MYOELECTRODE LIFT-OFF DETECTION

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Myoelectric signals that are detected at the surface of the skin are a summation of muscle motor unit firings. Because these firings are inconsistent, the myoelectric signals contain frequency components that vary in amplitude throughout the frequency spectrum. As detected, these signals are a function of anatomical and physiological factors, as well as various filtering features of the environment and of the electrodes and circuitry used for detection. The myoelectric signals traverse muscle, fatty tissues, and skin tissues, all of which act as a low pass filter, since higher frequency components are progressively more attenuated as the tissue depth increases. Upon reaching the electrodes at the surface of the skin, the characteristics of the electrodes and electrolytes of the skin serve as a high pass filter. When the signals reach the detection apparatus, further bandpass filtering is provided by the configuration of the electrode, amplifiers, and other circuit elements. The resulting detected surface myoelectric signal has a frequency spectrum that ranges from about 20-400 Hz, and has a maximum amplitude that ranges from about 0.5-2 mV.

When receiving myoelectric signals, it is preferable that they contain as little noise as possible. The noise that is encountered in detecting the myoelectric signals can be separated roughly into four categories [1]:

(1) extrinsic electrical noise, including all the sources that have nothing to do with the actual detection of myoelectric signals, such as lighting, heating, power lines, switching power supplies, and electrical equipment;

(2) biomechanical noise, including movement artifacts, which occur when the electrode and the skin move relative to one another;

(3) bioelectrical noise, which includes electrical activity from within the human body and not related to muscle activation, such as neural evoked potentials; and

(4) intrinsic electrical noise, which includes all the sources of noise from the detection apparatus, e.g., noise from operational amplifiers.

Generally, for detecting a myoelectric signal, a differential amplifier is used with an electrode pair. The electrode pair senses the voltage potential at two locations, while a reference electrode is provided at an electrically neutral location. The differential amplifier rejects almost all of the common modes by applying positive and negative amplification to the two received signals and adding them algebraically.

Biomechanical noise, which includes movement artifacts, typically provides large, low frequency signals that do not necessarily occur at both electrode contacts at the same time. Therefore, an electrode pair configuration with differential amplifier does not necessarily eliminate these sources of noise.

Both extrinsic electrical noise and biomechanical can occur when only one of the electrode contacts is in contact with the skin, since the electrode that is not on the skin acts as an antenna. In this situation, extrinsic electrical noise is far greater at the electrode contact which is not connected to the skin. Differentiating the signals from the electrodes leaves significant noise that contaminates the detected myoelectric signals. These two types of noise sources are frequently detected in dynamic situations where myoelectric activity is monitored as part of research studies or as a control input to prosthetic devices.

The myoelectrode with lift-off detection features an electrode pair for picking up myoelectric signals from the surface of the skin, and circuitry for processing the detected signal. The unfiltered signal derived from the differential amplifier is rectified, smoothed and compared to a threshold in a comparator. The comparator controls whether the filtered myoelectric signal or a ground signal will be provided as output. The threshold provided to the comparator is set to be about the maximum voltage that is expected to be received by the comparator, given the maximum voltage level that is provided by the electrodes and given the combined amplification caused by circuit components. Voltage levels exceeding the threshold are assumed to be excessive due to noise. The output of the comparator can also be provided at an output lead for analysis. The status of the comparator indicates, in an essentially binary manner, when the signals exceed that threshold, and hence when noise causes the output to be excessively large.

The new myoelectrode can be used for detecting signals for analysis, or can be provided to a motor in a prosthetic device, preferably through a rectifier and a smoothing stage. In addition, multiple circuits can be provided for use with an array of electrode pairs, or a single circuit can be provided with appropriate selection circuitry. For an array like the Liberty MyoArray™, such a circuit can be particularly useful since there is more risk that an electrode may become separated from the skin.

References

1 Loeb G.E *et al.*, "Electromyography for Experimentalists", Univ. Chicago Press, 1986.