6.16. ELECTROMYOGRAPHY (EMG): RECORDING AND ANALYSIS

Purpose of experiment:

To record electromyograms (EMG) and to examine their parameters

Tasks of experiment:

- To record an electromyogram (EMG) on the biceps muscle of your own upper arm while performing several contractions, and on the calf muscle while performing several different movements;
- To examine EMG parameters (frequency and voltage amplitude) of the recorded EMG at maximum contraction;
- To trigger a muscle stretch reflex in the lower leg musculature by tapping the Achilles tendon (Achilles tendon reflex);
- To record the compound action potential and determine the reflex latency and the conduction velocity.

Theoretical topics

- Membrane potentials of human cells.
- Action potential and its propagation.
- Electrical signals of the human body.
- Electromyogram.
- Muscle stretch reflex, Achilles tendon, reflex latency, conduction velocity, Jendrassik effect, facilitation.

Equipment and materials

Bio-amplifier, EMG electrodes, Reflex hammer, triggering, power supply, Electrode collecting cable, Electrode cream (gel), Connecting cords, Roll of adhesive tape (e.g. Elastoplast), Cobra3 Basic Unit with Universal Recorder software.

Theoretical part

Charge movement, electric fields, and voltages play essential roles in the body, but the complicated chemical and biological processes that induce such charge motion are only partially understood. However, the interplay of the resulting charges and fields is physical in nature and is well understood.

The importance of this human “bioelectricity” cannot be overemphasized as the function of every cell depends on it. Every neuron in the brain, every neuron transmitting any information within the body, every neuron enabling skeletal, cardiac, and smooth muscles is yet another vital
example. Electric voltages measured at different places in the body describe electrical activity, as is seen in Table 6.16.1.

**Table. 6.16.1. Typical amplitude of bioelectric signals.**

<table>
<thead>
<tr>
<th>Bioelectrical signal</th>
<th>Typical amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrocardiogram (EKG/ECG, heart)</td>
<td>1 mV</td>
</tr>
<tr>
<td>Electroencephalogram (EEG, brain waves)</td>
<td>10-100µV</td>
</tr>
<tr>
<td>Electromyogram (EMG, muscle)</td>
<td>300 µV</td>
</tr>
<tr>
<td>Transmembrane potential</td>
<td>100 mV</td>
</tr>
<tr>
<td>Electro-oculogram (EOG, eye)</td>
<td>500 µV</td>
</tr>
</tbody>
</table>

**Electrical Conduction through Blood and Tissues.** When voltage is applied across a metal, a current flows because electrons move under the influence of an electric field. When a voltage is applied across a solution containing positive and negative ions, current flows because both ions move under the influence of the electric field. The conductivity $\sigma$ of a solution is the sum of the contributions made by each ion to the current flow. For low concentrations of these ions, this contribution is proportional to the concentration $n_i$ for that ion, with a proportionality constant $A_{0,i}$:

$$\sigma = \sum_i n_i A_{0,i}$$  \hspace{1cm} (6.16.1)

Table 6.16.2 gives $A_{0,i}$, the molar conductance at infinite dilution for several common ions, while Table 6.16.3 gives typical concentrations of common ions in the blood and in cells. The resistance of a path can be determined using:

$$R = \rho L/A \text{ and } \rho = 1/\sigma.$$  \hspace{1cm} (6.16.2)

The resistance is an extensive property that depends on the intensive property resistivity $\rho$ of the material, and the cross-sectional area $A$ and length $L$ of the structure.

As with many materials, body tissues have dielectric properties, but still have some conductivity, and therefore can be considered as leaky dielectrics. The resistivity of body tissues is shown in Table 6.16.2.

**Table. 6.16.2. Low frequency resistivity of some body tissues, (Ω-m).**

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Resistivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>cerebrospinal fluid</td>
<td>0.650</td>
</tr>
<tr>
<td>blood plasma</td>
<td>0.7</td>
</tr>
<tr>
<td>whole blood</td>
<td>1.6 (Hct = 45 %)</td>
</tr>
<tr>
<td>skeletal muscle</td>
<td></td>
</tr>
<tr>
<td>- longitudinal</td>
<td>1.25-3.45</td>
</tr>
<tr>
<td>- transverse</td>
<td>6.75-18.0</td>
</tr>
<tr>
<td>liver</td>
<td>7</td>
</tr>
<tr>
<td>lung</td>
<td></td>
</tr>
<tr>
<td>-inspired</td>
<td>17.0</td>
</tr>
<tr>
<td>-expired</td>
<td>8.0</td>
</tr>
<tr>
<td>neural tissue (as in brain)</td>
<td></td>
</tr>
<tr>
<td>-gray matter</td>
<td>2.8</td>
</tr>
<tr>
<td>-white matter</td>
<td>6.8</td>
</tr>
<tr>
<td>fat</td>
<td>20</td>
</tr>
<tr>
<td>bone</td>
<td>&gt;40</td>
</tr>
<tr>
<td>wet skin</td>
<td>10$^5$</td>
</tr>
<tr>
<td>dry skin</td>
<td>10$^7$</td>
</tr>
</tbody>
</table>
Cell Membranes and Ion Distributions. The cell membrane divides the intracellular and extracellular regions in neurons and other cells. There are Na+, K+, Cl−, negatively charged proteins, and other charged species both inside the neurons (intracellular) and in the extracellular medium. The concentrations of these ions are such that there is charge neutrality (i.e., an equal number of positive and negative charges) in both the intracellular and extracellular fluids. However, there are negative charges on the inside of the cell membrane and positive charges on the outside of this membrane that produce a resting potential of −70 mV (Fig. 6.16.1).

This means that the intracellular medium is at −70 mV, when the extracellular potential is arbitrarily defined to be 0 V, as is the custom.

Since only potential differences are significant, we are not limiting the analysis by fixing the extracellular potential. This resting potential is the usual potential difference when there is no unusual neural activity and is known as the polarized state. (The propagation of an electrical signal would constitute this type of unusual activity.)

It will be shown that, while there is charge neutrality both inside and outside the membrane, the concentrations of each ion are not equal inside and outside the cell. The differences in ion concentrations on each side of the cell membrane are due to a dynamic balance. When there are changes in the permeability of the cell membrane to different charged species, there are transient net charge imbalances that change the potential across the cell membrane. For example, an increase in the membrane potential from −70 mV to the −60 mV seen in Fig. 6.16.2 is known as depolarization, while a decrease from −70 mV to say −80 mV is called hyperpolarization. Depolarization is due to the net flow of positive charges into the cell or negative charges to regions outside the cell. Hyperpolarization is due to the net flow of negative charges into the cell or positive charges to outside the cell. Such changes in ion permeability are often termed as changes in the ion channel.

Fig. 6.16.1. Ion concentrations (in mmol/L) in a typical mammalian axon nerve cell (ni) and in the extracellular fluid surrounding it (no), and their ratios (ni/no).

<table>
<thead>
<tr>
<th>Inside axon</th>
<th>Membrane</th>
<th>Extracellular fluid</th>
<th>n_i/n_o</th>
</tr>
</thead>
<tbody>
<tr>
<td>[K+] = 150</td>
<td>-</td>
<td>[K+] = 5</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>[Misc'] = 5</td>
<td></td>
</tr>
<tr>
<td>[Cl−] = 9</td>
<td>+</td>
<td>[Cl−] = 125</td>
<td>13.9</td>
</tr>
<tr>
<td>[Misc'] = 156</td>
<td>+</td>
<td>[Misc'] = 30</td>
<td>0.2</td>
</tr>
<tr>
<td>V = -70 mV</td>
<td>-</td>
<td>V = 0 mV</td>
<td></td>
</tr>
</tbody>
</table>

Charge neutrality Charge neutrality

Fig. 6.16.2. The membrane resting potential of −70 mV (inside the membrane relative to the always fixed 0 mV outside) – the polarized state, along with potential disturbances showing depolarization (voltage increases from the resting potential value), repolarization (returns to the resting potential), and hyperpolarization (decreases from the resting potential).

Figure 6.16.1 also shows the concentrations of some of the important charged species inside and outside the cell under resting (i.e., polarized) conditions. It can be seen that there are many more Na+ outside (145 mmol/L) than inside (15 mmol/L) the cell, but many more K+ inside (150 mmol/L).
mmol/L) than outside (5 mmol/L). Including miscellaneous positive ions outside the cell, there are 165 mmol/L of positive ions both inside and outside the cell. Similarly, there are many more Cl− outside (125 mmol/L) than inside (9 mmol/L) the cell, but many more miscellaneous negative ions (including proteins) inside (156 mmol/L) than outside (30 mmol/L). There are also 165 mmol/L of negative ions both inside and outside the cell.

Several driving forces determine the ionic concentrations in general, and these intracellular and extracellular concentrations in particular:

1. Concentrations naturally tend to be uniform everywhere, so concentration gradients across the cell membrane initiate flows of these species from the regions of higher concentration to regions of lower concentrations in order to equalize the intracellular and extracellular concentrations. This is described by Fick’s First Law of Diffusion:

\[ J_{\text{diff}} = -D_{\text{diff}} \frac{dn}{dx}, \quad (6.16.3) \]

where \( J_{\text{diff}} \) is the flux of ions in the \( x \) direction (the number of ions flowing across a unit area in a unit time), \( D_{\text{diff}} \) is the diffusion constant, \( n \) is the local concentration of ions, and \( \frac{dn}{dx} \) is the local concentration gradient.

2. Because the potential is negative inside the cell, we would expect positive ions to enter the cell and be more dominant in the intracellular fluid than in the extracellular fluid and for there to be such concentration gradients; this is true for K+ but not for Na+. Similarly, we expect negative ions to leave the cell because of the resting potential and be more dominant outside the cell than inside – and again for there to be concentration gradients; this is true for Cl− but not for the negatively-charged proteins, which form the bulk of the miscellaneous negative ions.

When charged species are in an electric field, they are accelerated and eventually attain a steady-state drift velocity, \( v_{\text{drift}} \), because of collisions that act as a drag force. As shown in Problem 12.7, the drift velocity of a given ion is:

\[ v_{\text{drift}} = \mu E, \quad (6.16.4) \]

where \( \mu \) is called the mobility and \( E \) is the electric field. The flux of ions due to this electric field is:

\[ J_{\text{select}} = n v_{\text{drift}} = n \mu E. \quad (6.16.5) \]

3. The cell membrane permeability and active processes cause the ion concentrations on either side of the membrane to deviate from the values expected from diffusion and the motion of charges in electric fields. The cell membranes are permeable to K+ and Cl−, which explains why they behave as expected. Proteins are never permeable to the cell membrane, which is why the concentration of negative-protein ions is unexpectedly high inside. The chemical mechanism called the Na+ pump (or the Na+-K+ pump) actively transports 3Na+ from inside to outside the cell for every 2K+ it transports from outside to inside the cell; this keeps Na+ outside the cell and K+ inside. The high Na+ concentration outside the cell is the result of the Na+ pump fighting against the driving electrical forces and the tendency to equalize concentrations (Fig. 6.16.3). The high K+ concentration inside the cell is the result of the electric forces and the Na+ pump fighting against the tendency to equalize concentrations. The high Cl− concentration outside the cell is the result of the electrical forces fighting against the tendency to equalize concentrations. The concentration of negative protein ions is unexpectedly high inside because they are large and not permeable to the cell membrane.

Figure 6.16.4. depicts the directions of motion for charged and neutral molecules for either the random thermal motion in diffusion or the directed effect of an electric field. Figure 6.16.5. shows
how a concentrated band of charged and neutral molecules changes due to either diffusion or an electric field.

![Fig. 6.16.3](image.png)

**Fig. 6.16.3.** Mechanisms for ion flow across a polarized cell membrane that determine the resting membrane potential.

![Fig. 6.16.4](image.png)

**Fig. 6.16.4.** The direction of motion for charged and neutral molecules due to (a) diffusion (at a given instant) and (b) an electric field.

![Fig. 6.16.5](image.png)

**Fig. 6.16.5.** An initial band of charged and neutral molecules (in (a)) changes very differently by the uniform thermal spreading in diffusion (in (b)) and the separation caused by an electric field (in (c)).

**Types of Cell Membrane Excitations.** There are two qualitatively different types of axon excitations: graded potentials and action potentials.

*Graded potentials* (Fig. 6.16.6) are minor perturbations in the membrane potential due to the binding of neurotransmitters, the stimulation of sensory reception, or spontaneous ion leakage through the cell membrane. There is no threshold needed to stimulate graded potentials, which can last for 5 ms to several min. Graded potentials can be either membrane depolarizations or hyperpolarizations. Successive graded potentials can add to one another. They propagate only short distances along the membrane before decaying.

*Action potentials* are qualitatively different from graded potentials in every way (Fig. 6.16.6). Initially they have relatively large depolarizations by ~15–20 mV above the resting value of −70 mV to a threshold of about ~ −55 mV. At this threshold potential the cell membrane opens up allowing Na+ transport. The potential lasts for 1–5 ms, and it always involves depolarization of the
membrane. Each action potential opens the cell membrane, and they do not add to one another. There is no decrease in potential along the entire length of the neuron cell axon, as this action potential leads to propagation of an electrical signal along the axon.

Fig. 6.16.6. The (subthreshold) graded potentials and (above threshold) action potentials.

**Effects of Electric Shock.** External electrical currents running in the body can cause damage by interfering with normal bodily function – for example, by preventing your otherwise operational skeletal and cardiac muscles from functioning normally – and by destroying tissues through thermal heating (Table 6.16.3). Muscles are controlled by a series of electrical impulses sent by the brain.

**Table 6.16.3.** Effect of currents (in mA) on the human body (for about 1 s). All values are approximate.

<table>
<thead>
<tr>
<th>Effect</th>
<th>DC</th>
<th>AC (60 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>slight sensation at contact point</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>perception threshold</td>
<td>3.5</td>
<td>0.7</td>
</tr>
<tr>
<td>shock</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– not painful, no loss of muscular control</td>
<td>6</td>
<td>1.2</td>
</tr>
<tr>
<td>– painful, no loss of muscular control</td>
<td>41</td>
<td>6</td>
</tr>
<tr>
<td>– painful, let-go threshold</td>
<td>51</td>
<td>10.5</td>
</tr>
<tr>
<td>– painful, severe effects: muscular contractions, breathing difficulty</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>– possible ventricular fibrillation (loss of normal heart rhythm)</td>
<td>500</td>
<td>100</td>
</tr>
</tbody>
</table>

External AC currents (60 Hz) above approximately 10mA override these signals and prevent you from exercising control over your muscles. You can barely control your muscles at 10mA and barely “let go” of an object. At higher currents your muscles are under external control, possibly leading to breathing and circulatory difficulties. Ventricular fibrillation occurs from 100mA to 4 A and paralysis occurs, along with severe burns (and death), at over 4 A.

The skin is a very important barrier to current flow ($I$). The resistance ($R$) through dry skin is roughly 100,000–600,000 ohms while through wet skin it is only about 1,000 ohms. If the skin barrier is overcome, the resistance drops (so there is more current flow per unit voltage, as per Ohm’s Law).
Body segment resistance (in ohms), ignoring skin contribution. As shown, 500 ohms is the contribution from one finger.

Figure 6.16.7 shows that the internal body resistance is low, approximately 400–600 ohms from head to foot and 100 ohms from ear to ear. The amount of current that can flow in the body induced by a voltage source (V) is limited by two factors: (1) Ohm’s Law says the current will be \( I = \frac{V}{R} \). (2) The current is sometimes limited by the voltage source itself.

Let us assume the skin barrier has been broken so that effective body resistance is about 500 ohms. (Please do not attempt this!!!) The 120V AC from a wall outlet will produce a current of 240 mA, which is over twice that needed to cause death through ventricular fibrillation. Circuit breakers typically trip at 15 A, so this flow through the body will be uninterrupted by the circuit breaker. How about DC sources? The current induced by the often-used 9V battery is 18 mA, which can cause a shock. (You can easily draw this current from such a battery.) The voltage across a car battery is 12V with 400–600A (cranking amps), so the resulting shock can be even worse.

**Electromyography.** About 40 per cent of the body is skeletal muscle, and perhaps another 10 per cent is smooth and cardiac muscle. Some of the same basic principles of contraction apply to all these different types of muscle.

All skeletal muscles are composed of numerous fibers ranging from 10 to 80 micrometers in diameter and each fiber is made up of successively smaller subunits. In most skeletal muscles, each fiber extends the entire length of the muscle. Except for about 2 per cent of the fibers, each fiber is usually innervated by only one nerve ending, located near the middle of the fiber.

The initiation and execution of muscle contractions occur in the following sequential steps:

1. An action potential travels along a motor nerve to its endings on muscle fibers.
2. At each ending, the nerve secretes a small amount of the neurotransmitter substance *acetylcholine*.
3. The acetylcholine acts on a local area of the muscle fiber membrane to open multiple “acetylcholine-gated” channels through protein molecules floating in the membrane.
4. Opening of the acetylcholine-gated channels allows large quantities of sodium ions to diffuse into the interior of the muscle fiber membrane. This initiates an action potential at the membrane.
5. The action potential travels along the muscle fiber membrane in the same way that action potentials travel along nerve fiber membranes.
6. The action potential depolarizes the muscle membrane, and much of the action potential electricity flows through the center of the muscle fiber. Here it causes the sarcoplasmic reticulum to release large quantities of calcium ions that have been stored within this reticulum.
7. The calcium ions initiate attractive forces between the actin and myosin filaments, causing them to slide alongside each other, which is the contractile process.
8. After a fraction of a second, the calcium ions are pumped back into the sarcoplasmic reticulum by a Ca++ membrane pump, and they remain stored in the reticulum until a new muscle action potential comes along; this removal of calcium ions from the myofibrils causes the muscle contraction to cease.

Skeletal muscle emits an electrical signal, whose recorded dependence is called an electromyogram (EMG). Electrical recording of the EMG using needle or surface electrodes is an important diagnostic indicator used in clinical neurology to diagnose neuromuscular disorders.
including peripheral neuropathies, neuromuscular junction diseases, and muscular dystrophies. The EMG is also used in research studies as an estimator of muscle activity for biomechanics and motor control experiments.

Electromyographs are quite universally applicable diagnostic systems. They can record, amplify, and measure the bioelectric activity of muscles and nerves under various circumstances. Their respective amplifiers perform high sensitivities, have a high input impedance, a large bandwidth, and very low noise. According to the configuration, the electromyograph may be equipped with an electric, acoustic, visual, and magnetic stimulator. The principal construction of an electromyography is: a personal computer (PC) or microcontroller (MC) that acts as the central control, signal processing, and storage unit of the EMG machine. It is equipped with a hard disk as data storage, PC monitor with color display, keyboard, and laser printer. The necessary components, like amplifier, analog-to-digital converter, and the stimulation units are integrated into EMG machines which are applicable in: Neurological practices, Neurological departments in hospitals, clinics, Neurological rehabilitation clinics, Neurosurgical clinics for intra-operative EP-monitoring, Neurological research, Orthopedic clinics, Sports medicine.

To match the various requirements, EMG machines are built of system components in a modular way. They vary especially in relation to the number of channels and the number and type of stimulators, software, and storage medium.

An EMG device is able to carry out a great number of neurophysiological examinations, where each examination has its own stimulation, recording, display, and evaluation characteristics. These different parameter settings are stored in the machine and may be changed or even newly designed by the user. Thus it is easily possible to get to numbers of 20–40 recording programs according to the stage of extension of the particular machine.

Electrodes. The standard electrode used in electromyography is the concentric needle electrode. In a steel cannula there exists a platinum central wire coated with an isolation layer (araldite). The potential difference between the platinum wire as the active electrode and the outer steel cannula as the indifferent electrode is amplified. The electrodes are mostly 2–6 cm long and 0.3–0.6mm in diameter. Their size and application are related to the size of the muscle to be recorded. In some cases, bipolar needle electrodes are also used. In this case, two central platinum wires isolated from each other are put in one cannula. It is necessary to use an additional ground electrode, which is applied on the examined extremity near the recording site.

In neurography and in somatosensory evoked potentials (SEP), stimulation and recording electrodes are applied. In both cases, surface electrodes are mostly used, and the ground electrode is placed in between. Only in rare cases and in specialized clinics are needle electrodes for recording and stimulation applied. These needles are applied in pairs – one proximal and one distal to the examined nerve, and with this technique larger and more pronounced potentials are achieved. In evoked potentials during clinical routine examinations surface cup electrodes are attached to the scalp; they are applied in a similar way to the EEG electrodes.

**Methodology**

With the exception of the heart muscle, the contractions of striated muscles can be controlled at will. This characteristic permits the observation of individual muscle group activities. An electromyogram (EMG) can be used to measure (record) the electrical activity (i.e. the sum of the action potentials) of a muscle or even of several muscles on the skin surface when they contract. For an electromyogram, the electrical activity of a muscle is recorded in the relaxed state as well as during contractions of varying strength.

When the muscle is at rest, no large amplitudes are to be seen, but numerous large muscle potentials (compound action potentials) can be observed when the muscle is flexed. (Fig. 6.16.8). The frequency of the EMG is between 50 and 100 Hz at maximum contraction. The amplitude of
the EMG depends on many factors such as the attachment of the electrodes, for example. It is 0.6 mV in the measurement shown (the 1000 times amplification)

![EMG upper arm](image1.png)

**Fig. 6.16.8.** Typical result of EMG of upper arm.

Tapping the Achilles tendon stretches the calf muscle and causes a reflex contraction in the muscle. This happens because the spindles sense the stretch and send an action potential to the motor neurons which then cause the muscle to contract. The amplitude of the muscle action potential is higher with tensed arm musculature than with relaxed arm musculature (approx. 3 mV compared to approx. 2 mV). The cause of this so-called Jendrassik effect is that, as a result of the tensing of the arm musculature, the other motoneurons of the spinal cord are innervated (facilitation).

The reflex latency (= the interval between the stimulation and the muscle action potential) is approximately 40 ms. With a nerve tract length \( l \) (Achilles tendon – spinal cord – muscle) of 2 m, the conduction velocity is 50 m/s (Fig. 6.16.9).

![EMG lower leg](image2.png)

**Fig. 6.16.9.** Typical result of EMG: the compound action potential of the lower leg
Procedures

Upper Arm:

1. Connect the instruments as shown in Fig. 6.16.10. Connect the bio-amplifier AMPLIFIER OUT to Cobra3, AMPLIFIER IN 2 (red to + and blue to -). Connect the electrode collecting cable to the bioamplifier AMPLIFIER IN.
2. Call up the COBRA3 MEASURE programme in Windows
3. Select UNIVERSAL WRITER as the measuring instrument
4. Put a little electrode cream on the electrodes and use adhesive tape to attach them firmly to the upper arm (biceps) in the sequence as shown (Fig. 6.16.11).
5. Do not allow the green cable to hang down, but (to reduce radiation interference) gather it together and tape it firmly to the arm (with the other cables).
6. Set the bio-amplifier to 1000 times amplification and EMG.
7. Set the measurement parameters (see Fig. 6.16.12) and go to measurement with CONTINUE and start MEASUREMENT
8. Briefly flex the muscle a few times during the measurement.
9. The recorded EMG should be similar to that in Fig. 6.16.8.
10. Calculate the voltage amplitude $U_m$ of the EMG (Fig. 6.16.8).
11. Calculate the period $T$ of the breathing cycle – the time duration between maximum values (Fig. 6.16.8).
12. Calculate the frequency of EMG ($f = \frac{1}{T}$).

Fig. 6.16.10: Experimental set-up.

Fig. 6.16.11. Attaching the electrodes.
Lower leg:

1. Connect the instruments as shown in Fig. 6.16.13.
2. Connect the bioamplifier AMPLIFIER OUT to Cobra3 ANALOG IN 2 (red to + and blue to -).

Fig. 6.16.12. Measurement parameters.

Fig. 6.6.13. Experimental set-up.
3. Connect the electrode collecting cable to the bioamplifier **AMPLIFIER IN**.
4. Connect one plug of the reflex hammer to the yellow **ANALOG IN 1** socket of the Cobra3 interface and the other plug to the red voltage output **OUT** socket.
5. Call up the **COBRA3 MEASURE** programme in Windows.
6. Select **UNIVERSAL WRITER** as the measuring instrument.
7. Put a little electrode cream on the electrodes and use adhesive tape to attach them firmly to the inside of the lower leg, above the Gastrocnemius muscle, in the sequence shown (Fig. 6.6.14).

![Fig. 6.6.14. Attaching the electrodes.](image)

8. Do not allow the green cable to hang down, but (to reduce radiation interference) gather it together and stick it firmly to the ankle (with the other cables).
9. Set the bio-amplifier to 1000 times amplification and **EMG**.
10. Set the measurement parameters (see Fig. 6.6.15) and go to measurement with **CONTINUE**.
11. Hold the bent lower leg of the (standing) test person with the left hand. Socks should be left on for better insulation; relax all muscles as much as possible.

![Fig. 6.6.15. Measurement parameters.](image)

12. Tap the Achilles tendon with the reflex hammer to trigger off simultaneously the muscle stretch reflex and the measurement.
13. Save the result and prepare for a new measurement.
14. Have the test person stretch his arm musculature; he should do this by hooking his hands together and strongly pulling them against each other as if to force them apart. Repeat the action potential measurement as described above.

15. The recorded EMG: the compound action potential should be similar to that in Fig. 6.16.9.

16. Calculate the voltage amplitude $U_m$ of the muscle action potential with tensed and relaxed arm (Fig. 6.16.9).

17. Calculate the reflex latency $T_L$ and the conduction velocity ($v = \frac{I}{T_{Lat}}$).

**Note**

ANALOG IN 1 is only required for triggering the measurement procedure with the reflex hammer. This (disturbing) channel can be removed from the diagram: Change ANALOG CHANNEL 2 to NO Y AXIS, and change ANALOG CHANNEL 1 to ANALOG CHANNEL 2.

**References:**