source $I_s$ and a parallel resistance $R_s$. The current at the terminals of the source is measured to be 9.975 mA when an ammeter with an internal resistance of 20 Ω is used.

(a) If adding a 2-kΩ resistor across the source terminals causes the ammeter reading to fall to 9.876 mA, calculate $I_s$ and $R_s$.

(b) What will the ammeter reading be if the resistance between the source terminals is changed to 4 kΩ?

**4.88** Consider the circuit in Fig. 4.144. An ammeter with internal resistance $R_i$ is inserted between $A$ and $B$ to measure $I_o$. Determine the reading of the ammeter if: (a) $R_i = 500\ \Omega$, (b) $R_i = 0\ \Omega$. (*Hint*: Find the Thevenin equivalent circuit at terminals *a*-*b*.)

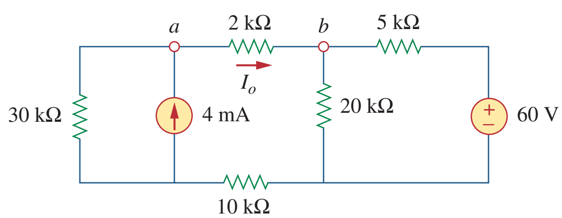


**Figure 4.144**
For Prob. 4.88.

**4.89** Consider the circuit in Fig. 4.145. (a) Replace the resistor $R_L$ by a zero resistance ammeter and determine the ammeter reading. (b) To verify the reciprocity theorem, interchange the ammeter and the 12-V source and determine the ammeter reading again.

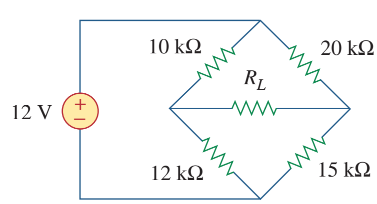


**Figure 4.145**
For Prob. 4.89.

**4.90** The Wheatstone bridge circuit shown in Fig. 4.146 is used to measure the resistance of a strain gauge. The adjustable resistor has a linear taper with a maximum value of 100 Ω. If the resistance of the strain gauge is found to be 42.6 Ω, what fraction of the full slider travel is the slider when the bridge is balanced?

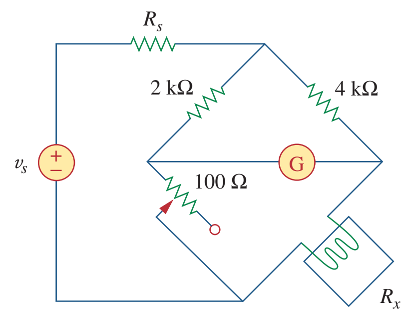


**Figure 4.146**
For Prob. 4.90.

**4.91** (a) In the Wheatstone bridge circuit of Fig. 4.147, select the values of $R_1$ and $R_3$ such that the bridge can measure $R_x$ in the range of 0–10 Ω.

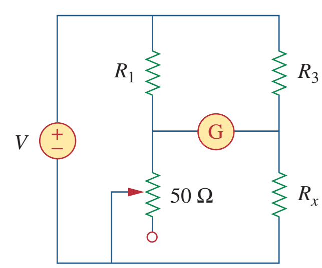


**Figure 4.147**
For Prob. 4.91.

(b) Repeat for the range of 0–100 Ω.

***4.92** Consider the bridge circuit of Fig. 4.148. Is the bridge balanced? If the 10-kΩ resistor is replaced by an 18-kΩ resistor, what resistor connected between terminals *a*-*b* absorbs the maximum power? What is this power?

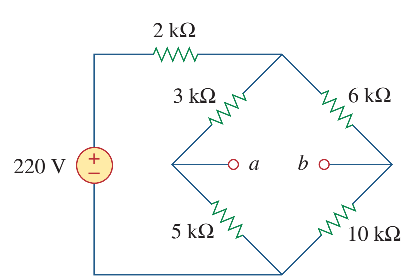


**Figure 4.148**
For Prob. 4.92.