

BME310

12 - Sensors

Homework

1. A load cell uses a Wheatstone Bridge and an OpAmp to measure the force on the knee of a person using an exoskeleton. What should the gain of the amplifier be to yield an output voltage between -10 and + 10 volts measuring 0.5 – 10 Newtons. Assume that the Wheatstone Bridge is powered with 10 volts has a sensitivity of 50mV/V/Newton

$$50mV / V / Newton \times (10V) \times (0.5N) = 0.25 \Rightarrow A = \frac{10}{0.25} = 40$$

$$50mV / V / Newton \times (10V) \times (10N) = 5V \Rightarrow A = \frac{10}{5} = 2$$

If we choose $A = 40$, then the output will be $(50 \times 10^{-3} \times 10 \times 0.5 \times 400 =)$ 10
to $(50 \times 10^{-3} \times 10 \times 10 \times 400 =)$ 200 volts

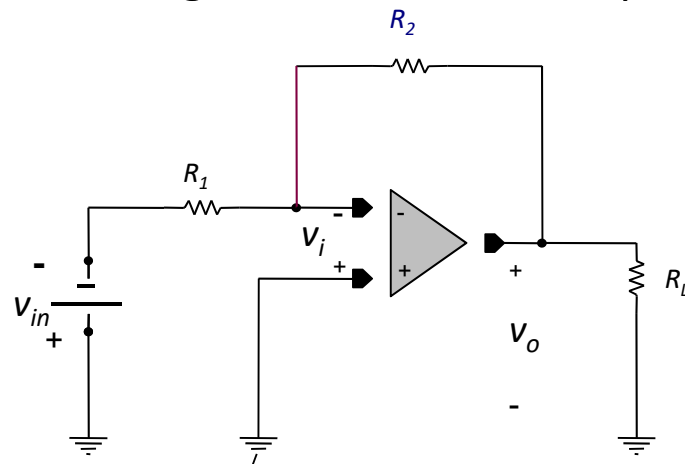
If we choose $A = 2$, then the output will be $(50 \times 10^{-3} \times 10 \times 0.5 \times 2 =)$ 0.5
to $(50 \times 10^{-3} \times 10 \times 10 \times 2 =)$ 10 volts

Choose $A = 2$

Homework

2. You have placed a force sensor in a shoe and want to measure the weight of an object a person is carrying. What sort of amplifier should you use. Assume the force sensor is a variable resistor. Draw the circuit diagram and show where the force sensor is placed in the circuit. Explain how your circuit will work.

Use an inverting op amp and place the sensor as R_1 . Since the gain of an inverting op amp is $-R_2/R_1$, with no pressure the output is zero. As the pressure is applied, then R_1 reduces and the gain is non zero. Feeding the sensor with a negative voltage will make the output positive.



Homework

3. HONORS STUDENTS ADD THE FOLLOWING

Research and describe how resistors can be used in Wheatstone bridge configuration as a strain gauge. Draw the strain gauge Wheatstone bridge circuit and calculate the bridge voltage under the cases of tension and compression.

The resistance of a resistance can be modelled as

$R = \frac{\rho L}{A}$; where L is its length, A is its cross sectional area and ρ is the resistivity of the material.

In tension, the resistance changes

$R = \frac{\rho L + \Delta L}{A - \Delta A}$; where ΔL is the increase in length and ΔA is the decrease in area.

Note that this yields a net increase in resistance, h , $R + h$.

In compression, the resistance changes

$R = \frac{\rho L - \Delta L}{A + \Delta A}$; where ΔL is the decrease in length and ΔA is the increase in area.

Note that this yields a net decrease in resistance, h , $R - h$.

Homework

3. HONORS STUDENTS ADD THE FOLLOWING

Research and describe how resistors can be used in Wheatstone bridge configuration as a strain gauge. Draw the strain gauge Wheatstone bridge circuit and calculate the bridge voltage under the cases of tension and compression.

Take 2 resistors in the opposite positions, r_A and r_D , are placed so that they both increase in resistance when under tension and decrease in resistance under compression.

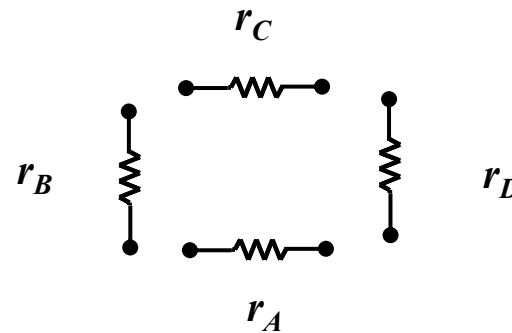
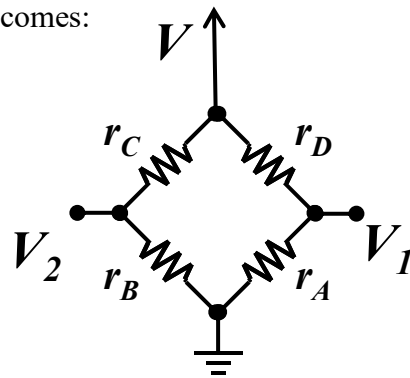
Take the other 2 resistors in the opposite positions, r_B and r_C , are placed so that they both increase in resistance when under tension and decrease in resistance under compression.

However the placement is such that when r_A and r_D are in tension the others r_B and r_C are in compression and visa versa.

Furthermore, assume that all 4 resistors have the nominal value R .

Therefore the bridge voltage becomes:

$$V_2 - V_1 = V \left(\frac{r_B}{r_B + r_C} - \frac{r_A}{r_A + r_D} \right)$$



Homework

3. HONORS STUDENTS ADD THE FOLLOWING

Research and describe how resistors can be used in Wheatstone bridge configuration as a strain gauge. Draw the strain gauge Wheatstone bridge circuit and calculate the bridge voltage under the cases of tension and compression.

Under ideal conditions, the bridge voltage is:

$$V_2 - V_1 = V \left(\frac{r_B}{r_B + r_C} - \frac{r_A}{r_A + r_D} \right) = V \left(\frac{R}{2R} - \frac{R}{2R} \right) = 0$$

When $r_B = R + h$ and $r_D = R + h$ are under tension, then $r_A = R - h$ and $r_C = R - h$ are under compression.

Under this case, the bridge voltage is:

$$\begin{aligned} V_2 - V_1 &= V \left(\frac{r_B}{r_B + r_C} - \frac{r_A}{r_A + r_D} \right) = V \left(\frac{R+h}{R+h+R-h} - \frac{R-h}{R-h+R+h} \right) = V \left(\frac{R+h}{2R} - \frac{R-h}{2R} \right) \\ &= V \left(\frac{R+h-(R-h)}{2R} \right) = V \left(\frac{h}{R} \right) \end{aligned}$$

And when these resistors are under compression:

$$V_2 - V_1 = \frac{R-h-(R+h)}{2R} = -V \left(\frac{h}{R} \right)$$

