Principle of function of strain gauge force sensor

This paper describes the basic principles of function of strain gauge force sensor, the design of sensor and its connection to the electronic unit.

Keywords: spring body, strain gauge, k-factor, electronic bridge, signal conditioner.

The principle of the function of the strain gauge force sensor is shown on Fig. 1. For simplicity, consider the steel bar L and the cross-section S, which you influence the tension force F. The bar extends in the direction of the axis, and according to Hook's law, the extension is proportional to the applied force, i.e. ΔL / L ≈ F. Suppose that a resistive conductor with a cross-section Sw is glued along the entire length of the bar. Its electrical resistance is R = ρ L / Sw, where ρ is the specific electrical resistance of the conductor. By extending the bar, the length of the conductor increases, but its cross-section decreases. As a result, the resistance of the conductor increases by ΔR. The relative increase in resistance ΔR / R is also to some extent linear and ultimately proportional to the applied force. From this we can derive the basic equation that describes the conversion of mechanical value (force) to electrical (resistance):

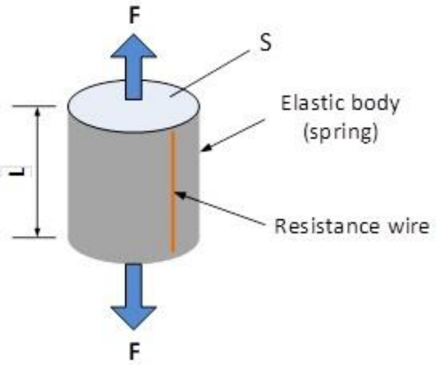

Fig. 1. The principle of the function of strain gauge force sensor

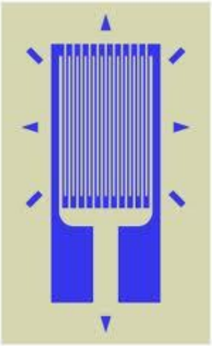

Fig. 2. Strain gauge

$$\frac{\Delta R}{R} = k \frac{\Delta L}{L}$$

The coefficient k is called the k-factor. If we denote the relative deformation ε = ΔL / L, then according to Hook's law the mechanical stress equals σ = εE where E is the modulus of elasticity of the bar. Practically this means that the relative change in resistance will depend not only on the value of the force F but also on the properties of the material used. It is therefore different whether the sensor will be made of e.g. steel or aluminum. In practice, deformation is not measured by a resistance conductor, but by an element called a strain gauge. A conventional metal strain gauge is a foil approximately 10 x 12 mm in size and has a meander-shaped metal layer (Fig. 2). The K-factor of the metal strain gauge equals approximately 2. There are also semiconductor strain gauges which have a k-factor of up to about 200, but have other drawbacks, in particular temperature instability. The strain gauges are bonded to the body with a special epoxy adhesive. In practice, one strain gauge is rarely used in sensor design. Several strain gauges are applied to the body, usually four and are connected to the bridge. This gives a greater signal and better sensor properties. The nominal bridge resistance is usually 350 Ω.

Design of a simple force sensor

An example of a simple force transducer is a flat steel beam, wedged at one end and bent at the other (Fig. 3). Four strain gauges are applied to the beam, two from above and two from below. When the force F is applied, the beam is bent and as a result the upper strain gauges (T1, T3) are stretched and the lower strain gauges (T2, T4) are compressed. To maximize the signal, strain gauges are connected to the bridge as shown in Fig. 4. Strain gauges T1, T3 increase their resistance, strain gauges T2, T4 decrease. If a supply voltage is applied between Exc+ and Exc- terminals, the voltage across the diagonal of the bridge will increase (as is indicated by the symbols +. On this principle, i.e. part of the sensor structure is compressed under the force, part is stretched, the most of the standard strain gauge force sensors work. The body of the structure is called a spring body and there are four strain gauges applied (two are compressed, two are stretched) all connected to the bridge.

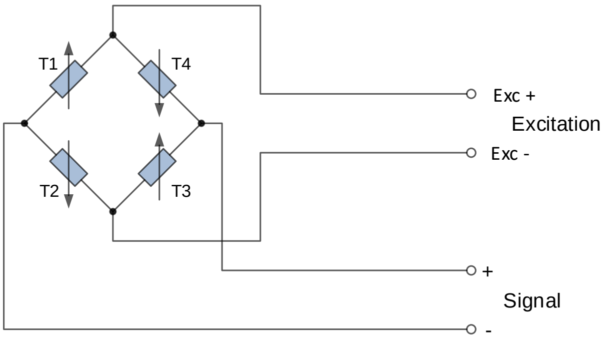

Fig. 4. Connection of strain gauges in the sensor

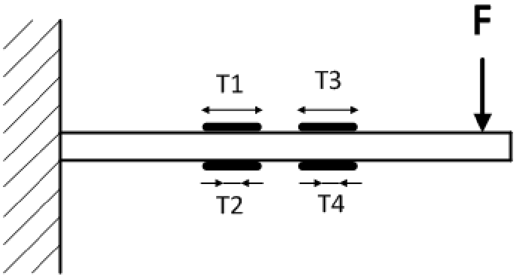

Fig. 3. Simple force sensor

Connecting the sensor to the electronic unit

From the design of the strain gauge force transducer it is clear that the electronic signal processing unit must have at least two parts. They are: excitation supply for the bridge and signal amplifier. The unit is usually called a signal conditioner and its block diagram including sensor connection is shown in Fig. 5. As you can see the signal conditioner has some other blocks. The converter power supply block is needed when the output should be also negative voltage. An active filter is used to reduce noise and increase the output signal stability. With some transmitters, the cut-off frequency of the filter can be switched. A current converter is necessary if a current signal is also required as the output. EMS168 and EMS170 have all mentioned blocks.

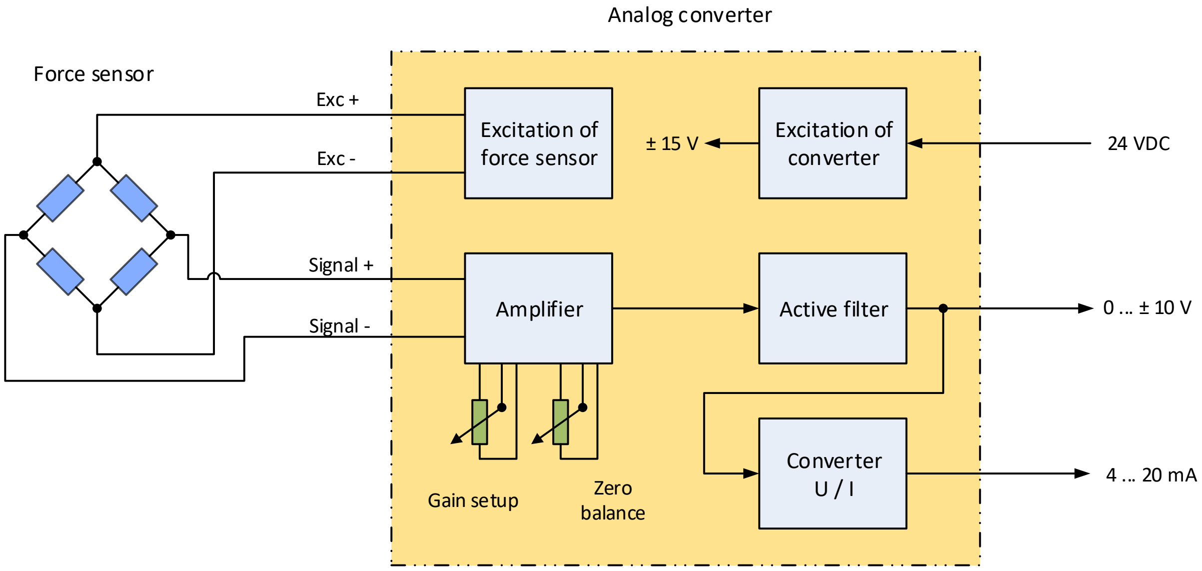

Fig. 5. Block diagram of the transmitter with connected sensor