A THREE-STATE MYO-ELECTRIC CONTROL*

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Abstract—A myo-electric system which permits on-off control of two functions from a single control site is described. Designed for control of externally-powered prosthetic and orthotic appliances, the system may be used with a wide variety of control sites due to its high sensitivity. The electro-mechanical relays used at the output are capable of controlling load currents up to 1A. The initial clinical trial, with a young AE amputee, has been successful. Circuit development and further clinical evaluation are now being carried out concurrently.

1. INTRODUCTION

Total functional replacement of a paralysed or amputated limb is prohibited chiefly by lack of adequate control sites. Myo-electric control is a partial solution, because it facilitates use of otherwise unsuitable control sites. However, a shortage still exists. Thus it is important to make effective use of existing sites.

In a myo-electric control system, the electrical activity in a muscle is the control signal. This activity can normally be controlled, by the patient, over a wide range. This range of control should be exploited. One method of doing so is to provide proportional or analog control. For instance, the closing force of a prosthetic hook may be made dependent upon the myo-electric activity in a muscle, (BOTTOMLEY, KINNIER WILSON and NIGHTINGALE, 1963). However, many appliances may be operated adequately with on-off control. This paper describes a control system which utilizes two levels of myo-electric activity at a single site to provide independent on-off control of two functions.

2. DESIGN OBJECTIVES

In designing this system, four objectives were to be met. Independent on-off control of two functions was to be provided, using only one control site. To permit operation from a variety of control sites, it was necessary that the system employ a relatively small myo-electric signal. Further, it was necessary that it functioned satisfactorily with surface electrodes, as, at that time, no percutaneous electrodes suitable for chronic use by patients had been developed. Finally, in order to give maximum flexibility in the choice of the controlled appliance, it was required that electro-mechanical relays be employed as the output switching elements. This provides complete electrical isolation between the control circuit and the controlled appliance.

It was not required that the battery voltage correspond to that used for any particular appliance, as this would not be consistent with the objective of facilitating use with a variety of appliances. No stringent specification was placed upon the size and weight of the system. Rather, it was decided to emphasize construction of a relatively compact working model, suitable for trial use by patients, using assembly techniques which would facilitate design changes.

3. CONTROL SYSTEM

A simplified block diagram of the myo-electric control system is shown in Fig. 1. In this, as in most existing prosthetic systems, visual and

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Acoustic feedback are used by the operator to determine the state of the controlled appliance. In complex systems it will probably be necessary to supplement these methods by additional feedback paths from the appliance to the central nervous system.

In order to achieve maximum reliability, recently-developed electrodes, Beckman Type 350059 Biopotential Skin Electrodes, are used. These are applied without special skin preparation, using Beckman non-abrasive electrode jelly. The resulting impedance of the myoelectric signal source, including tissue impedance and electrode/tissue interface impedance, is less than 10,000 Ω (typically 2000) and reasonably stable. To avoid skin damage from repeated use of adhesives at the control site, non-adhesive elastic bandage is used to hold the electrodes in place. (Electrode attachment remains a difficult problem in locations where this expedient is not applicable.)

The output of the rectifier controls a modified Schmitt trigger circuit in which the loads are two relays. With no input signal both relays are de-energized. A small myoelectric input, equivalent to approximately 250 μV pk–pk sinusoidal input at 100 c/s will cause Relay 1 to be energized. A larger signal, equivalent to approximately 300 μV input, will cause Relay 2 to be energized and Relay 1 to be de-energized. The time constants of the circuit are such that it is possible to go directly from the zero signal state to condition in which Relay 2 is energized without causing operation of Relay 1, thus permitting independent control of the two relays.

The relays are Babcock Type BR-5, with contact rating 1.0 A. This is adequate for control of most small motors likely to be used in prostheses, as well as for operation of solenoid valves for control of hydraulic or pneumatic systems. For evaluation of the control system, an electric motor driven hook, developed by Mr. C. McLaurin, at the Ontario Crippled Children's Centre, Toronto, has been used.

The control unit is contained in a drawn aluminium case, filled with a rigid urethane foam, and weighs approximately 200 g. The battery now being used with the control unit weighs approximately 200 g, and is conserva-

![Fig. 1. Simplified block diagram of a myo-electric control system.](image-url)