# COMPONENTS

## COMPONENTS FOR SIGNAL ACQUISITION AND PROCESSING IN EXTERNALLY POWERED PROSTHETICS

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*Summary*

*It is observed that fitting of electric hand prostheses is sometimes difficult due to the patient's special needs and desires. Some of these problems can be solved by designing the control components as modules, and thereby rendering a new dimension of flexibility to such systems. Standard myo-electric antagonistic control may be modified to three-state control, even employing mechanical movement transducers.*

*A program of modules is under development. It is suggested that international standardization of the modules is a natural next step, once the modular approach is generally accepted.*

### Introduction

Successful fittings of motorized artificial hands on a wide basis have been reported from several countries, including Austria, Italy, The Netherlands, The Soviet Union, and Sweden. Although the range of acceptance of these devices varies considerably depending upon the source of information, it is beyond doubt that many devices are indeed applied with immediate success. This does not mean, however, that all is well, even accepting the fact that the powered artificial hands applied are not very well designed, technically and functionally. A perhaps even more serious drawback with present systems is their rigidity. Prosthetists are quite commonly confronted with patients who are in need of an artificial arm or hand, but who lack the ability of producing an adequate control signal from the amputation stump. Myo-electric control, for example, requires two separate control sites in the stump region, but many patients lack either the innervation of the muscles or the ability to separate their function. In these cases,

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modifications of the original system have to be carried out, aiming at solutions such as control of the prosthetic hand by means of either mechanical switches or myo-electric three-state logic. This development is not only very time-consuming but is, unfortunately, successful only in the more ambitious centers.

The situation as described here means that the patient must conform to the limited kinds of prosthetic aids available, rather than be supplied with a device built for him, taking into consideration his special desires and disability. This paper is concerned with the design of modular control systems that make it easy for the prosthetist to assemble a custom-made control system for the powered aid of an amputee.

## The Modular System Concept

The principle of modular control systems is best demonstrated through an example. Consider the block diagram of a reasonably sophisticated myoelectric hand-prosthesis (Fig. 1). There is a great number of blocks in this figure, each of them representing a function essential to the performance of the entire system. It is certainly possible to envision each one of the blocks as a hardware module. It would, however, be impractical to allow such flexibility, which would, in fact, approach a complete detail-for-detail assembly process for every new patient. Alternatively, Figure 2 shows a block diagram with the same basic function as the one in Figure 1. Again associating the blocks with hardware modules, we find that in this case the lack of flexibility does not allow some of the important adjustment to be made. As a compromise, the modular approach may be contemplated.

The advantage of the modular approach put forward in the present report is, as indicated in the preceding paragraph, that it allows systems to be built to fit individual patients, considering their personal desires and disabilities. We consider, as an example, the fitting of myo-electrically controlled hands. A number of variations, which will affect the design of the control system are possible:

(a) There is a pair of electrode sites with good discrimination available in the stump region: standard systems are applicable.

(b) Two sites with low separation are available: standard systems may be applicable.

(c) Only one site is to be found: some logic arrangement must be employed.

(d) No suitable EMG-site can be found: a mechanical control site should be sought.

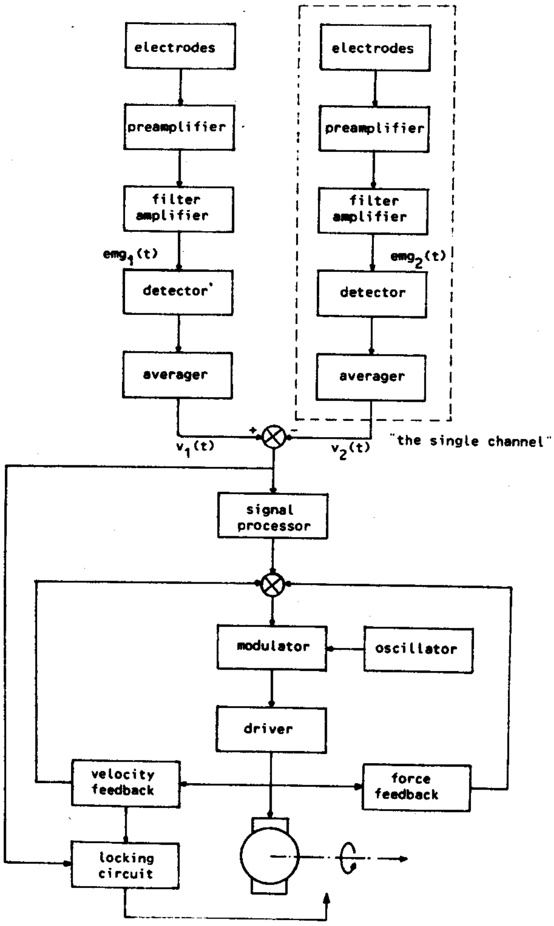


Fig. 1. Block diagram of a myo-electrically controlled finger flexion/extension system (the SVEN hand).

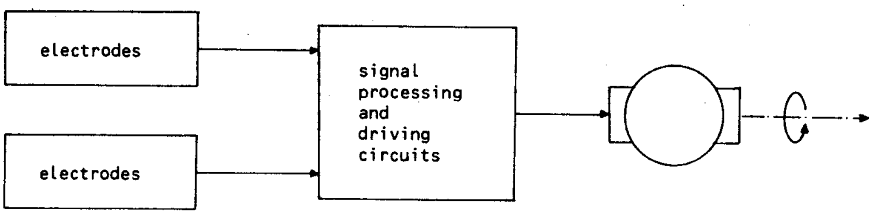


Fig. 2. Modules of a practical hand-prosthesis

Without elaborating upon the significance of the statements, we observe that the desires of the patients vary:

(I) The patient needs only straight-forward on-off function.

(II) The patient has a need of a graded, proportional control of force and velocity.

Standardized control systems do not presently make it possible to meet all the demands (a) through (d) in combination with the needs (I) and (II). Figure 3 shows a block-diagram of a practical design. The two blocks are interconnected in such a way that the first block delivers an amplified EMG into the second one. Still, the signal needs some processing in order to be useful for control (Fig. 1). This processing is performed in the second block which contains all the residual electronics.

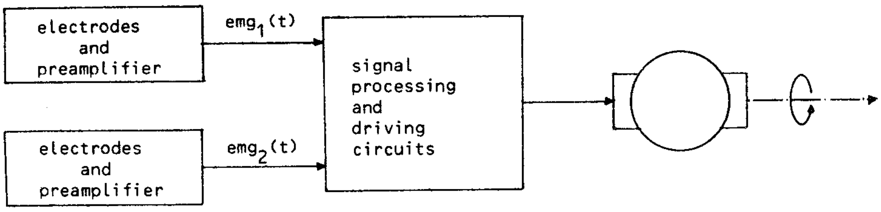


Fig. 3. Modules of a prosthesis with active electrodes.

It is interesting to note that the EMG itself is not synonymous with information; but the EMG contains information which must be decoded. In one sense, the EMG can be looked upon as a modulated carrier wave in a communication system, and just as in telecommunications the "receiver" can be used as a concept, here called a "single channel" /1/. The EMG can indeed be modeled as an amplitude-modulated wave,

$$emg(t) = u(t) \cdot n(t),$$

in which n(t) represents a random function with Gaussian amplitude distribution, and u(t) represents information (on, for example, the contraction level of the muscle). The single channel presents the signal v(t) at the output. This signal is obtained via detection, for example, performing the operation

$$v(t) = \frac{1}{T}\int_{t-T}^{t} |emg(t)|^k \, dt,$$

k denoting a constant. There is no reason as far as system design is concerned why the myo-electric receiver should not be contained in one module. It may be of interest to perform additional processing of the signal in a subsequent block, but it is hard to see why the modulated wave should be made available between two modules.

The block diagram in Figure 4 shows modules which are naturally associated with a hand prosthesis system if the above discussion is considered. The first module contains electrodes, preamplifier, signal detector and averager. The second module contains the electronics necessary to operate the electric motors of the device. Furthermore, a third module can be added to the second one to modify the systems electronics in various ways: this may make possible, for example, the use of a single input signal to control active closing and opening of a hand /2/.

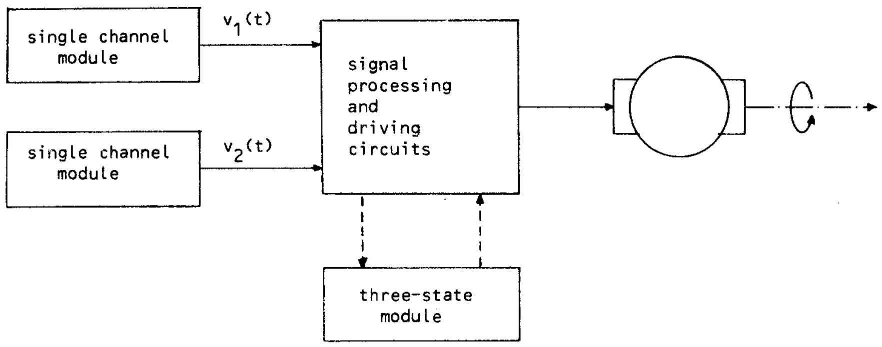


Fig. 4. Modules for a hand-prosthesis, allowing adequate flexibility for fitting to patients with different desires and disabilities

The obvious advantage of this modular approach lies in the ease with which the system can be modified to accommodate the various degrees of freedom needed in order to built a system around the patient. Figure 5 shows examples of how the idea can be implemented, including, e.g., the use of mechanical control sites and three-state myo-electric control.

In the prosthetics research program carried out at The Department of Applied Electronics, Chalmers University of Technology, and

The Laboratory of Clinical Neurophysiology, Sahlgren Hospital, Goteborg, Sweden, some efforts are being made to develop a modular control system. The first step was to develop a pre-amplifier module, later to be included in a complete myo-electric signal single channel unit. It was decided to use a design compatible with a commercially available system (Viennatone). The internal electronics, however, is an original development. Three operational amplifiers in flat-pack capsules are assembled on miniature printed circuit-boards. The characteristics of this module are shown in Table 1. It should be emphasized that this performance is achieved at moderate expense (Fig. 6). Parts for the module cost less than $ 20.

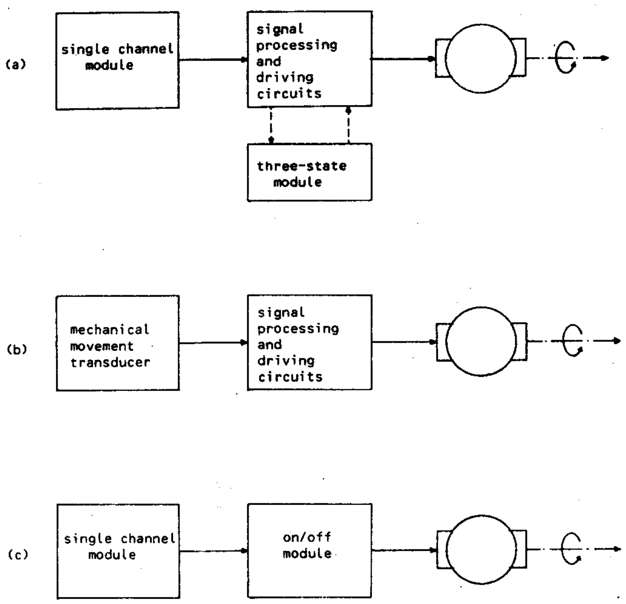


Fig. 5. Examples of variations of the system depicted in Figure 4;
(a) myo-electric three-state control,
(b) mechanical movement control,
(c) myo-electric on-off control.

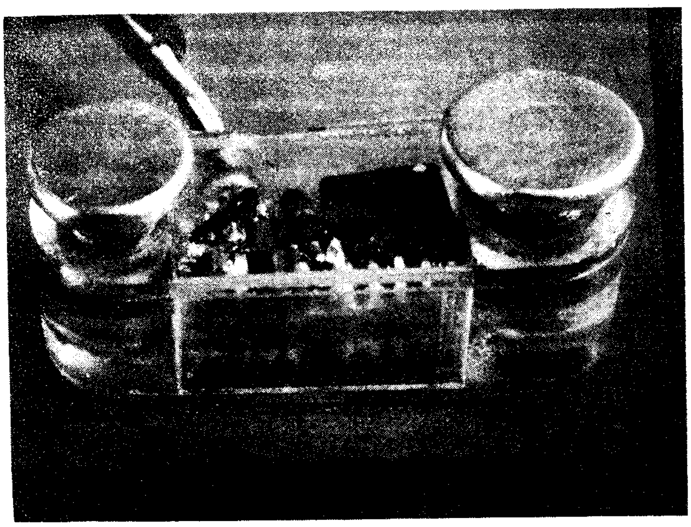

Fig. 6. Preamplifier module for control of the SVEN hand

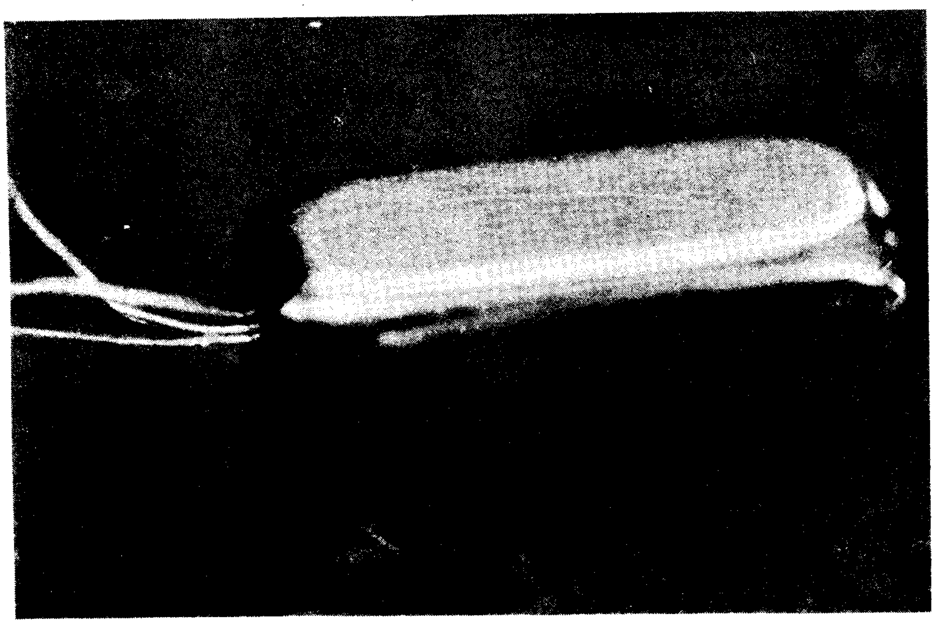

Fig. 7. Skin contour transducer

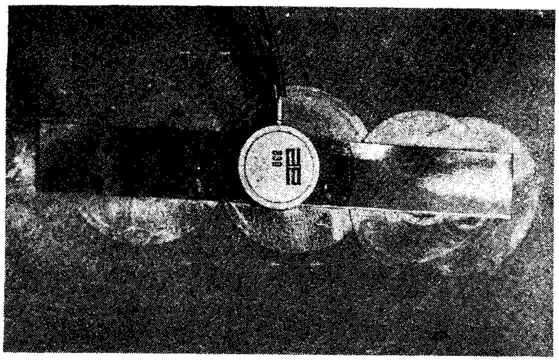

Fig. 8. Muscle movement transducer

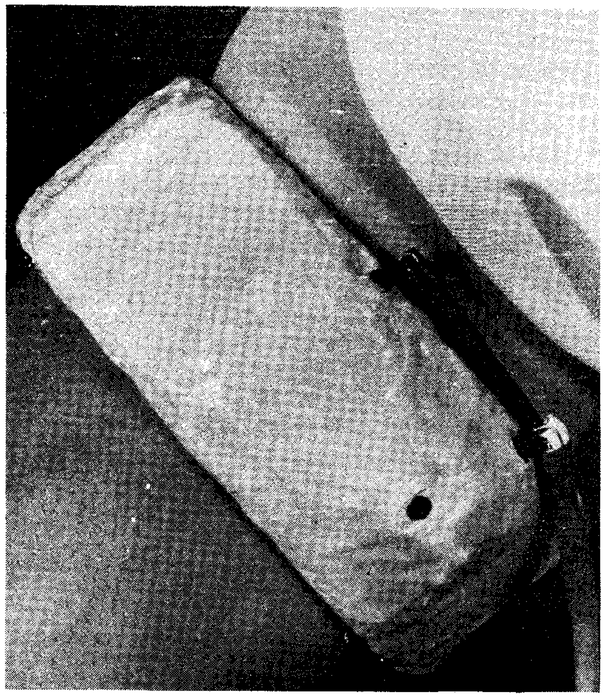

Fig. 9. Telemetry system for wireless acquisition of EMG from muscles in the stump

Table 1.
Preamplifier Module Characteristics

| | |
|---|---|
| Gain at 125 Hz | 40 |
| Input impedance | 4.4 Mohm differential |
| Bandwidth | 0-10 kHz |
| Noise | 3 μV RMS referred to input |
| Common-mode rejection ratio | 90-100 dB; ±2 dB (-10° to +50°C) |

Alternative designs of the completed module include mechanical movement modules /3/ and an FM telemetry module /4/, all of them compatible with the input of the module containing the system electronics. Figures 7 and 8 show the movement transducers, and the telemetry system is illustrated in Figure 9. These modular components have been designed for applications not only in prosthetics, but in powered orthotics as well.

Implications for International Standardization

The appearance of the module concept makes it natural to discuss standardization of components, including setting standards for the electrical input/output characteristics of the modules, and perhaps also their physical design. Such standardization should make it possible to assemble systems from parts produced by different manufacturers. Of course, the standardization rules must be subject to considerable discussion before a decision can be reached on how they should be set.

In the case of a myo-electrically controlled hand-prosthesis the first module may be specified as indicated in Table 2. The values given in the table have been arrived at through the research and development carried out in the work on the multifunctional SVEN hand /5/. It is seen that the standardization does not specify the module in all details. It does not contain information on, e.g., noise properties or the common-mode rejection ratio. Such details form a figure-of-merit characterization which is of course of great interest to the designer but immaterial as far as standardization is concerned.

Some comments are relevant with regard to the table. The Swedish system operates on a voltage of ±12 V, the negative voltage obtained through a d.c./d.c. conversion. Stabilized ±8.2 V is used to drive the electronic circuits, and this voltage is available at the input of the second module. This same voltage can be used to drive movement transducers employed in alternative designs. This voltage level makes it natural to use a dynamic range of ±5 V as maximal output signal. The low output impedance is a consequence of the use of an output operational amplifier, and makes the system much less sensitive to artifacts.

Table 2.
EMG Single Channel Unit

| | |
|---|---|
| Electrode | Surface, differential |
| Operating voltage | ±8.2 volts |
| Output resistance | < 1 kohm |
| Dynamic range, output | -5 to +5 volts, d.c. |
| Smoothing time-constant | 100 milliseconds |

The alternative modules are, of course, designed to match the second module inputs. The input of the second module is specified in Table 3. It is assumed that buffer stages with high input impedance are available. The three-state module can operate from the output of the buffer stage, controlling a switching circuit determining the mode of operation of the electric motors.

Table 3.
System Electronics Unit

| | |
|---|---|
| Operating voltage | ±8.2 volts |
| Input resistance | > 100 kohm |
| Input dynamic range | -5 to +5 volts |
| Modes of operation | antagonistic control, three-state logic |

The example thus given may serve as a first hint of how modular systems can be arrived at in this field, and the possible advantages associated with their use.

## References

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