# AN EMG CONTROLLED MULTICHANNEL STIMULATOR

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## Abstract:

A myoelectric controlled stimulator for the functional electrical stimulation is described. It is capable of picking up the electromyogram of a muscle with reduced voluntary activity and controlling the muscles excitation as a force amplifier.

## Introduction:

A paralysed handicapped will have no or only partiell voluntary control of the normal muscle functions of his limbs. By means of Functional Electrical Stimulation (FES) it is possible to stimulate these muscles to compensate partially the functional deficit. To control the stimulation one way is to pick up the myoelectric activity of a voluntarily controlled muscle. This is especially useful if this muscle participates naturally in the intended movement. The contraction of a partially paralysed muscle, which is essential to execute a certain movement, may be controlled in the same manner. A blockdiagram is shown in fig. 1:

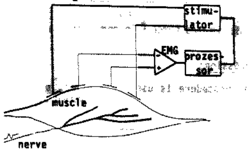


Fig. 1: Block diagram of the EMG controlled stimulator

The closed loop installed this way has a positive feedback, generating maximum force output. In order to avoid this we suppress the stimulation artefacts and the electromyographic activity caused by the stimulation by opening the loop. A sufficient control signal has to be obtained through adequate processing of the normal EMG and by the extraction of stable control parameters for the stimulation.

## Method:

Usually rectification and smoothing of the myoelectric signal is sufficient to estimate the muscle force. However this simple methode is to sensitive to the artefact generated by the stimulation. To obtain a stable estimation of the force we gained advantage of a method which is described in /1/. Additionaly we developed a procedure to suppress the stimulation artefacts:

The distribution of the EMG amplitudes may be described as a zero-mean gaussian process. As the muscle activity and accordingly the EMG amplitude e(t) increases the variance of the EMG amplitude distribution increases and also the probability $p(|e|>\delta_1)$, that the absolute EMG amplitude $|e(t)|$ exceeds a certain threshold $\delta_1$. The EMG signal is sampled 200 to 600 times per second. If these samples $a_i$ have an absolute amplitude which is larger than the threshold $\delta_1$, $a_i = 1$ otherwise $a_i = 0$. These samples $a_i$ are sequentially entered to a shiftregister and at every sampling time the $a_i$ of the last 256 values are added up. The resulting sum $A = \sum a_i$ is an estimate of the muscle activity.

With the help of a look-up table the relationship between the force produced by the muscle and the force estimated from the EMG is linearisised. The result is shown in fig. 2.

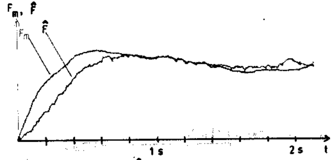


Fig. 2: Estimated force $\hat{F}$ in comparison with measured force $F_m$

Artefact suppression:

A special procedure is used to suppress the stimulation artefact. Fig. 3 shows a measured EMG signal including a stimulation artefact.

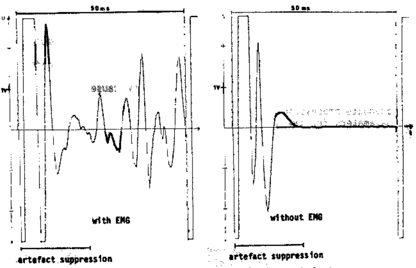


Fig. 3: EMG signal and stimulation artefact

Each time a stimulation pulse occures, a large artefact signal is picked up by the EMG electrodes. In order to suppress this artefact, we introduced a threshold $\delta_2$ which is a little bit above the highest expected EMG amplitude. Each time the signal surpasses the threshold $\delta_2$ due to an artefact, the sampling of the EMG signal is stopped for about 10 ms. The result is illustated in fig. 4.

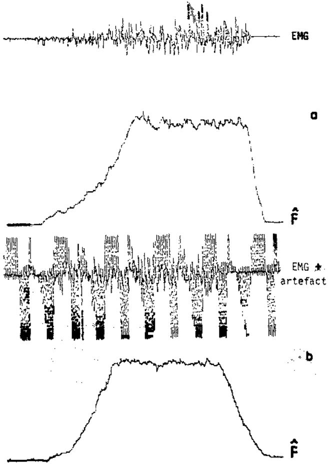


Fig. 4: EMG signal and processor output with and without stimulation

The figure above shows, that the artefacts in the unprocessed EMG signal e(t) has only a little influence on the output signal $\hat{F}$.

The performance of the EMG controlled stimulator is shown in fig. 5. The output of the EMG processor $\hat{F}$ (an estimate of the voluntary innervation) is plotted in relation to the measured force with and without stimulation. It is obviously that the force corresponding with a certain level of innervation is larger with the support of the stimulation than without it. Therefore the stimulation unit may also be called a "myoelectric force amplifier"

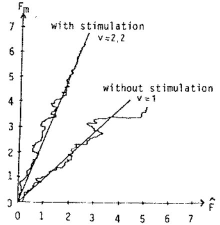


**Fig. 5: EMG - force relation**

## Realization:

**The** processed EMG **signal** controls in our unit **up to four stimulation channels.** The stimulation pulses of the four channels **are generated** sequentially in one block and 10 ms later the EMG is picked up **for the rest of** the time interval till the next sequence. **Because** the stimulator **pulses are charge compensated the artefact is** minimal.

**The EMG amplifier is decoupled from the EMG processing unit by the use of optocouplers and dc/dc-converters. Then the signal passes a fourth order Bessel highpass filter to eliminate the dc-offset and movement artefacts of the electrodes. The cut off frequency of the filter is set to 100 Hz to attenuate the 50 Hz line noice. The filter reacts with a well damped oscillation to the stimulation pulse. Then the filtered EMG signal is rectified to save processing time.**

**After analog-digital-convertion the signal is processed with a Z80 microprocessor in CMOS technology according to the methode described above. The relation between the estimated force and the stimulation amplitude is figured in four look-up tables, one for each stimulator. We use a special algorithm to enter the values into this table:**

### Movement program:

The progress of a movement program is divided into 256 sequential steps. Each of these steps is attributed with a certain combination of stimulation parameters. Only those steps at which the linear relation between the estimated force and the stimulating pulse changes, have to be changed. All the other steps are linearily interpolated. Fig. 6 explains this programming:

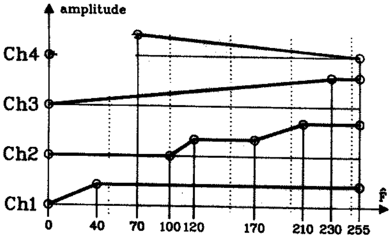


Fig. 6: The movement program

With this method it is possible to generate complex movement programs by changing only a few steps of the program.

## Conclusions:

The control of incomplete paralysed muscles may be generated in a simple way: The remaining voluntary electromyographic activity of a muscle controls its own excitation without the use of other muscles. Instability caused by the feedback structure is avoided by decoupling the stimulation and the EMG. Supplementary the EMG processor may be used to control congenial muscles or other implements.

## References:

/1/ Dunfield V., Shwedyk E.: Digital e.m.g.Processor, Med. Biol. Eng.Comp., 1978, 16, pp. 745 - 751

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