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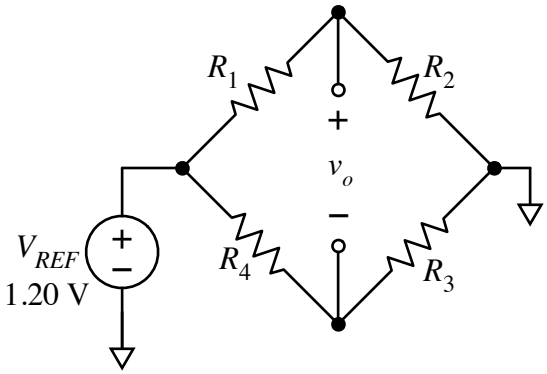
Many types of sensors utilize a change in resistance to detect a change in some physical quantity. For example, a resistance thermometer (RTD)[1] measures temperature. A resistive strain gauge[2] indicates tension and compression by changes in a resistor that is stretched or squished by a small amount. While resistive-type sensors are simple to understand and build, the fractional change in resistance ($\Delta R/R$) when measuring is usually very small, much less than 1%.

To help detect such small changes, the resistors can be put into a *Wheatstone bridge*[3] configuration – shown at right. In the bridge, the output voltage will be zero if the resistors all have the same value — the bridge is said to be balanced. If one or more of the resistances change, the bridge becomes unbalanced and a voltage develops between opposite corners. The bridge is useful because it tends to cancel out effects that are the same for all elements in the arms of the bridge and emphasizes differences in the elements.



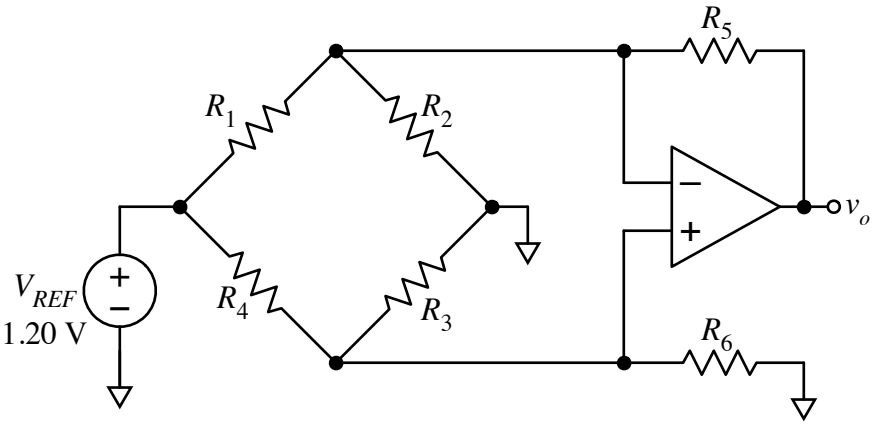
As an example of an application, we might put four strain-gauge resistors in the arms of a bridge — two of will stretch as the mechanical beam (or whatever) is strained, $R_2 = R_4 = R + \Delta R$, where R is the nominal resistance and ΔR represents the change in resistance due to strain. The other two resistors will be on the other side of the beam and will compress, giving $R_1 = R_3 = R - \Delta R$.

- Calculate the output voltage of the Wheatstone bridge where there arm resistances are changing as described in the above paragraph, with $R = 120\ \Omega$ (a typical value) and $\Delta R = 0.6\ \Omega$.

  v_o = _____

- The voltage change in the bare Wheatstone bridge is still small-ish. A much larger change in voltage can be obtained by the using the bridge in conjunction with a form of difference amp.

  Using the same resistance values as in the calculation above, calculate the output voltage of the circuit at right. Use $R_5 = R_6 = 12\ \text{k}\Omega$.



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[1] https://en.wikipedia.org/wiki/Resistance_thermometer

[2] https://www.me.psu.edu/cimbala/me345/Lectures/Strain_gages.pdf

[3] The bridge is the official icon of Eta Kappa Nu, so all HKN members must stand up and salute while doing this problem.

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v_o = _____