The behavior of potential divider under load

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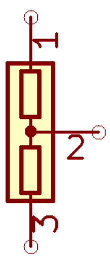
1 Introduction

Voltage divider is an ubiquitous and vesrsitaile electric component. It consists of two resistors connected in series with output terminal between them (See Figure 1. All resistive sensors in its core are voltage dividers, where the sensor itself is one of the resistors in a circuit allowing for reading analog signal from them, as the sensor changes its resistance in accordance to some external variable like light, reaction force or temperature. What potential dividers are not good for is providing power to a load, which will be explored in this paper.

Figure 1:



2 Output voltage of a potential divider without load

The output voltage of a voltage divider is measured across R_2 (Figure 1, so the formula for the output can be derived from Ohm's law

$$V_{out} = IR_2 \tag{1}$$

$$I = \frac{V_{in}}{R_1 + R_2} \tag{2}$$

$$V_{out} = \frac{V_{in}R_2}{R_1 + R_2} \tag{3}$$

From equation above, we can already see that output of resistive sensors is not linear, except in the case of potentiometer, where the resistance of the whole system is fixed.

3 Output voltage of a potential divider under load

Figure 2:

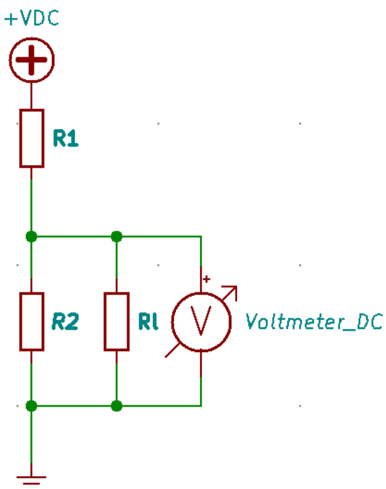


Figure 2 shows the model the analysis is build upon, where R_1 and R_2 are resistors of the potential divider, R_l is the resistive load and V_{out} being measured using the voltmeter.

If a resistive load were to be connected to a potential divider, then it may be interpreted as if the connected resistor with load in paralel were one resistor connected in series. The formula for resistance in a parallel circuit is stated in equation (5).

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n} \tag{4}$$

From that equation we can state that if any load were to be connected to the divider, the net resistance of R_2 and R_l is going to be lower than one of sole R_2. We can derive the output voltage from equation (3)

$$R_p = (\frac{1}{R_2} + \frac{1}{R_l})^{-1} = \frac{R_2 R_l}{R_2 + R_l} \tag{5}$$

$$V_{out} = \frac{V_{in} \cdot R_p}{(R_1 + R_p)} \tag{6}$$

$$V_{out} = \frac{V_{in}(R_2 R_l)}{R_1(R_2 + R_l) + R_2 R_l} \tag{7}$$