MUSCLE EFFORT DEGREE MEASUREMENT

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Indicating the muscle effort degree is useful to determine sensible loading of the muscle and obtain objective estimation of muscle fatigue.

In this paper an effort meter for indicating the applied effort from the loading muscle is proposed and described. The developed effort meter consists of strain gauge – sensor element to detect the applied effort, amplification circuit and indicating circuit. The apparatus is easy to realize and with low cost. The designed device can be used for investigation of muscle fatigue for example in the fitness centers.

Keywords: muscle fatigue, effort meter, strain gauge

1. INTRODUCTION

Investigation of muscle fatigue is necessary to determine sensible and useful loading of the muscle.

It is well established that prolonged, exhaustive endurance exercise is capable of inducing skeletal muscle damage and temporary impairment of muscle function. Although skeletal muscle has a remarkable capacity for repair and adaptation, this may be limited, ultimately resulting in an accumulation of chronic skeletal muscle pathology [1].

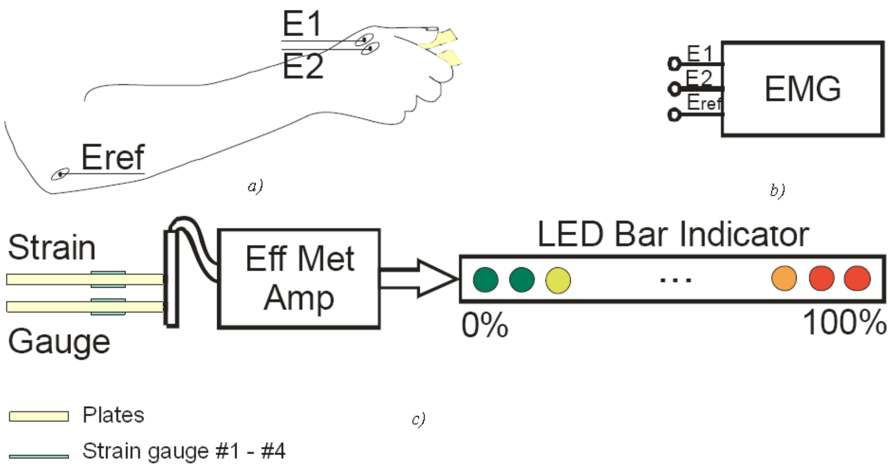

Fig.1.System for investigation of muscle fatigue
a)Position of electrodes; way of catching the strain gauge; b)Electromyograph; c)Effort meter.

If loading is stopped at time muscle fibers can be restored, if not they destroyed.

Sensitive noninvasive method for objective estimation of muscle fatigue could help in optimization of training programs. Under experimental conditions the skeletal muscle could be loaded in a controlled manner, allowing the muscle adequate time to repair and adapt. The regeneration process will be complete, and normal muscle function and morphology will be fully regained.

To investigate the muscle fatigue it was designed a system for acquisition of EMG signals – electromyograph EMG (see Fig.1 b). It was designed and realized an effort meter too. Its purpose is to indicate the applied effort degree (muscle loading). The electromyograph and the effort meter are used together. When the strain gauge is catched the electromyogram is recording. It is sustained identical effort level while the muscle fatigue occurs. At the same time it is observed the change in the recording electromyogram.

2. Principle of Operation and Practical Realization

To provide possibility for widely spread of objective estimation of muscle fatigue it is necessary to have relatively inexpensive apparatus.

The strain gauge has been in use for many years and is the fundamental sensing element for many types of sensors.

The full-bridge configuration is the best to use because it is linear while the others (a quarter-bridge, a half-bridge) are not [2].

With a full-bridge configuration the output voltage is directly proportional to applied force (effort) with no approximation (provided that the change in resistance ΔR caused by the applied force is equal for all four strain gauges).

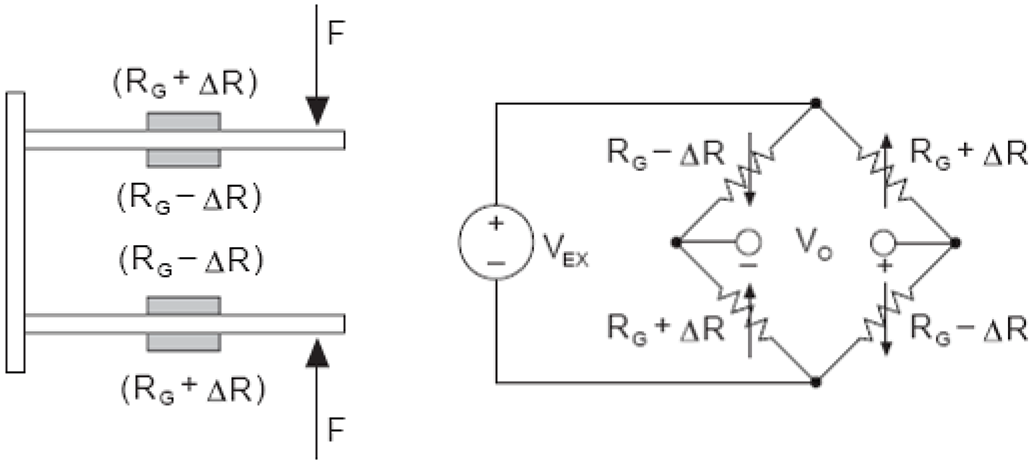

Fig.2. Full-bridge with applied force F on it

The output voltage is directly proportional to the change in resistance caused by applied force [3]:

$$\frac{V_O}{V_{EX}} = \frac{R_G - \Delta R}{(R_G - \Delta R) + (R_G + \Delta R)} - \frac{R_G + \Delta R}{(R_G + \Delta R) + (R_G - \Delta R)} \quad (1)$$

In the equation:

ΔR – The change in strain gauge resistance on account of applied voltage;

R_G – The strain gauge resistance;

V_{EX} – The supply voltage for the Wheatstone bridge;

V_O – The output voltage for the Wheatstone bridge.

$$V_O = \frac{\Delta R}{R_G} * V_{EX} \qquad (2)$$

The equations given above for the Wheatstone bridge circuits assume an initially balanced bridge that generates zero output when no strain is applied. In practice however, resistance tolerances and strain induced by gauge application will generate some initial offset voltage. It is used a special offset-nulling (balancing) circuit to adjust the resistance in the bridge to rebalance the bridge to zero output.

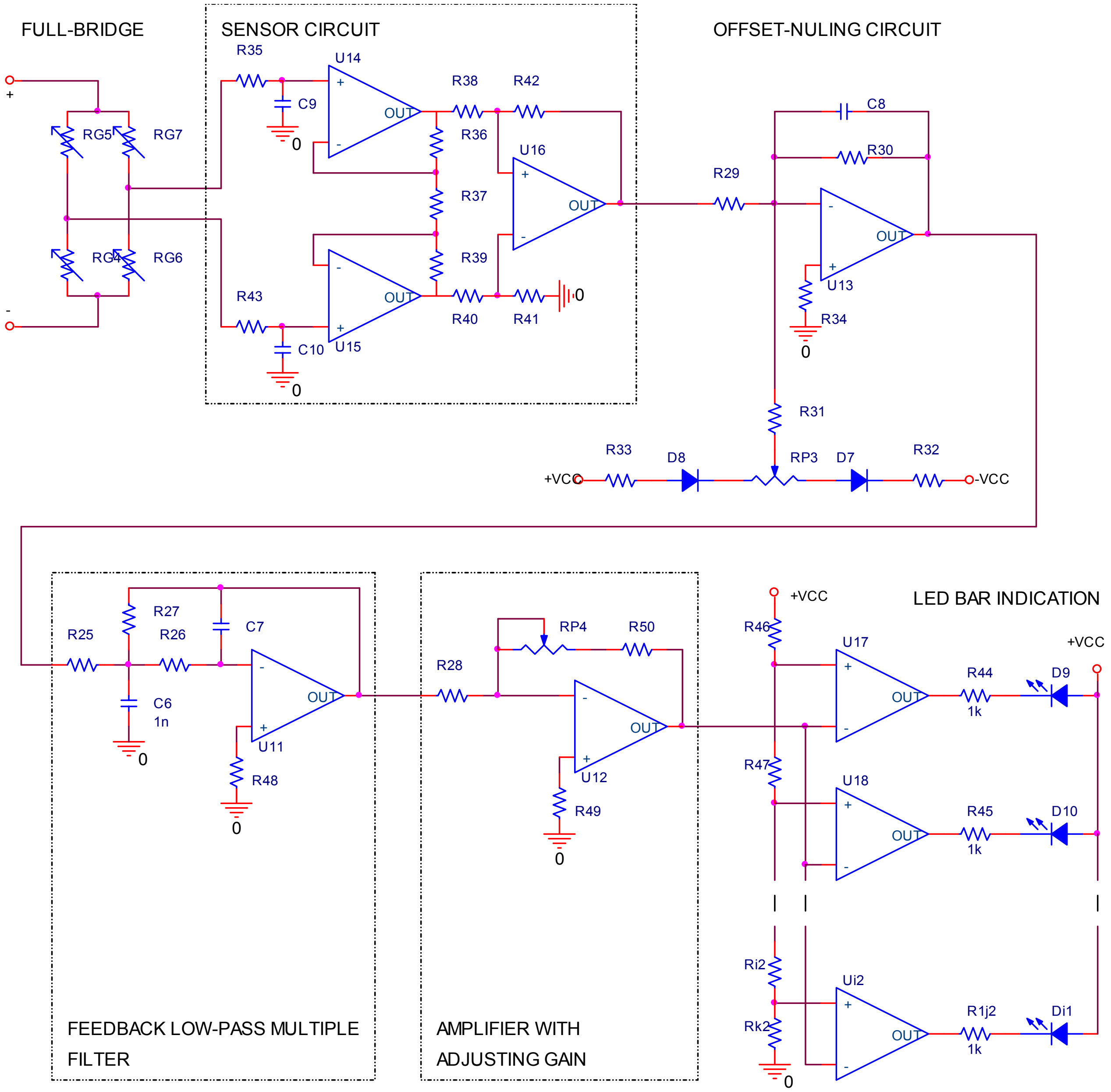

Fig.3. Schematic diagram of the effort meter

In practical performance of the strain gauge test specimen are used two plates. They are fixed together in the one end. And strain gauges are arranged (glued) in both sides of each plate (Fig.1,2). The effort is applied over other ends.

Strain gauges witch were chosen are LK11 [4] because they are the most suitable for our purposes.

The complete Wheatstone bridge is excited with a stabilized DC supply (V_{EX}). It is possible to provide three ways for excitation: DC excitation, AC excitation and bipolar excitation. The last two ways are recommended for more precise measurements but for the application of the apparatus the choice is justified [5].

As effort is applied to the bonded strain gauge resistive changes take place and unbalance the bridge. This results in an output voltage related to the change in the gauge resistance which on its part is related to the applied effort value.

As important as it is to choose the right strain gauge, the choice of an amplifier is even more critical for achieving high precision. Strain measurements can be no more accurate than the amplifier that processes the signal from the strain gauges.

As the signal value V_O in the output of the Wheatstone bridge is a very small (few milivolts) difference voltage in the presence of a relatively large dc bias voltage it is obvious (see also equation 1) that the appropriate kind of sensor circuit is an instrumentation amplifier. At the inputs of the sensor circuit there are passive low-pass filters for reducing the voltage fluctuations caused by high-frequency noise. The first order filters were designed with frequency response at 36 kHz. The gain of the stage is 40.The next stage is offset-nulling circuit. It allows adjusting the zero point of the system. It provides amplification 1.5. There are different variants for offset-nulling circuits but this one is completely convenient.

It is used passive low-pass filter. Feedback low-pass multiple filter [5] is chosen because of possibility to change the bandwidth in wide ranges. The passive elements choose due the necessities. For the purposes of the investigation the circuit is calculated for cut-off frequency 305Hz. And the gain is 5.

The aim of the last stage is to adjust the gain of the amplification circuits. The total gain of the Effort meter is about 600.

Amplifying part of the Effort meter provides amplification to increase the signal value to a suitable level for actuating the comparators in the LED bar indicator. The LEDs are divided on colours for easily reading the percentage of applied effort.

3. CONCLUSION

The prototype of the proposed effort meter is working properly. This apparatus is a low-cost solution which without any kind of changes or small changes is easily to adopt for use in fitness centers, rehabilitation centers or even at home to determine the appropriate muscle loading.

4. REFERENCES

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