LOW LEVEL RESPONSE OF BOCK AND STEEPER ELECTRODES

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ABSTRACT

For many years myoelectric fittings have been limited by the need for signals of at least 20 \mu \text{V} \text{ when using convenient in-socket myoelectrode-amplifiers. With the introduction of the Bloorview-MacMillan MyoMicro\textsuperscript{TM} technology, the controller is able to further amplify the patient myosignal. To evaluate the Bock 13E125 and Steeper Electrodes for providing suitable signals for control in the region below 20 \mu \text{V}, both electrodes were tested at each gain setting. The Bock electrode gives the best signals in the 1 to 5 \mu \text{V} range while the Steeper electrode is less sensitive. With suitable downstream amplification, both electrodes will provide proportional control with signals of 0-10 \mu \text{V}.}

BACKGROUND

When prosthetics mainly used threshold electronics, it was sufficient to have electrode-amplifiers (called just electrodes by most manufacturers) with a minimum threshold transition of about 20 \mu \text{V}. Proportional control, however, requires a range of output values to control speed, grip force or other useful functions. Further, many patients have the capability of making maximal sustained contractions that generate as little as 5 \mu \text{V} of signal. To handle this class of patient, Motion Control and Liberty Technology, but especially the former, have developed signal acquisition systems with the required sensitivity.

While the specialist may wish to use many different electrode systems, practitioners making only a few myocontrolled systems a year would like to use just one electrode for everything. With the introduction of the Liberty Technology VariGrip\textsuperscript{TM} Controllers for one to three devices, it is now possible to add digital, post-electrode amplification to achieve control over a wide range of muscle input amplitudes. Bock and Steeper electrodes were evaluated alone and with the VariGrip\textsuperscript{II} system to see just how well they work as patient interfaces.

Three types of tests were done. First, each electrode was tested with a low level balanced differential input. Next, each electrode was used to generate output control signals for a Liberty Technology VariGrip Controller using the simulated input. Finally, systems were shipped to practitioners who have fitted patients requiring great sensitivity.

The Test Setup

An artificial input signal was fed to the electrode being tested from a Steeper Myoelectric Signal Simulator. This unit, which is no longer available, generates a simulated myosignal which has proven to work well for diagnosing prostheses. For each data point, the input signal was first calibrated by feeding it to an Otto Bock 757M5 Myotester. While this unit is known to give readings that vary somewhat from the most accurate possible electronic instrumentation, it generates numbers that everyone in the myoelectric control field is familiar with. Electrode outputs were measured using a Hewlett Packard 3456A Digital Voltmeter. The greatest source of error was the
setting of the input voltage especially at low levels in the 1 to 10 µV range. The electrodes evaluated were the Otto Bock 13E125 and the RSL Steeper SC01 (D12839). They were operated with an input of 60 V from a power supply or from the internal voltage regulator when attached to a VariGripII.

**What an ideal electrode looks like**

To understand the data collected from the Bock and Steeper electrodes it is easiest to establish a working vocabulary by first describing an ideal electrode. One aim is to use these electrodes as sensors for the Liberty Technology VariGripThim Controller. The analog-to-digital converter in this unit divides 6V into 1024 equal pieces giving a minimum signal of 5.9mV. There are many instances where a maximum signal of only 5mV has been used to operate proportional prostheses. Ideally the patient should be able to “divide” the space between 0 and 5µV into at least 10 parts. Thus the 0.5µV signal should produce a minimum of 10µV out of the electrode at a reasonable electrode gain setting.

Figure 1 shows input-output plots for an ideal electrode with six gain settings. Each plot is a straight line passing through the point zero, zero. As the gain setting increases the slope or steepness of the lines also increases. Since this is an ideal electrode, the change in this slope is uniform from one setting to the next. You can calculate the gains; 0.8V per 100 mV is a gain of 8,000. The other gains are 16, 24, 32, 40 and 48 thousand.
The less than ideal electrode

Figure 2 shows a typical problem electrode. The response curve has two knees, one at 37μV and one at 63μV. These sudden changes in the gain make it difficult for a patient to get good proportional control. On one side of the lower knee the gain is 1100 and on the other side 9000. The user has to work nine times harder to
change the output signal below the knee.

Figure 3 shows the offset problem. This electrode shows an output even with no input. With the MyoMicro software offsets can be cancelled out by giving the electrode a suitable “noise floor” setting. Figure 4 shows another problem. The electrode is essentially useless for inputs less than 40µV, and there is no way to get information from low levels of myoelectric activity.

The Bock 13E125 data

Figure 5 shows the response of the Bock electrode from zero to 100µV while Figure 6 shows only the region from zero to 15µV. This electrode is not ideal, but it is good enough for all practical purposes. There is some knee effect. For instance, the low end of the G=3 curve has a gain of 16,000 while it is 60,000 at higher levels. The gain then decreases at still higher levels. However, there are no sharp changes in gain and we are not aware of any clinical feedback saying that the response is not acceptable. The low level response of the electrode is of particular interest. The response for a gain setting of 1 has become too small to measure on this graph, but the other plots show a uniform change of gain as one goes from G=2 to G=5. The actual gains are 7,000, 16,400, 23,800 and 32,300. They are almost perfectly spaced 8000 apart. There is practically no improvement in gain above G=5. Finally, this electrode has considerable offset and the offset changes with gain. However, the offset can be removed if a deadband or noise floor is used. This is standard procedure with MyoMicro software and the VariGrip II Controller.
The Steeper SC01 data

An obvious deficiency in Figure 7, the response of the Steeper SC01 electrode, is the knee effect. If one extends the relatively-straight-line sections of the plots down to zero, one sees the following: G=1 is essentially useless; G=2 is useful from 55 to 100µV; G=3 from 40 to 100µV; G=4 from 30 to 100µV; G=5 from 20 to 100 µV, and 6 from 10 to 100µV. Figure 8 shows that only G=5 or G=6 might be useful in the 1 to 5 µV region. The actual gains for the G=4 to G=6 curves were 1700 at 14µV for G=4, 3800 at 11µV for G=5 and 5700 at G=6. This should be compared to the low level gains of 16 to 24 thousand for a comparable region of the Bock plot. The Steeper electrode also shows an offset voltage at low levels.

Selecting the right system gain.

Since the purpose of this study was to qualify electrodes for use with the VariGrip II Control System, it made sense to study how much system gain was needed with various levels of patient maximal signal. Figure 9 shows the result of setting the Bock electrode at G=3 and then adjusting the gain of the VariGrip Controller so that a given µV input would give a 100% signal to the motor controller. The chart can be used to select an appropriate gain if the patient signal is known, or it can be used to calibrate the patient input in µV if the gain for easily achieving a 100% signal is known.

Myoelectric control with weak muscles.

It is the nature of the myoelectric signal that it varies in a random way that requires some level of filtering when going from the raw myoelectric signal to a DC control voltage. The need for filtering is most apparent at low levels where only a few muscle fibers are producing the signal. The Bock and Steeper electrodes were tested at low levels with a live subject to evaluate the usefulness of the low level signals. The Bock electrode was set at 3 and the Steeper at 5.5 to produce similar outputs. With a gain of 55 programmed into the VariGrip II controller, the Bock electrode produced a jittery control signal. The Steeper electrode required a gain of 70 for a comparable signal. For practical use, both signals require the setting of some noise floor to reject inadvertent signals and noise. Without further filtering, the jittery signals degrade proportional performance. The MyoMicro program has recently been modified by the addition of a filter to address this problem. There was not time to evaluate the filter before writing this report.
CLINICAL RESULTS

The VariGrip II Controller has now been applied to two patients using system gains of about 55 and a Bock electrode gain setting of 3. These fittings are successful and the patients are well pleased. This makes it likely that more low level patients will be fitted with this system using the familiar Bock electrode. Similar success is possible with the Steeper electrode, but only at the highest gain setting. An additional benefit to setting the Bock electrode gain to G=3 is that the prosthetist can then make minor gain adjustments in the field by increasing or decreasing the gain at the electrode.