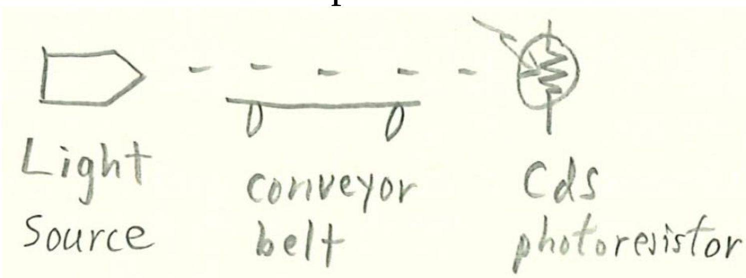
Conductance Sensing, Continued

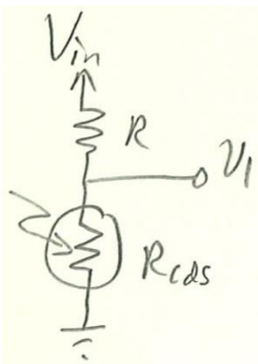
Consider this example:



CdS photoresistor → a cadmium sulfide cell: its resistance decreases with increasing light intensity

Objects on the conveyer temporarily block the beam of light → R_{CdS} ↑

Put the sensor in series with R:

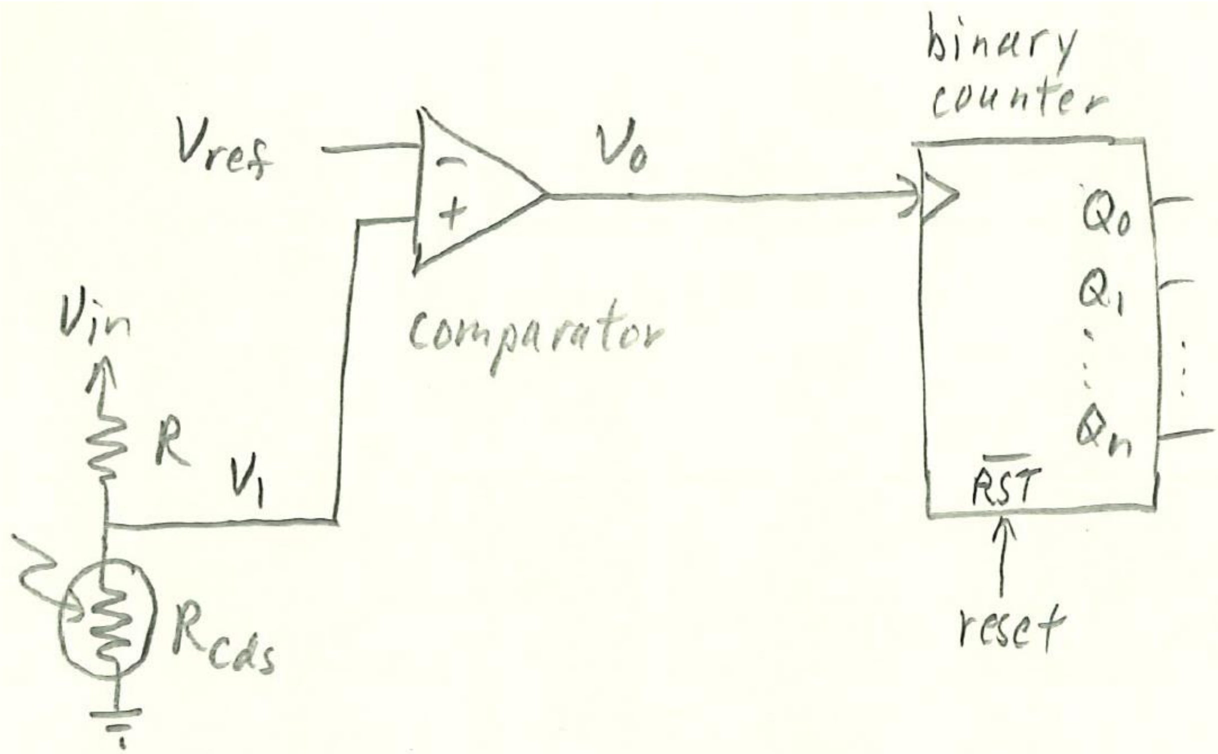


$$v_1 = V_{in}\frac{R_{CdS}}{R + R_{CdS}}$$

Light intensity ↑: R_{CdS} ↓: v_1 ↓

Light intensity ↓: R_{CdS} ↑: v_1 ↑

Now consider this interface circuit:



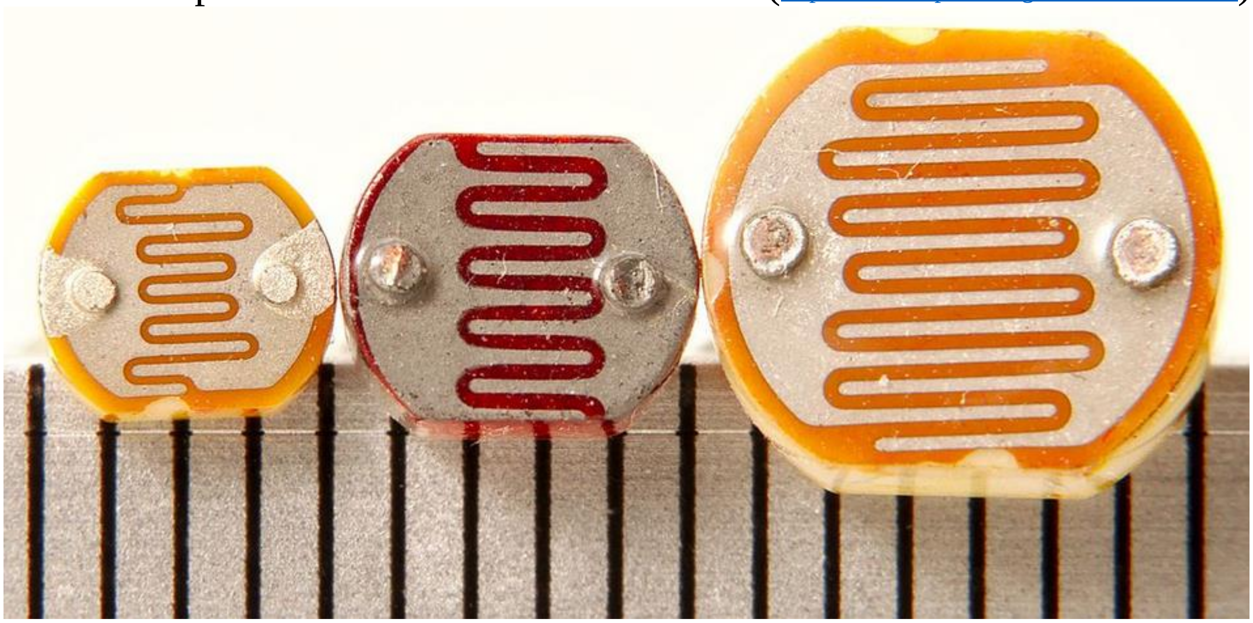
No object in the light path: R_{CdS} low, $V_1 < V_{ref}$, V_o low (logic level 0)

Object in the light path: R_{CdS} high, $V_1 > V_{ref}$, V_o high (logic level 1), counter increments by one

The example above approximates conductivity sensing.

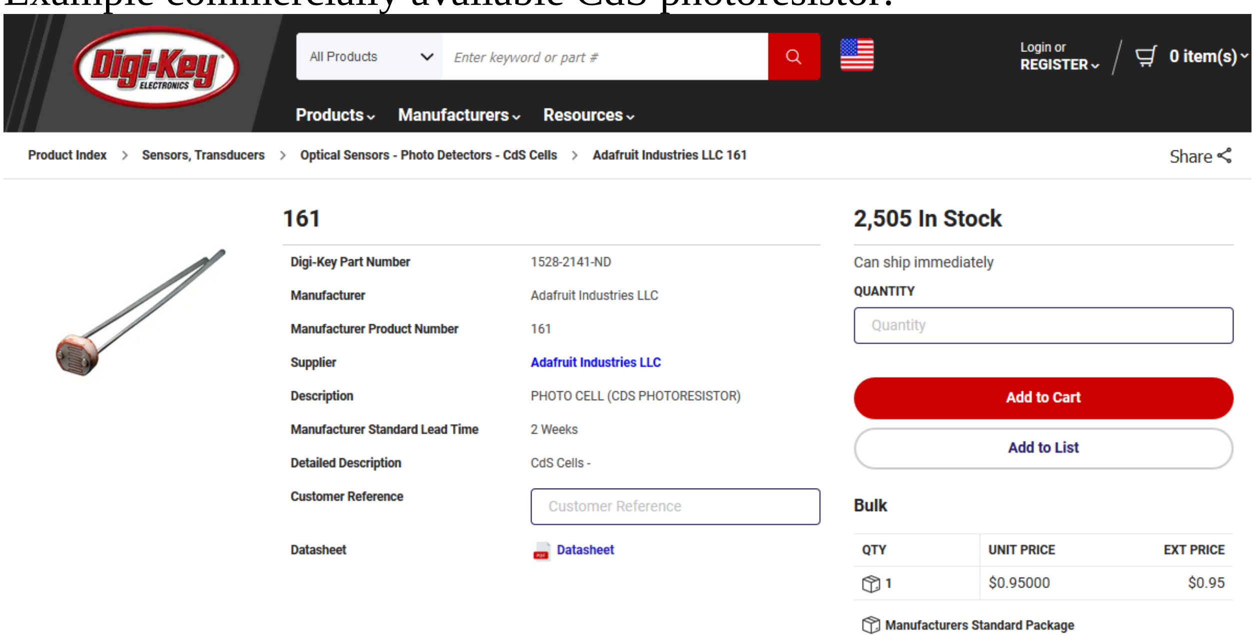
A CdS photoresistor is a semiconductor device that exhibits photoconductivity. CdS is a semiconductor material (usually n-type), and is used in one type of photovoltaic cells. Light above a certain frequency possesses enough energy to free an electron, creating an electron-hole pair to conduct electricity, thereby lowering resistance. R_{dark} can be up to several MΩ, while R_{light} can be as low as several hundred Ω. CdS is highly toxic, a known carcinogen, and is sometimes used in yellow tattoo die.

Three CdS photoresistors next to a mm scale (https://en.wikipedia.org/wiki/Photoresistor)



CdS photoresistors are an older technology, and are relatively low frequency (~10s of Hz response to a change in light intensity). They are fairly low cost.

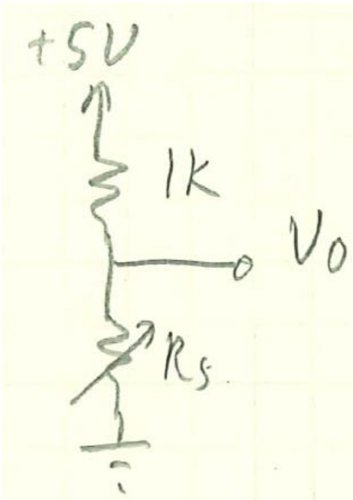
Example commercially available CdS photoresistor:



Resistance Sensing

1. A single resistance sensor

Consider a resistive sensor, R_s, where $R_s \propto measurand$:

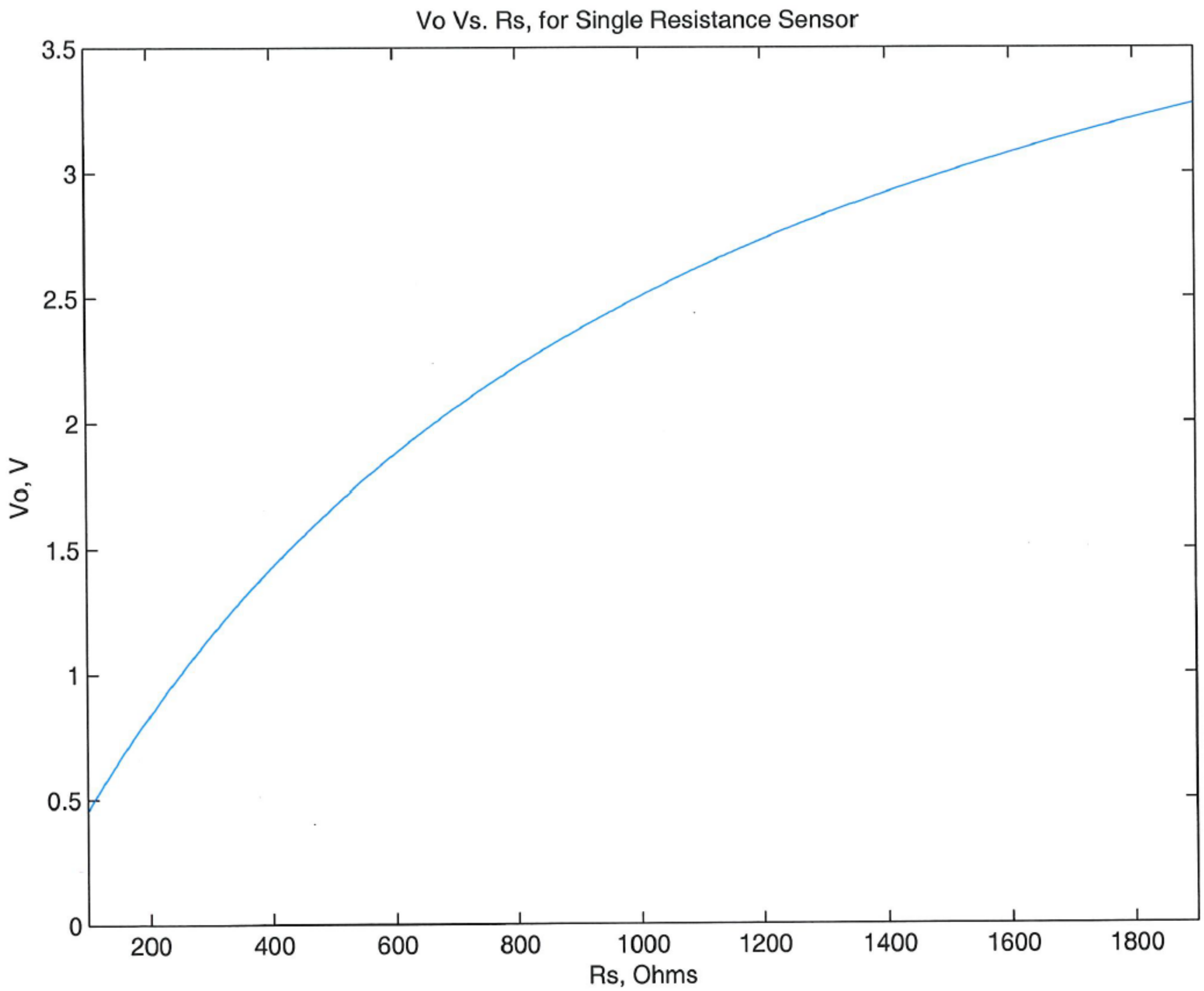


$$V_o = \frac{5R_s}{1000 + R_s}$$

Notice the V_o is a nonlinear function of R_s.

A plot of V_o vs. R_s is shown on the next page,

where $100\ \Omega \leq R_s \leq 1900\ \Omega$.

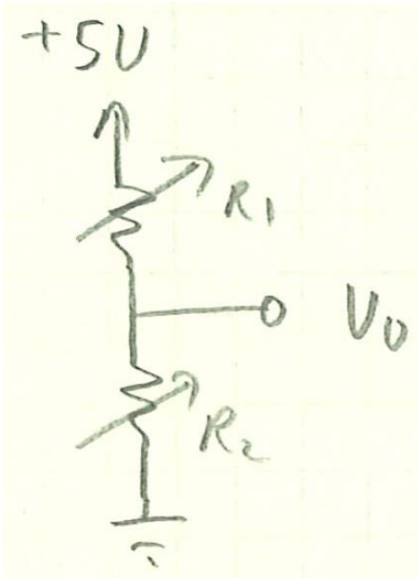


Although the interface circuit is powered off of 5V, the output voltage only ranges from about 0.4 V to 3.3V.

Although R_s might be linearly proportional to the measurand, V_o is clearly not linearly proportional to R_s. Is this a problem? It might be or it might not be, depending on the application.

2. A differential resistance sensor

Here, the sensor consists of two resistors, R_1 and R_2, similar to a potentiometer, where the measurand causes one resistor to increase in resistance while the other one decreases by the same amount.



$$V_o = \frac{5R_2}{R_1 + R_2}$$

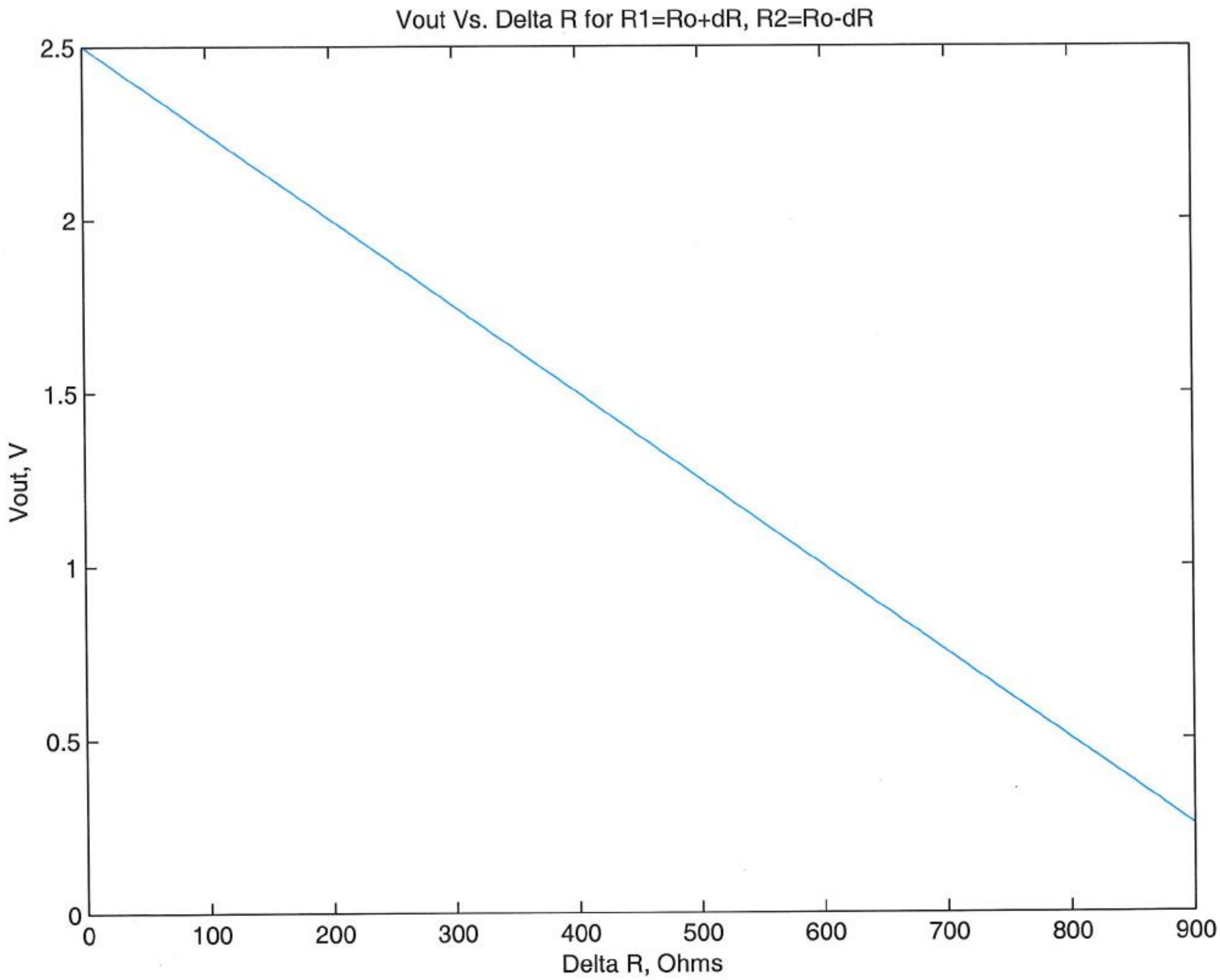
Let's let: $R_1 = R_o + \Delta R$ and $R_2 = R_o - \Delta R$,

where R_o is a constant and ΔR is a function of the measurand.

Therefore: $V_o = \frac{5(R_o - \Delta R)}{R_o + \Delta R + R_o - \Delta R} = 2.5 - 2.5\frac{\Delta R}{R_o}$

Observe that V_o is now linear function of ΔR.

Example: Let Ro = 1 kΩ and 0 Ω ≤ ΔR ≤ 900 Ω

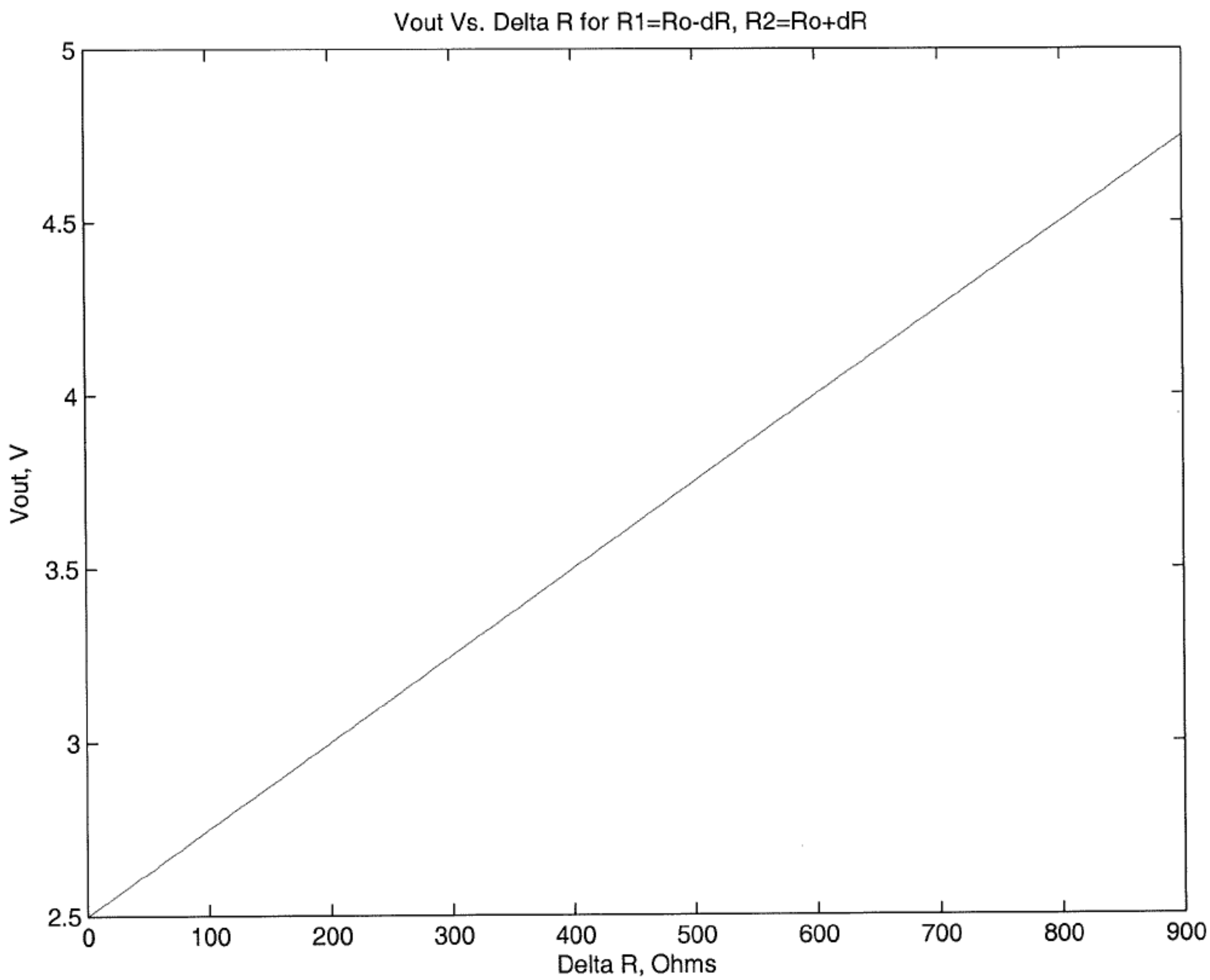


V_o is now linearly proportional to -ΔR, but it only goes from about 0.25 V to 2.5 V.

Similarly, let: $R_1 = R_o - \Delta R$ and $R_2 = R_o + \Delta R$, resulting in

$$V_o = \frac{5(R_o+\Delta R)}{R_o-\Delta R+R_o+\Delta R} = 2.5 + 2.5\frac{\Delta R}{R_o},$$

yielding:



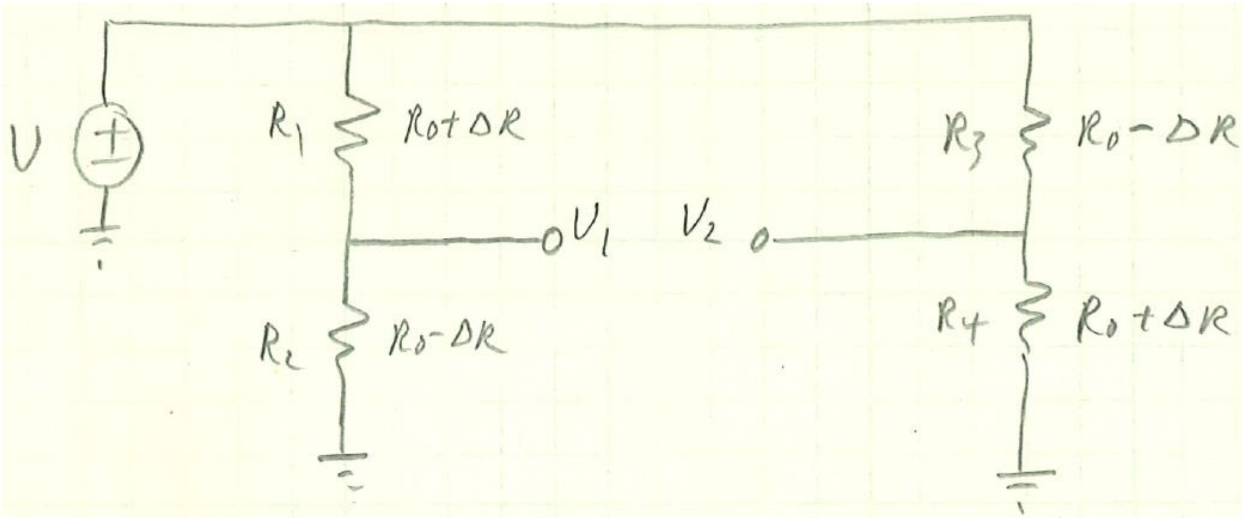
Which is still a linear response, but the slope is now positive, with V_o between about 2.5 V and 4.75 V.

3. Dual differential resistance sensor

Some resistance sensors consist of 4 resistors, arranged as two differential pairs:

$$R_1 = R_o + \Delta R$$
$$R_2 = R_o - \Delta R$$
$$R_3 = R_o - \Delta R$$
$$R_4 = R_o + \Delta R$$

Let's connect the 4 resistors as shown below:



Notice that the resistors are connected to realize two differential pairs where one is inverted compared to the other one. The is called a <u>Wheatstone Bridge</u> sensor configuration.

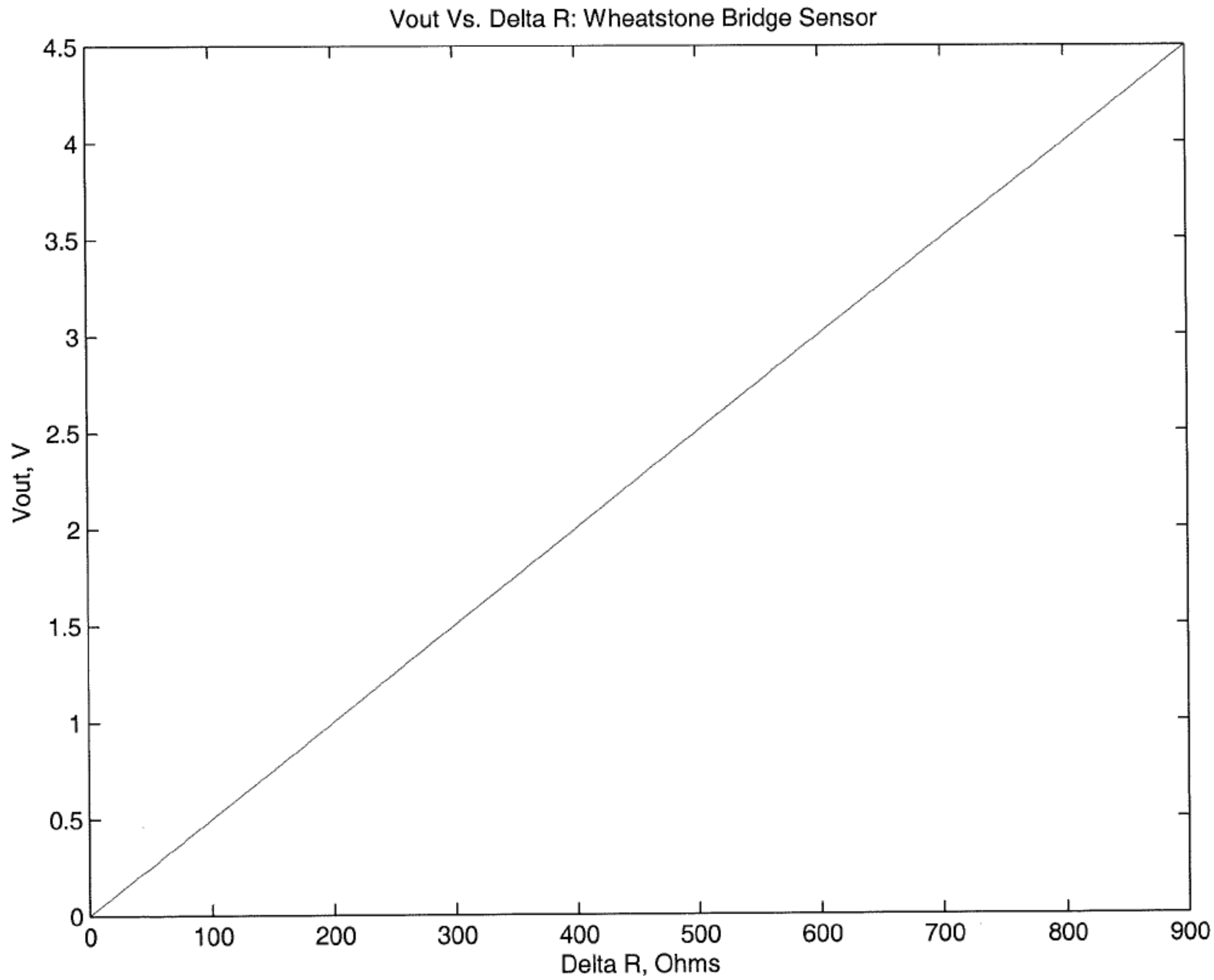
$$V_1 = \frac{V(R_o - \Delta R)}{R_o + \Delta R + R_o - \Delta R} = \frac{V(R_o - \Delta R)}{2R_o}$$

$$V_2 = \frac{V(R_o + \Delta R)}{R_o + \Delta R + R_o - \Delta R} = \frac{V(R_o + \Delta R)}{2R_o}$$

Let's define: $V_o = V_2 - V_1 = \frac{V(R_o+\Delta R)}{2R_o} - \frac{V(R_o-\Delta R)}{2R_o} = V\frac{\Delta R}{R_o}$

Example: $R_o = 1\ k\Omega$, $V = 5\ V$, $0\ \Omega \leq \Delta R \leq 900\ \Omega$

yielding:



V_o is a linear function of ΔR.

Notice that this configuration has a larger V_o range (0 V to 4.5 V) than with the 2-resistor differential resistance sensor, i.e. this is a more sensitive sensor.