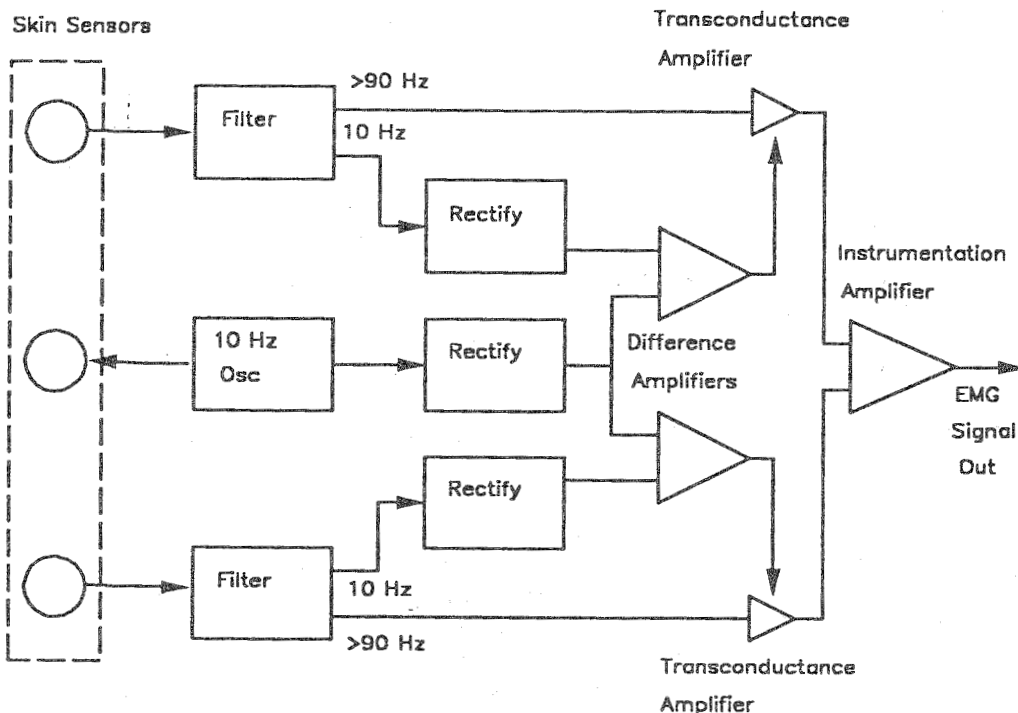


AUTOMATIC COMPENSATION OF SKIN CONDUCTANCE IN ELECTROMYOGRAPHIC SENSING



In sensing the minute electrical signals that trigger muscular movement, the signal to the amplifier input may have an impedance that varies over several orders of magnitude. For a fixed amplifier input impedance, the skin-sensor resistance and skin impedance act as a voltage divider which causes a voltage drop in signal amplitude. This invention provides a consistent amplitude signal over a wide range of skin impedance and contact resistance of the skin-sensor interface.

In applications that require sensing of muscle movement, it is convenient to use the small electrical voltages associated with muscle contractions. This voltage is known as an electromyographic (EMG) signal because it is associated with muscle movement. To sense the EMG signal, usually requires electrical contact with the skin with some conducting material. The boundary between the skin and the contacting sensor is poor and its characteristics will change over time. There are both short and long term effects that will cause interference with the desired EMG signal.

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In trying to process EMG signals, contamination of the signal occurs because of noise induced in the skin-sensor interface and amplitude variations caused by the conductance of the skin. These conditions are very dynamic and require methods to minimize their effects.

The resistance of this signal path may vary from 50K ohms to 200M ohms. The effect of the amplitude of the signal can be calculated using the following formula for a voltage divider:

$$V = Z1 / (Z1 + Z2)$$

where:

- V = voltage drop from the source to amplifier
- Z1 = the skin resistance + skin-sensor contact resistance
- Z2 = the input impedance of the amplifier.

For example, operating into an amplifier which has an input impedance of 10M ohm can give a drop of .005 (50K/(50K + 10M)) to 20 (200M/(200M + 10M)). This range of variations is large and can cause problems in analyzing the signal.

Continuous adjustment of the desired EMG is possible by using a reference signal and adjusting the gain of amplification derived from this received signal. A test signal of low amplitude (10 millivolts) is inserted into the skin and picked up by another sensor. This reference signal experiences the same changes in skin resistance and skin-sensor resistance as that of the desired EMG signal. It thus becomes a reliable gauge of signal variations.

The figure provides a block diagram of the steps involved in processing the signal. After the EMG and reference signals have been received, they are split apart using simple filters. Typically, the EMG signal of interest would be in the range of 90-500 Hz. By using a reference signal of 10 Hz, the frequency is high enough to prevent polarization of cells within the skin but low enough (several octaves) to use inexpensive filters to distinguish it from the EMG signal.

The reference signal is filtered, rectified and compared to the original signal. The difference between the outgoing and received signals is primarily attributed to the effects mentioned earlier. Effects of battery level or other reference signal variations are minimized by comparing the signal sent out with the signal received. Variations in signal phase propagation and RC delay are avoided by comparing the rectified voltage levels of the two signals.

The desired EMG signal is filtered to remove the reference signal and fed into a transconductance amplifier. This type of amplifier has the property that the gain of the amplifier is proportional to the

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voltage applied to its control gate. In this case, the control gate is connected to a signal that is proportional to the reference signal received.

In examining the system in its dynamic state, assume the skin becomes dryer and the resistance changes from 50K ohms to 1M ohm. A higher resistance will cause the received amplitude of the EMG and reference signal to be smaller. The difference between the reference signal sent out and the signal received will be large, and more gain will be given to the amplifier. The EMG signal having experienced the same attenuation will receive a greater amplification and thus the EMG output signal amplitude will remain constant.

These are methods to lower the skin-sensor interface such as conductive creams or burying the sensor under the skin directly into the muscle. These alternatives range from messy to dangerous and thus the impetus for this invention.

Often times when compensation is required, another technique called chopper stabilization is used. This approach turns on a reference signal, saves its amplitude, and switches back to the unknown signal. Although very effective in some situations, it has serious side effects in this application. The long time required to switch between these two states to ensure that the spurious effects of the change have subsided means that part of the actual event of interest could be missed. This missing information gives rise to another set of problems during the signal processing stage of analysis.