RECENT DEVELOPMENTS IN UPPER EXTREMITY POWERED PROSTHESES.

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ABSTRACT

Problems traditionally associated with upper extremity powered prostheses can be solved by using modern components and manufacturing methods. The difficulties that may be encounterd are outlined and some factors needing to be considerd are mentioned. Component types only recently available are discussed.

The Problems

1. Weight. Particularly the case with using powered elbows.

2. Excessive size.

3. High power consumption.

4. Reliability problems.

5. Difficulties in use.

6. Susceptibility to electrical interference.

7. Performance variation from unit to unit and with temperature changes.

8. In addition, we have identified a clinical need to provide systems which provide a large variety of different control regimes.

In this paper we will concern ourselves only with the electronic engineering problems.

Electronic control packages fabricated using surface mount and thick film technologies are smaller and lighter than their predecessors.

One problem yet to be tackled satisfactorily is that of battery size and weight. Nickel-Cadmium rechargeable cells are used routinely because they are capable of being recharged, are safe and fairly reliable and have a reasonable energy density. Nevertheless it would be extremely advantageous if more compact lighter batteries were available in rechargeable form.

The approach that must be taken meanwhile is to make the most effective use of the energy in the cells used. Electronic circuits must therefore have very low quiescent current consumption and losses in the power drivers must be as low as possible.

Modern operational amplifiers consume a few hundred microamps and CMOS logic circuits typically use only less than ten microamps.

For the power stages, MOSFET's are the preferred devices. Because they are voltage controlled, the drive circuits need to provide very little current.

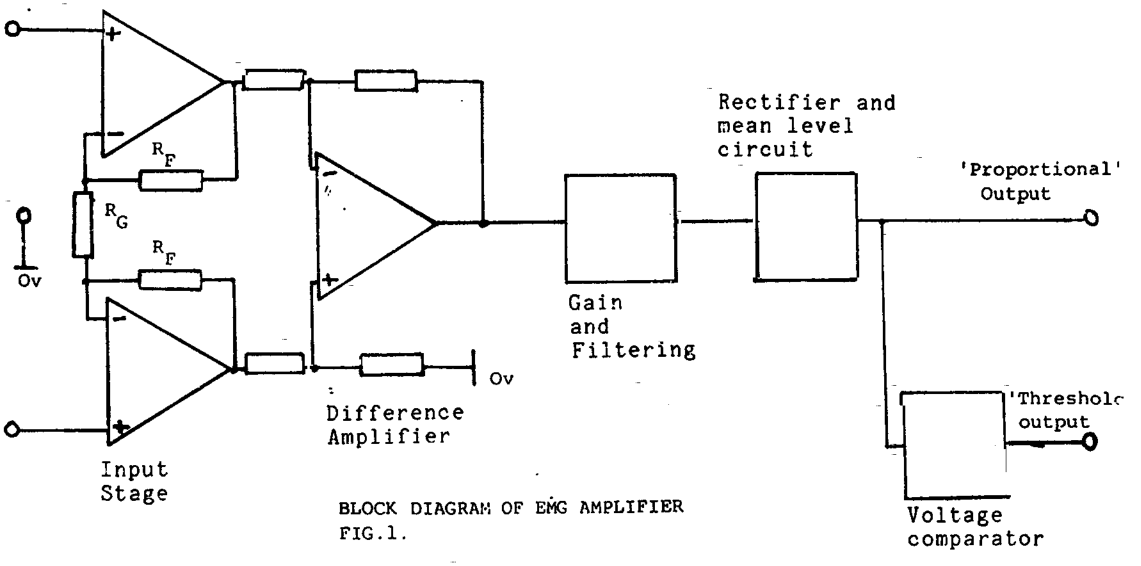
With respect to reliability it is important to provide proper worst case analysis at the design stage and to ensure that properly run quality assurance (Q.A) and inspection procedures are adopted. Suitable encapsulants should be used to provide protection against ingress of dirt and contaminants. These may also help to provide protection against mechanical shock and vibrations.

If the design is flexible many different control regimes may be assessed and the correct one for each patient can be chosen.

Details of circuit components

1) Operational Amplifiers

The most widespread use of operational amplifiers in prostheses is in EMG amplifiers. A simplified EMG amplifier is illustrated in Fig 1.



BLOCK DIAGRAM OF EMG AMPLIFIER
FIG.1.

a) Open Loop Gain.

High open loop gain ... needed so that accurate and predictable closed loop gains over the full bandwidth of the EMG signals can be achieved without too many amplification stages.

b) Input Offset Current.

For the input stage low input offset current is required. The reason for this is that it is desirable to D.C. couple the skin electrodes to the input of the amplifier. If A.C. coupling were used, the time constants of the two input circuits would have to be too closely matched for practical implementation, to prevent common mode to differential mode conversion.

Since D.C. coupling must be used, the input stage bias currents flow through the electrodes and into the skin. Since the resistances that each electrode 'sees' are unmatched it is important that the input offset current (the difference between the bias currents) is low to prevent saturation of the input stage.

c) Common Mode Rejection Ratio.(CMRR).

The EMG amplifier is normally required to have as high a common mode rejection ratio as possible. Common mode signals as high as 5v pk-pk at 50 or 60Hz can be encountered. If the EMG amplifier has a CMRR of 110dB this will mean the equivalent input signal due to common mode pickup will be 15 μV pk-pk which is about the limit of acceptability.

d) Current Noise Density.

A further important consideration is low current noise levels. The source impedance of EMG signals is high and unpredictable. Most operational amplifiers are designed for low Voltage Noise but in this particular case, Current Noise needs to be low since the signal source impedance is high.

e) Input Voltage Range.

Another important feature of the input stages is a good Common Mode Input Voltage Range, to prevent overloading of the amplifier by the high common mode voltages. In addition the input must not be sensitive to damage by transients.

f) Input Impedance.

Yet another factor in good amplifier design is the need for very high input impedance to prevent Common Mode to Differential conversation caused by the unbalanced source imbalances.

2. Programmable Logic Devices.

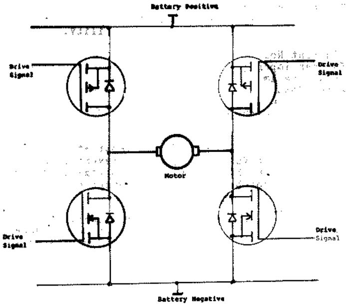
An interesting development which is appropriate in the design of upper extremity prostheses is provided by the introduction of Programmable Logic Devices.

We have used these devices to carry out simple combinational logic and 'state machine' designs. The latter are designs in which the internal logic patterns of the device can be altered by externally applied signals and output signals can be created by logical combination of the internal patterns or 'states'. The device can be made to adopt differing internal states in response to the order in which external signals are applied. This provides sequential patterns of outputs.

MOSFETS

3. The advent of power FET's has simplified the design and flexibility of motor drive packages.

To provide bidirectional control of the motor the normal H-bridge configuration must be used. (See fig.2)



H-Bridge Configuration

Fig. 2.

Fig.2

Power FET's have built-in power diodes which protect them from damage by the energy stored in the motor inductance when the current is switched off.

Parameters of interest are the gate-source switching threshold and the effect of gate source voltage on drain-source resistance. Since prostheses commonly run off 6v or 12 v supplies the gate source voltage must be assumed to be about 5v (allowing for a discharging battery). This means usually that a device with a far greater voltage, current and power rating than necessary will be selected to keep the drain-source on resistance low. If the MOSFETS are used in such a way that they are turned on and off rapidly such as in servo systems, because the input parasitic capacitance must be charged and discharged during each switching operation the drive circuit must be able to do this quickly and devices with low input capacitance must be sought.

CONCLUSION

For prostheses modern devices allow improved performance and modern fabrication techniques allow complex circuits to be made to fit the small space available. In particular Programmable Logic Devices are invaluable to provide the next generation of flexibly programmable control schemes and allow sensible progression from simpler control regimes towards possible microprocessor controlled prostheses.