Department of Electrical and Computer Engineering
The Johns Hopkins University
520.137 Introduction to Electrical and Computer Engineering – Fall 2018

# Homework Assignment II

**Reading Assignment:** Lecture Notes; Kerns-Irwin Chapter 3.

1. Consider the resistive circuit in a diamond topology on the left of the figure below. This is commonly known as the *Wheatstone Bridge*, often used in electrical measurement applications. Note that this circuit can be redrawn as shown on the right side.

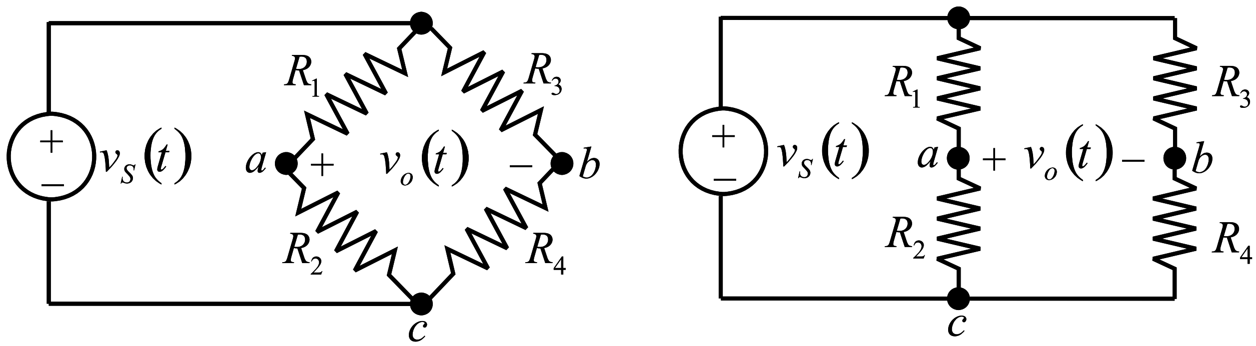


Figure 1: The Wheatstone Bridge.

   (a) Find $v_{ac}(t)$ – the voltage across the resistor $R_2$ – and $v_{bc}(t)$ – the voltage across the resistor $R_4$ – as a function of the source voltage $v_S(t)$.

   (b) Find $v_O(t)$ – the voltage across nodes $a$ and $b$ – as a function of the source voltage $v_S(t)$ given that $R_1 = R_4$ and $R_2 = R_3 = 2R_1$. *Hint:* $v_{ab}(t) = v_{ac}(t) - v_{bc}(t)$.

   (c) If the source voltage is $v_S(t) = 9\cos(4\pi t)$, find the period, frequency, average voltage $V_{AVE}$, and root-mean-squared voltage $V_{RMS}$ for $v_O(t)$.

   (d) Sketch the instantaneous power $p_S(t)$ generated by the voltage source given the same set-up as in Part (b) and (c).

   (e) If the stock room only carries $1\Omega$ resistors, design and sketch your resulting Wheatstone Bridge where $v_O(t)$ is always precisely $\frac{1}{6}v_S(t)$.

   (f) Suppose that the source voltage is $v_S(t) = 9\cos(4\pi t)$ and $R_1 = 1\Omega, R_2 = 2\Omega, R_3 = 3\Omega, R_4 = 4\Omega$. Find the Thevenin equivalent circuit looking into the 2 terminals $a$ and $b$.

   (g) With the same set-up as in Part (f), find the Norton equivalent circuit looking into the 2 terminals $a$ and $b$.

2. The circuits below models the voltage produced by the generator of a power plant and $R_S$ models the resistive losses in the generator, wire, and transformers. Resistances $R_1$, $R_2$, and $R_3$ represent the various loads connected by a customer. Assume that $R_1 = R_2 = R_3 = R_S = R$.

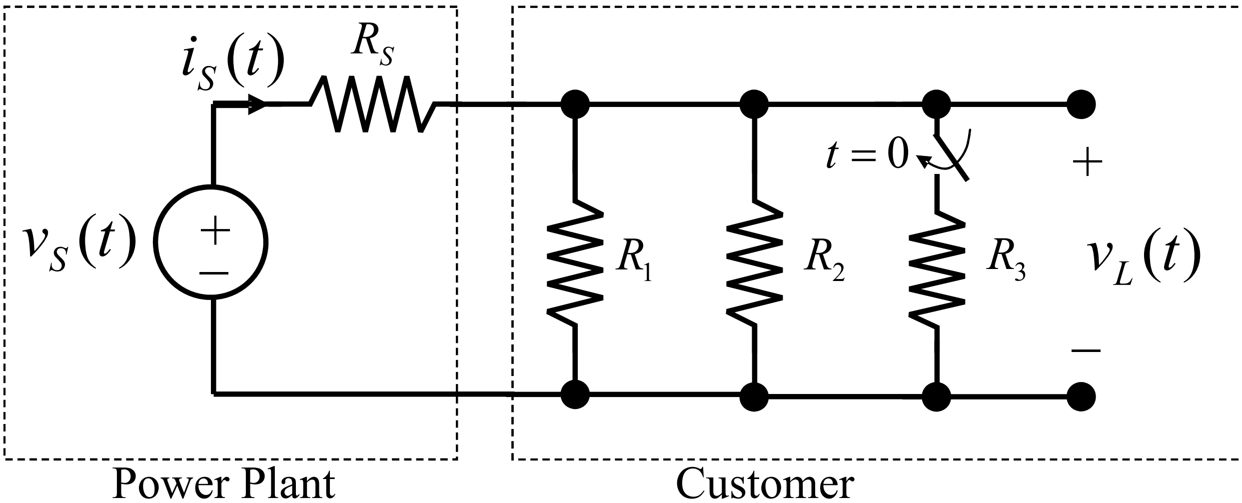


Figure 2: An electrical network model with power plant and consumers.

(a) Find the load voltage $v_L(t)$ as a function of the source voltage $v_S(t)$ for $t < 0$ (before the customer closes the switch and connects the third load).

(b) Find the load voltage $v_L(t)$ as a function of the source voltage $v_S(t)$ for $t > 0$ (after the customer closes the switch and connects the third load).

(c) Sketch the load voltage $v_L(t)$ and the source current $i_S(t)$ as functions of time assuming that $v_S(t)$ is a DC source with peak value of $150V$.

(d) Sketch the source current $i_S(t)$ as a function of time assuming that $v_S(t)$ is a $60Hz$ AC source with RMS value of $170V$.

(e) For the AC source above, how much energy does the voltage source at the power plant produce over one source period (cycle) before and after the switch is closed?

(f) **Bonus:** What is the Thevenin and Norton equivalence (from the 2 right-most terminals) of this circuit if there are $N$ connected customers in parallel?

Due date: **September 21** in class