A Review of EMG recording technique

Imteyaz Ahmad
Dept of ECE BIT Sindri, Dhanbad, Jharkhand
Dr. F Ansari
Dept of Electrical Engg., BIT Sindri Dhanbad, Jharkhand
Dr. U.K. Dey
Dept of Mining Engg., BIT Sindri Dhanbad, Jharkhand

Abstract:

Electromyogram signals are frequently used to evaluate muscle injuries. They are also used extensively in biofeedback training equipment. This study investigates the electrical activity of muscles and the interrelationship of muscles and nerve fibers. Muscle potentials are observed and measured on an oscilloscope. By placing electrodes into a skeletal muscle we can monitor the electrical activity of the muscle. EMG is used to detect muscular disorder along with muscular abnormalities caused by other system disease such as nerve dysfunction. Neuro muscular disorder also can be known with the help of EMG. EMG is also used for diagnose of Neuro muscular performance. It is observed that there is alternating relationship between the contractions of biceps and triceps the relaxation of one forces the contraction of the other. EMG signals have been recorded at the various positions like point Biceps, point triceps and point contractions. The frequency range of the muscle spikes covers a bandwidth from DC to over 2 KHz. This recording belongs to a normal subject.

Keywords:-EMG; point Biceps; point triceps; point contractions.

Introduction

Small electrical currents are generated by muscle fibres prior to the production of muscle force. These currents are generated by the exchange of ions across muscle fibre membranes, a part of the signaling process for the muscle fibres to contract. The signal called the electromyogram (EMG) can be measured by applying conductive elements or electrodes to the skin surface, or invasively within the muscle. Surface EMG is the more common method of measurement, since it is non-invasive and can be conducted by personnel other than Medical Doctors, with minimal risk to the subject. Measurement of surface EMG is dependent on a number of factors and the amplitude of the surface EMG signal (sEMG) varies from the uV to the low mV range (Basmajian & DeLuca, 1985). The amplitude and time and frequency domain properties of the sEMG signal are dependent on factors such as (Gerdle et al., 1999):

• the timing and intensity of muscle contraction• the distance of the electrode from the active muscle area• the properties of the overlying tissue (e.g. thickness of overlying skin and adipose tissue)• the electrode and amplifier properties• the quality of contact between the electrode and the skin. In most cases, information on the time and intensity of muscle contraction is desired. The remainder of the factors only exacerbates the variability in the EMG records, making interpretation of results more difficult. Nevertheless, there are methods to reduce the impact that non-muscular factors have on the properties of the EMG signal. For example, much of this variability in the EMG signal can be minimized through:

• using the same electrodes and amplifier (i.e. same signal conditioning parameters)• ensuring consistency in the quality of contact between the electrodes and the skin Measuring and accurately representing the sEMG signal depends on the properties of the electrodes and their interaction with the skin, amplifier design, and the conversion and subsequent storage of the EMG signal from analog to digital form (i.e. A/D conversion). The quality of the measured EMG is often described by the ratio between the measured EMG signal and unwanted noise contributions from the environment. The goal is to maximize the amplitude of the signal while minimizing the noise. Assuming that the amplifier design and process of A/D conversion exceed acceptable standards (see below and Gerdle et al., 1999), the signal to noise ratio is determined almost exclusively by the electrodes, and more specifically, the properties of the electrode – electrolyte – skin contact..
Signal Conditioning and Amplification

Advent of modern electronics and the process of differential amplification have enabled the measurement of EMG signals of low noise and high signal fidelity (i.e. high signal to noise ratio). With differential amplification, it is now possible to measure the full effective bandwidth of the EMG signal. Typical band pass frequency ranges are from between 10 and 20Hz (high pass filtering) to between 500 and 1000Hz (low-pass filtering). High-pass filtering is necessary because movement artifacts are comprised of low frequency components (typically <10Hz). Low pass filtering is desirable to remove high-frequency components to avoid signal aliasing (see Gerdle et al., 1999). In the past, it was common to remove power-line (A/C) noise components (i.e. either 50 or 60Hz) by using a sharp notch filter. There are problems with notch filtering because EMG has large signal contributions at these and neighboring frequencies. The result of notch filtering is the loss of important EMG signal information, so notch filtering should be avoided as a general rule. Amplification is also necessary to optimize the resolution of the recording or digitizing equipment (for more information see Gerdle et al., 1999). Amplifiers of high quality have adjustable gains of between, at least, 100 and 10 000 to maximize the signal to noise ratio of the EMG signal during each recording. This range of gains provides the sufficient range of amplifications for surface EMG signals which can range typically from 0 to 6mV peak to peak (Basmajian & DeLuca, 1985). The quality of the EMG signal, in part, depends on the characteristics of the amplification process. While there may be several stages of amplification, the most important stage is often described as pre-amplification. Pre-amplification implies the first stage of amplification, close to the signal source. There are several important parameters in preamplifier signal conditioning of the EMG signal.

Properties of an ideal pre-amplifier

There are several important properties to consider in a pre-amplifier:
• High common mode rejection ratio
• Very high input impedance
• Short distance to the signal source
• Strong DC signal suppression

Common Mode Rejection Ratio (CMRR)

Bipolar electrode arrangements are used with a differential amplifier, which functions to suppress signals common to both electrodes. Essentially, differential amplification subtracts the potential at one electrode from that at the other electrode and then amplifies the difference. Correlated signals common to both sites, such as from power sources and electromagnetic devices, but also EMG signals from more distant muscles are suppressed. The common mode rejection ratio provides an index on the extent to which common signal components are attenuated from the signal. As such it is desirable to have the highest common mode rejection (CMR) possible. At the moment the best CMRR that can be realistically achieved with current technology is about 120 (dB/Octave @ e.g. 50Hz). The CMR is expressed in logarithmic form, thus an increase in CMRR from 90 (dB) to 110 (dB) is an increase of 100 x.

Actual Circuit Diagrams

The differential amplifier is used where a difference in potential has to be amplified in the presence of an interfering common-mode voltage. Such interference frequently comes from 50 Hz power line fields, man-made electrical noise, or radiation from other electrical equipment.
Figure 1 shows the basic circuit arrangement for a differential amplifier.

If an out-of-phase (differential) voltage is applied to the inputs of amplifiers A and B, the current flow in A will increase while the current in B will decrease. If both amplifiers and associated parts are identical, the amplifier currents $i_1$ and $i_2$ will be equal and opposite, the net current will be zero and no voltage drop will occur across resistor RC. Under these conditions the output signal is a function of twice the gain of one amplifier.

If both signal inputs are in phase, both (+) or (–), this is called the common-mode signal. In the case of such signals from the pickup power lines, both $i_1$ and $i_2$ will increase or decrease simultaneously, causing a voltage drop on RC. This common-mode voltage results in degeneration (voltage drop on RC) and a reduction in amplifier gain.

Of key importance is the ratio of the [differential signal gain ($A_{diff}$)] to the [common-mode gain ($A_{cm}$)]. This relationship is called the common-mode rejection ratio (CMRR) and is expressed by equation (2-1)

$$CMRR = 20 \log_{10} \frac{A_{diff}}{A_{cm}}$$

(2-1)

Where the CMRR is expressed in decibels.

The CMRR shows the ability of a differential amplifier to attenuate common-mode signals appearing simultaneously with differential signals. CMRR is a ratio of two gains, as shown in equation (2-2)

$$CMRR = 20 \log_{10} \left( \frac{V_{out\text{diff}}}{V_{in\text{diff}}} \right) / \left( \frac{V_{out\text{cm}}}{V_{in\text{cm}}} \right)$$

(2-2)

In determining the CMRR, the two signals (common-mode and differential) are adjusted at the input to produce the same output voltage. For equation (2-2), $V_{out\text{cm}} - V_{out\text{diff}}$.

Therefore, CMRR can be computed from the input voltages as shown in equation (2-3).

$$CMRR = 20 \log_{10} \frac{V_{in\text{diff}}}{V_{in\text{cm}}}$$

(2-3)

The CMRR is then +65 dB. Good amplifiers have CMRR values which range from +60 dB to +100 dB. When two or more such amplifiers are cascaded, the CMRR of each can be add...
The transistors Q1-Q2 are the input differential pair, while transistors Q3, Q5 and Q6 make the common emitter resistor (RE). CMRR is 80 to 86 dB, and the bandwidth (open loop) is 3 MHz. The input impedance is high, about $10^{12}$ ohms and the output impedance is low under 100 ohms. The high-input impedance of the amplifier is a necessary design element, since the amplifier could easily load down the signal source.

The adverse effect of electrode contact resistance on signal input is an additional consideration. Losses incurred at the lead contacts with the skin decrease the available input signal to each amplifier. In the circuit shown in Figure 2, the electrode contact resistors (R3, R4) are in series. High input impedance of the amplifier, however, minimizes the signal loss.

The input signal to an amplifier from an EMG voltage is dependent both on the amplifier’s input impedance and on the resistance of the electrodes placed on the Patient’s body. The input voltage depends on the losses at the lead contacts. This is shown by equation (2-4).

$$EMG_{in} = \frac{Z_{in} \times EMG_{voltage \ source}}{Z_{in} + R \ of \ electrodes}$$

As can be seen from the equation, amplifier input impedance and electrode resistance greatly affect the input signal to the amplifier. The following example shows the effects of input resistance and electrode contact resistance of the received signal voltage. Contact resistance losses are most critical with IC’s whose inputs have resistances of 1 mega ohm or less. One such IC is the MC3403, a forerunner of the TL074. If two amplifiers of an MC3403 IC are used, the total differential input resistance would be 2 mega ohms. Consider the effects of poor electrode contact resistance on the signal source.

It can be shown using equation (2-4) that only 5-10% of the EMG signal is lost. Under good conditions, a loss of less than one percent is possible. Since the TL074 has an input of over $10^{12}$ ohms, only a very small portion of the input signal voltage would be lost.

Since the TL074 is a quad, three of the amplifiers can be used for recording the ECG, EMG, or EEG signal voltage. Two amplifiers are used for the differential input, and one for a single-ended output amplifier. A typical circuit arrangement is shown in Figure 2.

The gain of the inverting amplifier A4 is determined by the ratio of the R1/R8 (100KΩ/8.2KΩ) resistors ($A = 12$). The gain of the differential amplifier is determined from equation.
The gain (shown in the circuit diagram of Figure 3 is: \[ A_{\text{diff}} = 2 \times \frac{100 \, \Omega}{6.8 \, \Omega} \]

\[ A_{\text{diff}} = 29 \]

The gain of the input stage can be controlled by varying the 10 KΩ resistor (R5) between pins 6 and 13. As the resistor is made smaller, the gain is increased. This resistor should not be zero since the circuit might oscillate under high gain conditions. In the circuit shown, resistors of 1% tolerance (or less) should be used, since both halves of the circuit must match. The value of R10 should be adjusted to obtain the best balance of the two signals input to A4. This balance achieves the highest possible CMRR.

**PATIENT LEAD SAFETY**

In medical instrumentation, patient safety is a major consideration. When taking an EMG, the right leg may be common to earth ground on some medical recorders. If a line voltage comes in contact with a hand, arm, or part of the body, a current flow through the body takes place. Less than one milliampere of current through the heart is sufficient to cause fibrillation. If, however, the patient is totally isolated from ground, the potential shock hazard is greatly reduced. Figure 4 shows how, by using an optocoupler, a differential instrumentation amplifier can be isolated from the circuits that follow, as well as from the earth ground. The optocoupler contains an infrared LED and a sensor. The sensor can be a photodiode, phototransistor, or photodarlington. The LED-to-sensor insulation breakdown voltage ranges from 1500 volts to over 20,000 volts, depending on the device used.
OBSERVATION:-

It is observed that there is an alternating relationship between the contractions of biceps and triceps; the relaxation of one force causes the contraction of the other. The action potentials of the muscles (hundreds of fibers) form a wide variety of pulses encompassing a wide range of frequencies. Because of the random display of voltages, an
oscilloscope would be the best instrument for displaying the signal. EMG potentials can be measured on the frontal region sometimes used in biofeedback studies.

![Figure-5 Biceps and triceps muscles](image)

EMG potentials depend on a series of preliminary procedures. Each electrode site was rubbed with alcohol, electrode paste, and electrodes firmly attached. Loose electrodes will cause artifacts, and tight ones will constrict blood circulation.

Measurement was first made on the biceps and triceps. The frequency range of the muscle spikes covers a bandwidth from DC to over 2 KHz. The instrumentation panel, or EMG instrument, was arranged for recording voltage from the range of 3 Hz to 1KHz.

The low-frequency response of an amplifier system was limited either by reducing the value of the coupling capacitor or by inserting special filters refer to the circuit shown in Figure-5, or to the actual panel circuit. The high-frequency roll-off was controlled by leaving switches A1 and A2 open or closed, and the low end was rolled off at approximately 3 Hz by opening A4. Switch B1/B3 was closed and B2/B4 was opened. This increased the amplifier gain. For a one-volt amplifier output, a system gains of 5,000 to 50,000 (75-95 dB) was required. Digital oscilloscope was used to record data from EMG recorder. The output was seen from TP15 on the oscilloscope and also seen the waveforms through DSO on the PC by connecting the output (TP-15) to Ch1/Ch2 through parallel port.

DIP switches SWA and SWB were kept in the Kit as follows:

![SWA and SWB DIP switches](image)

The various waveforms (almost) at different points are as shown below:

- Waveform of biceps 1.3:
- Waveform of biceps 2.1:
Waveform of Contraction point C2.1:-

Waveform of Triceps T1.1:-

Waveform of Triceps T1.2:-

Waveform of Triceps T2.1:-
CONCLUSION

A typical EMG ranges from 0.1 to 0.5 milli volt that may contain frequency components extending up to 10KHz. Modern EMG machines are PC Based. EMG signal is usually recorded by surface electrodes or by using needle electrodes. The amplitude of the EMG signal depends upon the various factors such as type and placement of electrodes, degree of muscular exertions. The needle electrodes in contact with single muscle fiber will pickup spike type voltages where as a surface electrodes pickup many overlapping spikes and therefore produces average voltage effects. EMG signals have been recorded for various positions point Biceps, point triceps and point contractions. This recording belongs to a normal subjects. Electromyogram are used to indicate the voltage levels present in specific muscles of the body. It is observed that there is alternating relationship between the contractions of biceps and triceps the relaxation of one forces the contraction of the other. The frequency range of the muscle spikes covers a bandwidth from DC to over 2 KHz.

1) EMG signals can be used for determining muscle tension and the physical state of the patient.
2) Muscles are contracted by the nerve fibers. These fibers have a resting potential which is quickly reversed upon stimulation.

3) The end of the nerve fibers produces a chemical discharge which causes muscles to contract.

4) EMG amplifiers are similar to EEG amplifiers except that their gain is less and their frequency responses may be broader.

References


