DESIGN AND CONSTRUCTION OF A BAND TO POSITION AND SET ELECTROMYOGRAPHIC SURFACE ELECTRODES FOR USE ON THE UPPER LEG

by

GENE PAUL MASTERS

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May 1977

Signature of Author Signature redacted
Department of Mechanical Engineering
May 12, 1977

Certified by Signature redacted
Thesis Supervisor

Accepted by Signature redacted
Chairman, Departmental Committee on Thesis

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Submitted to the Department of Mechanical Engineering On March 15, 1977 in partial fulfillment of the Requirements for the Degree of Bachelor of Science

ABSTRACT

A band of cloth, elastic, and Velcro was constructed to position and hold steady surface electrodes in a pre-amplifier casing used to measure myoelectric signals in the upper leg. The band was evaluated in a number of tests on both normals and amputees, and was found to function in a favorable manner.

Thesis Supervisor: Woodie C. Flowers

Title: Associate Professor of Mechanical Engineering

ACKNOWLEDGEMENTS

I wish to thank my advisor, Woodie Flowers, for his aid and consultation, and especially for pointing out the obvious when I just couldn't see it.

And I would like to voice my appreciation to Don Grimes, who was there when a question needed answering, or a hand lent.

TABLE OF CONTENTS

INTRODUCTION

The minute changes in electrical potential accompanying contraction of the muscle fibers can be recorded by a process called electomyography. These myo-electric signals (MES) can be measured by the non-invasive technique of applying surface electrodes to a portion of the skin overlying the muscles. These signals can then be used for the control of a prosthetic device.

One of the problems in MES research is the difficulty with attaching the recording electrodes to the skin in such a manner that clear, reproducible measurements may be made with a minimum of discomfort to the subject.

Difficulties with current methods

Applying the electrodes with tape holds them to a single area of the skin, and allows for good measurements, but causes some problems in the actual attachment and removing the tape pulls hair from the skin and causes pain. This pain is experienced during repositioning of the electrodes. Also, each electrode must be taped separately in place, which does not allow for easy placement, or simple repositioning of an electrode group.

Wrapping the electrode to the limb under some type of elastic cloth (such as an Ace bandage) causes difficulty with exact placement of the electrodes, as the position of the electrodes with respect to the muscles cannot be seen when the cloth is in place. Also, on a tapered limb, which is often quite pronounced in the more conical limbs of the amputee, such a cloth will often slip upon flexion and relaxation of the limb, thus shifting the position of the electrode. This slippage of the electrode will cause a non-MES signal to be transmitted.

There are basically two types of slippage, (1) the sliding of the skin over the underlying layers, and (2) the sliding of the electrode faces with respect to the skin.

Slippage (1) causes a change in the DC level of the recording very similar to that produced by a change in the pressure holding the electrode to the skin. This shift is most likely due to a change in the conductance of the cutaneous layers under different pressures. These shifts occur at the same frequency as the stimulus, and are independent of the method used to hold the electrodes, as this slippage is almost entirely between the skin and muscle layers.

Slippage (2) causes a rapid and large fluctuation in the signal. When the electrode slips with respect to the skin the change is only momentary, although of significant magnitude, and the signal returns to near the value it had before the slipping began. This noise source should be avoided.

<u>A solution</u>

A simple band that strapped electrodes firmly to the limb, yet allowed no slippage with respect to the skin seemed desirable. The band would ideally show the location of the electrodes, with respect to the muscle groups of the limb, perfectly clearly in order to allow exact positioning. It should also be designed to allow the simultaneous measurement of signals from all of the surface muscles of the limb.

The band must be light and cover little surface area to keep perspiration to a minimum. Undue moisture can easily short out the measuring electrodes. It should be easily cleaned for sanitary purposes, comfortable to allow long, easy usage by the subject, and durable so that it will be able to last for a long period of time.

The purpose of this thesis was to design and construct such an electrode-band for use on the upper leg, with surface electrodes in preamplifier packs. The band was then evaluated on both normal and amputee subjects.

DESIGN

The Jacobsen electrode is a preamplifier pack with removable electrode faces. (See Figures 1 and 2) The dimensions are shown in the diagram below.

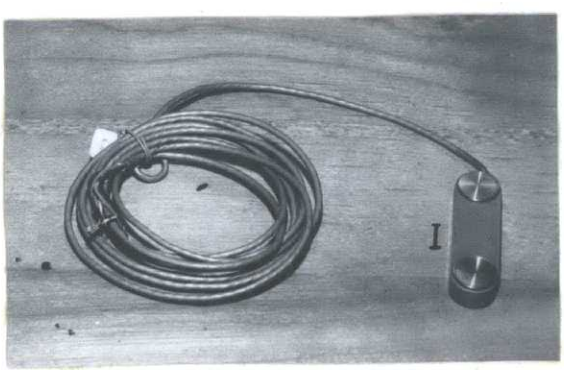


Figure 1: Photograph of Jacobsen electrode

Scale is 1 cm.

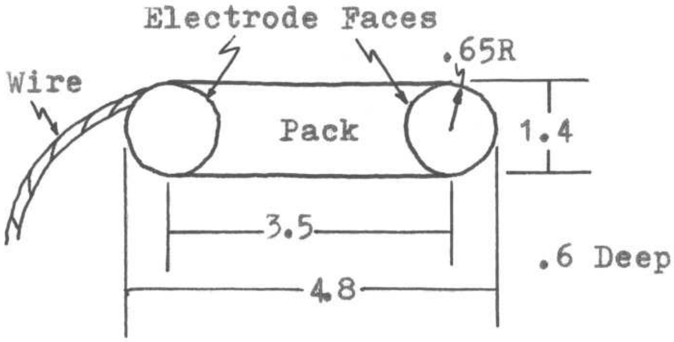


Figure 2: Jacobsen electrode

Dimensions in cm.

The prototype band was constructed of modular units made from non-rolling elastic, Velcro, and light drill cotton cloth. (See Figures 3 and 4)

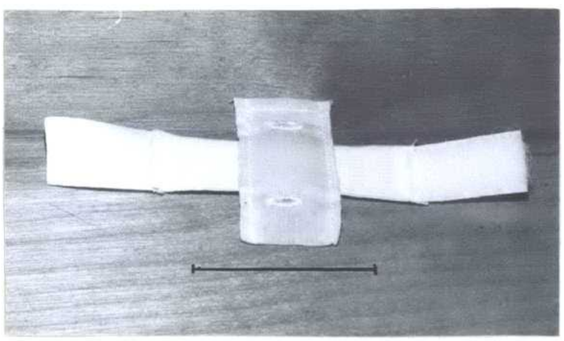


Figure 3: Photograph of modular unit

Scale is 5 cm.

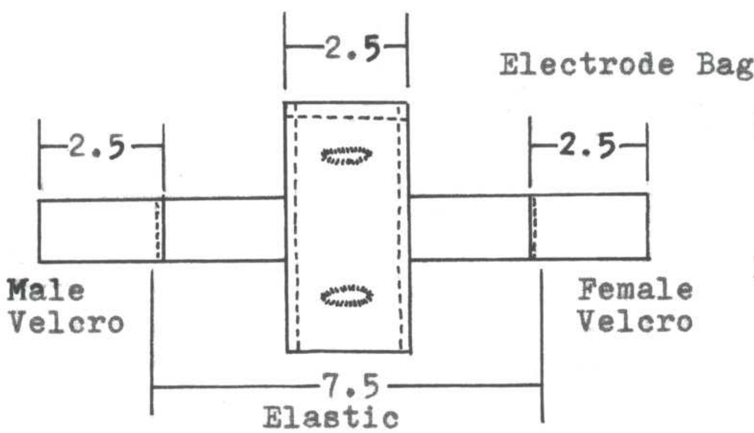


Figure 4: Modular Unit

Dimensions in cm.

The cotton electrode bag was first sewn to fit the electrodes. The pattern and dimensions for this bag are given in Figure 5.

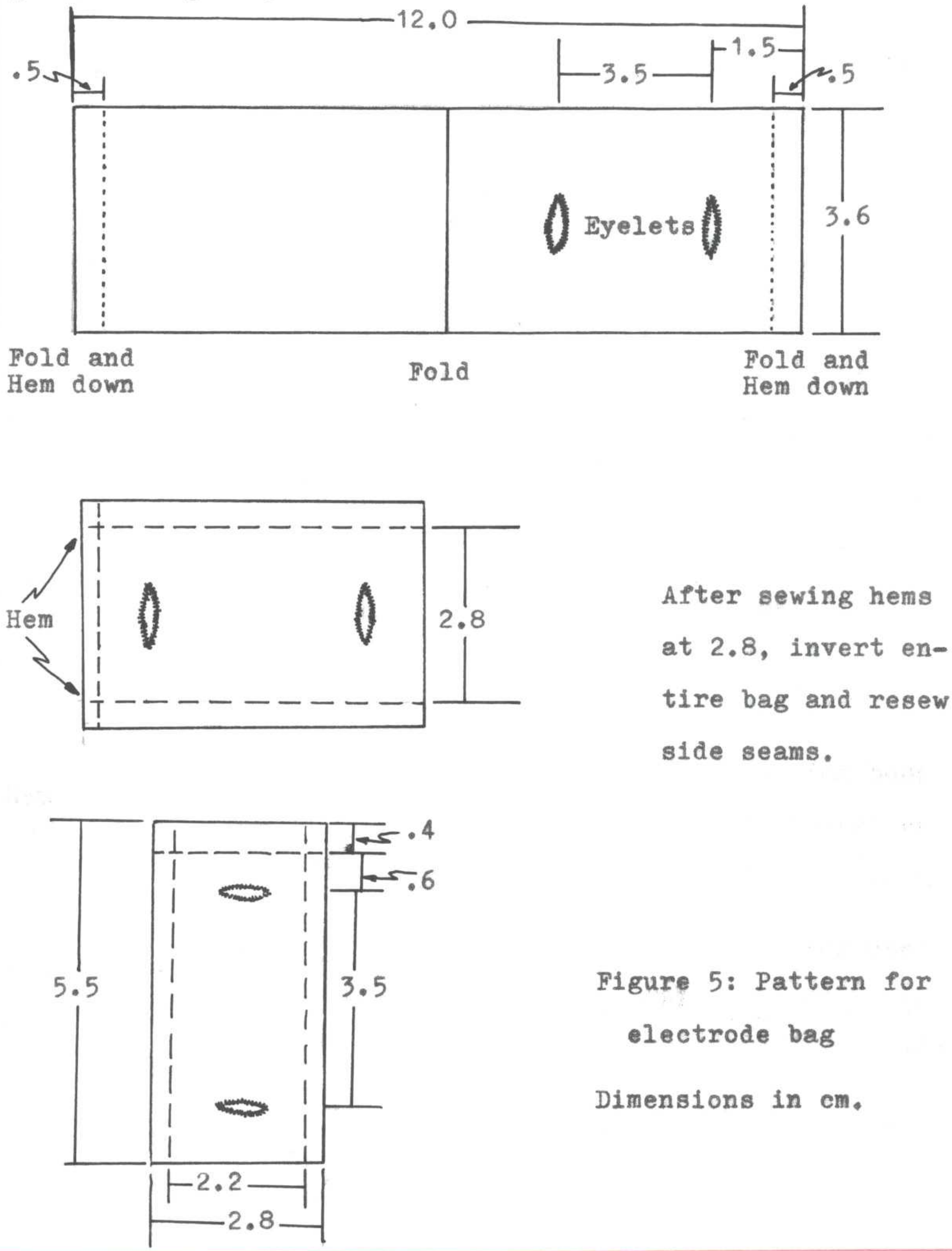


Figure 5: Pattern for electrode bag

Dimensions in cm.

The completed electrode bag was then stitched to the elastic, and one end each of the elastic stitched to male and female Velcro. Care was taken to ensure that the female Velcro (fuzzy) always faced the skin, while male Velcro (scratchy) faced away from the skin.

Each bag seam was double stitched, and every seam connecting different materials was quadruple stitched. All sewing was done at 16 stitches to the inch.

The modular units can be attached together to accommodate virtually any circumference above 11.5 cm, and smaller modules can be made in similar fashion to circumnavigate even smaller perimeters.

A waist belt of male Velcro holds the upper end of 2 female Velcro vertical supports which prevent any downward slipping of the bands. (See Figures 6 and 7) These vertical supports can maintain the position of more than one band, so that multiple bands can encircle a limb. Using the size modules developed in the prototype, three bands are required to simultaneously measure MES's from all of the surface muscles in the upper leg. (For additional information, see Appendix A)

Figure 6: Photograph of band being worn on right leg of subject

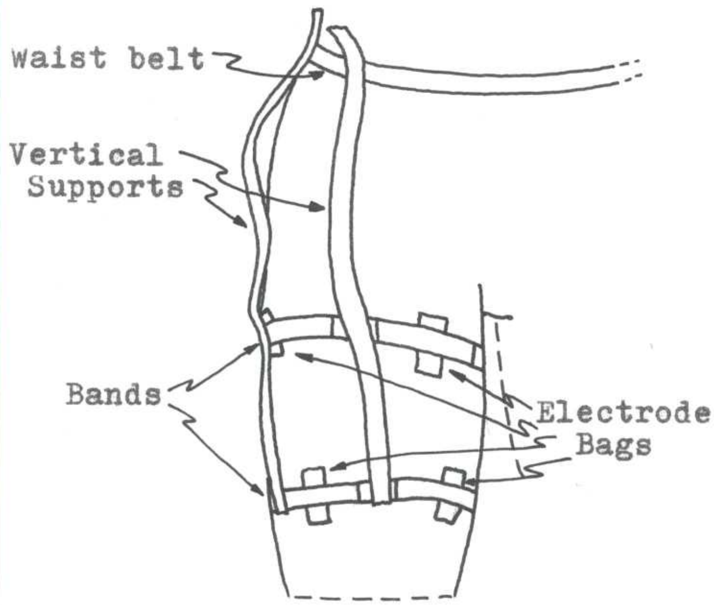


Figure 7: Diagram of band on right leg showing waist belt, two vertical supports, and two bands

EVALUATION AND RESULTS

Seven tests were used to evaluate the performance of the electrode holding band.

Test 1: Comfort

A normal subject wore the band under his clothing for approximately 8 hours while going about his daily business. As the subject was a student, this entailed walking several miles, much sitting, and a good bit of standing. No discomfort was noticed, and the band did not noticably shift.

Test 2: Contortion

The band was placed on a normal subject's right leg, and the position of a forward and rearward bag were marked on the skin. The subject then contorted the leg to various positions and the electrode bags showed negigable drift.

Test 3: Walking

A normal subject, wearing the band, walked at a fairly rapid pace (104 steps/minute) for ten minutes. To allow for extreme rearward extension of the leg during the second experiment, the support straps had had some slack left in. The band slid downward approximately .6 cm in about 30 seconds of walking and remained there throughout the rest of the testing period.

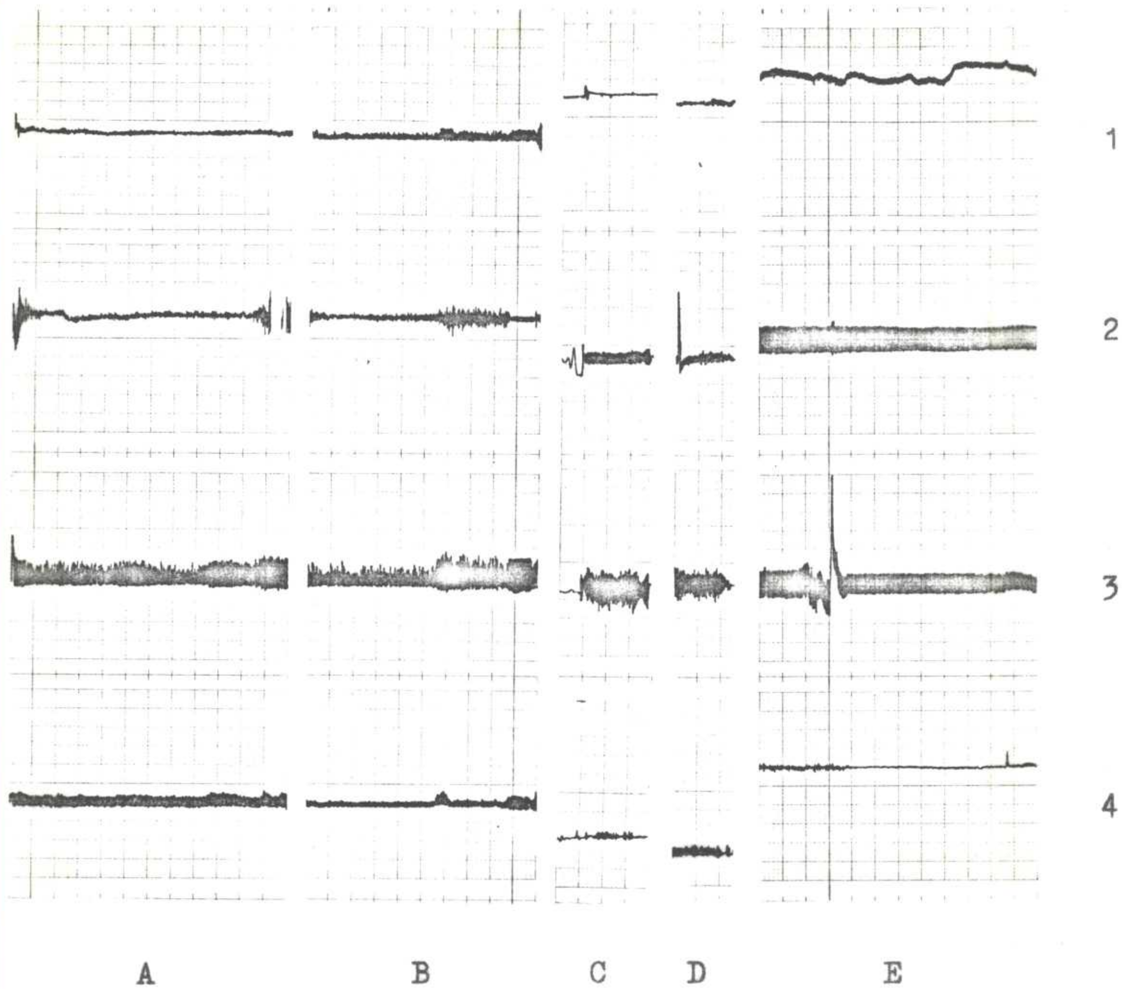
Test 4: Measurment and Reproducibility

The subject wore a single band containing 4 electrode pairs situated one each on the front, back, outer, and inner side of the leg. MES activity was then recorded using 2 EMG processors and a chart recorder. (For schematic of EMG processor, see Appendix B)

Recordings were made during adduction, abduction, flexion and extension of the hip joint, and while running in place. This was done four times, two runs each on two separate days to determine reproducibility of the results. (See Figures 8-11 on following pages)

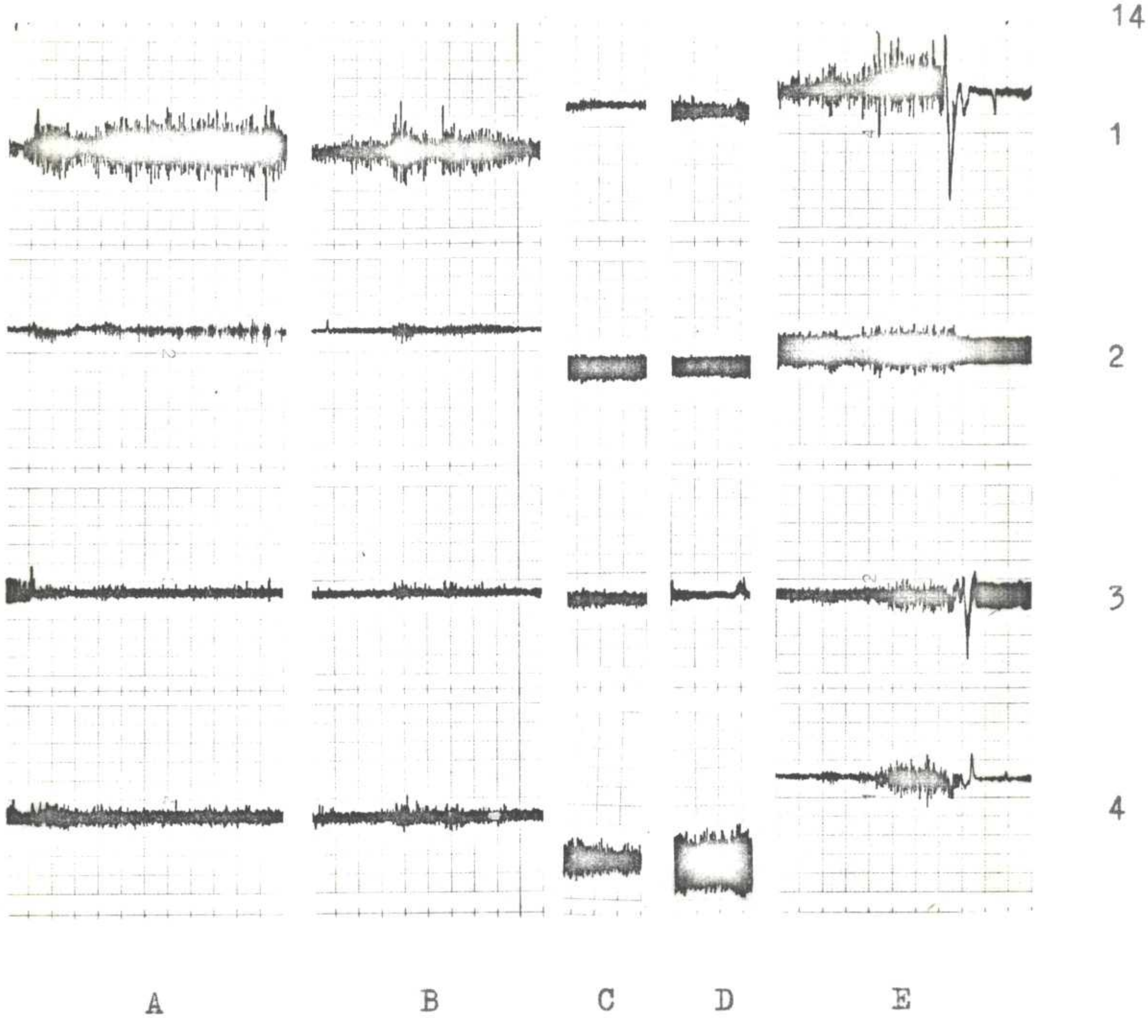
The figures show recordings made on a normal subject (Sections A,B,C, and D) for four separate tests, and on an above-knee (AK) amputee subject (Sections E). The first line of each figure shows the recordings made from the electrode on the outside of the leg. The second line shows the front; the third, the inside; and the fourth, the back.

The recordings obtained from each area of the leg match quite well from test to test, considering the different gains used on the processor on different days.



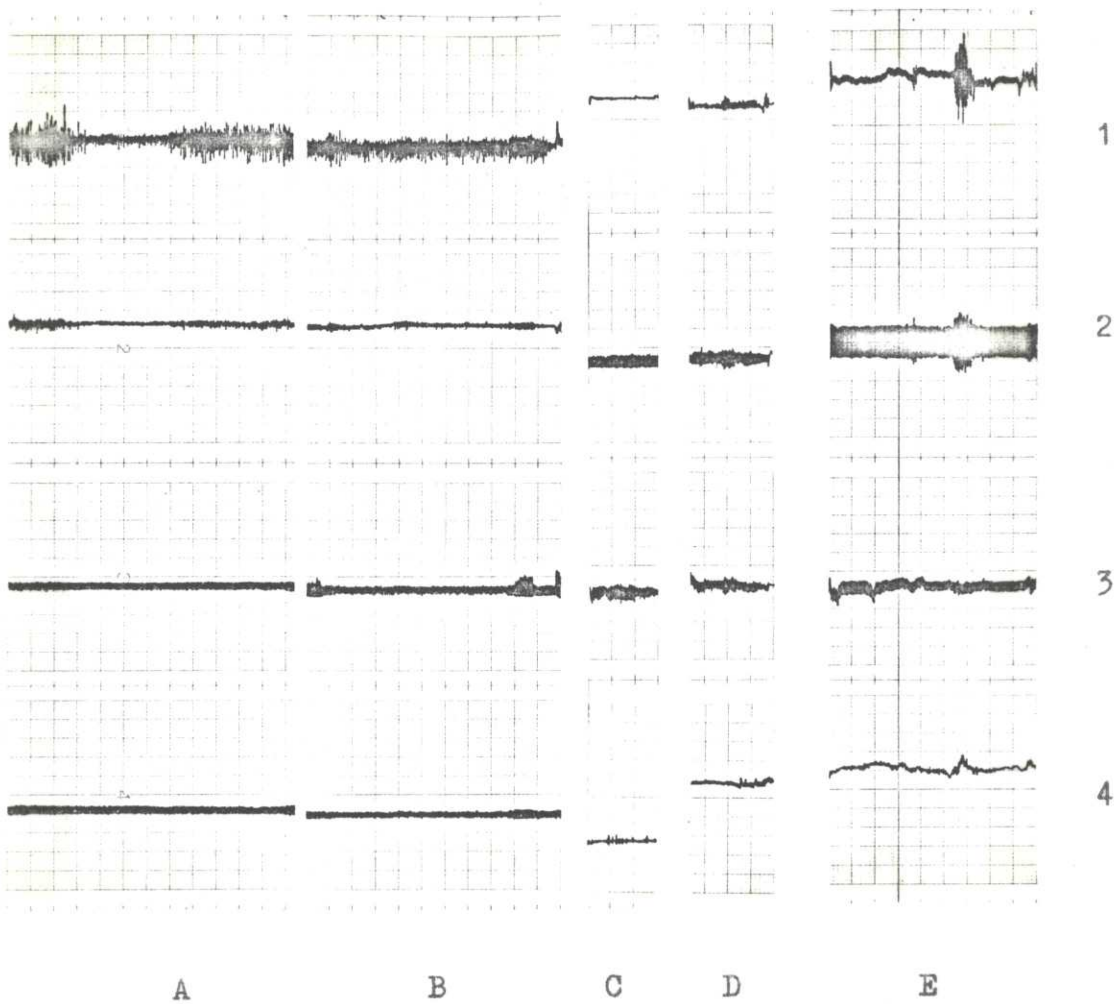
Recordings from 1) outside, 2) front, 3) inside, and 4) back of leg during flexion of the hip joint. Sections A and B are two separate runs on the same normal subject on the same day. Sections C and D are two separate runs by the same subject on a later day. Section E is from an AK amputee subject.

Figure 8: Flexion



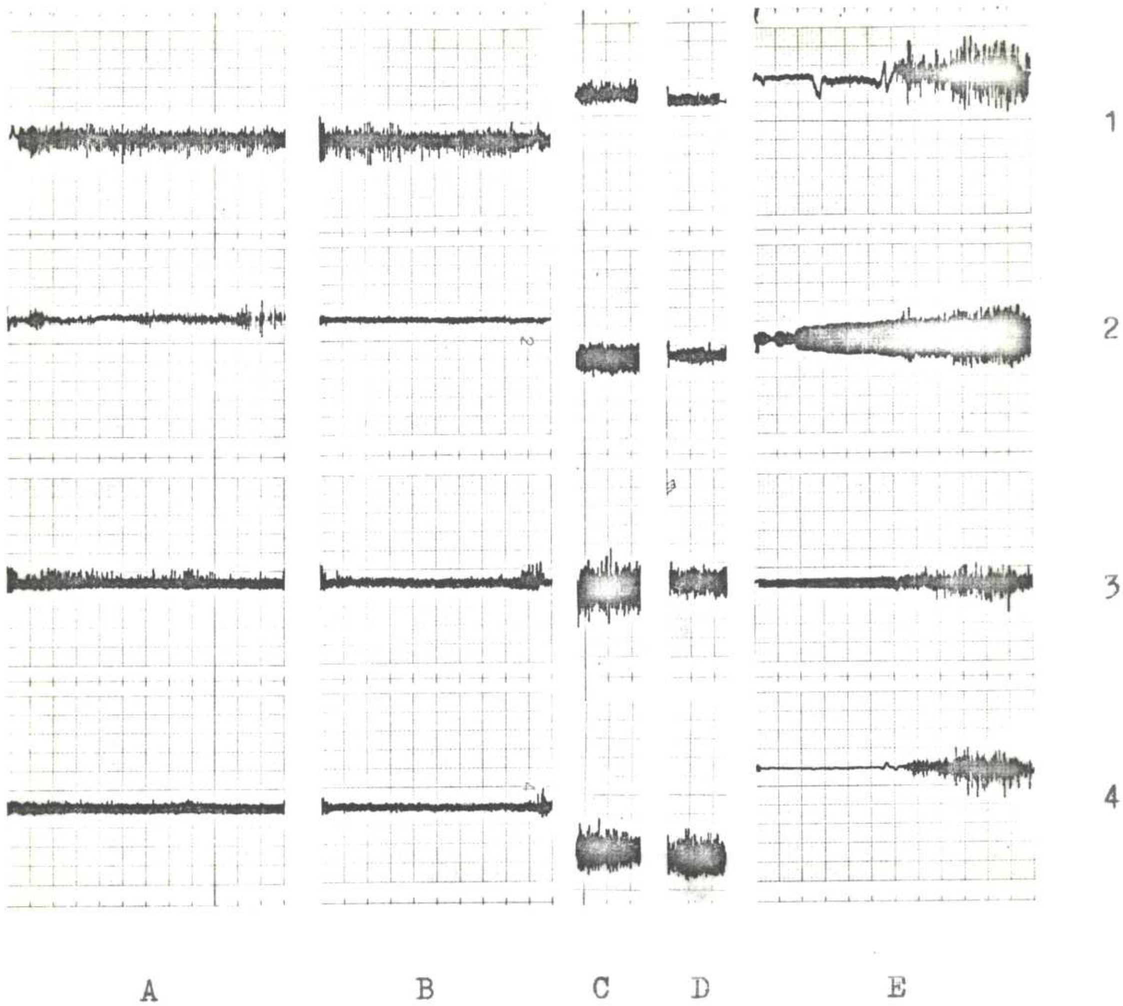
Recordings from 1) outside, 2) front, 3) inside, and 4) back of leg during extension of the hip joint. Sections A and B are two separate runs on the same normal subject on the same day. Sections C and D are two separate runs by the same subject on a later day. Section E is from an AK amputee subject.

Figure 9: Extension



Recordings from 1) outside, 2) front, 3) inside, and 4) back of leg during abduction of the hip joint. Sections A and B are two separate runs on the same normal subject on the same day. Sections C and D are two separate runs by the same subject on a later day. Section E is from an AK amputee subject.

Figure 10: Abduction



Recordings from 1) outside, 2) front, 3) inside, and 4) back of leg during adduction of the hip joint. Sections A and B are two separate runs on the same normal subject on the same day. Sections C and D are two separate runs by the same subject on a later day. Section E is from an AK amputee subject.

Figure 11: Adduction

Runs made on the same day give a very close match, because the processor settings were not moved, and the band simply removed from the subject for a period of time, then replaced.

Section E on each figure shows less agreement than the first four, yet still there is a basic similarity. The difference is most likely due to the drifting of the muscles after amputation, and the amputee's different method of using his leg.

Test 5: Double Band

This was done the same as the fourth test, but with a double band (See Figure 7) to determine if the differences between the recordings from the upper and lower electrodes could be explained by the anatomy of the muscle configuration. (See Figures 12-15 on following pages) The differences recorded were not extreme, and could be explained by the fact that an electrode will signal in response to more types of leg activity when near the hip. This is because the electrodes, which pick up changes in potential for a certain area under them, record muscle activity from more types of muscles (e.g. flexors and extensors). This is due simply to the fact that the muscles are found closer together in the vicinity of the hip.

Test 6: Stability on Amputee

A single band was worn by an amputee subject, on the stump, while the subject stood on his good leg. The stump

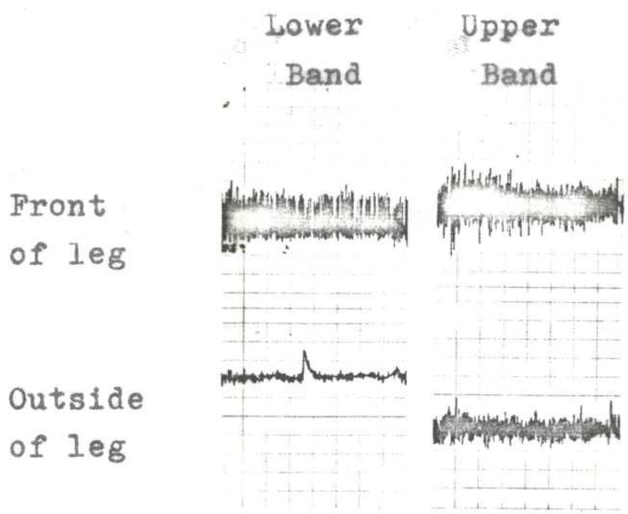


Figure 12: Recordings during flexion of the hip joint using a double band

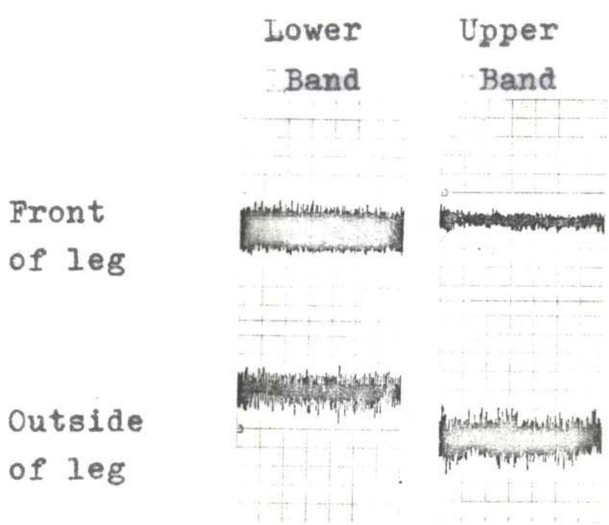


Figure 13: Recordings during extension of the hip joint using a double band

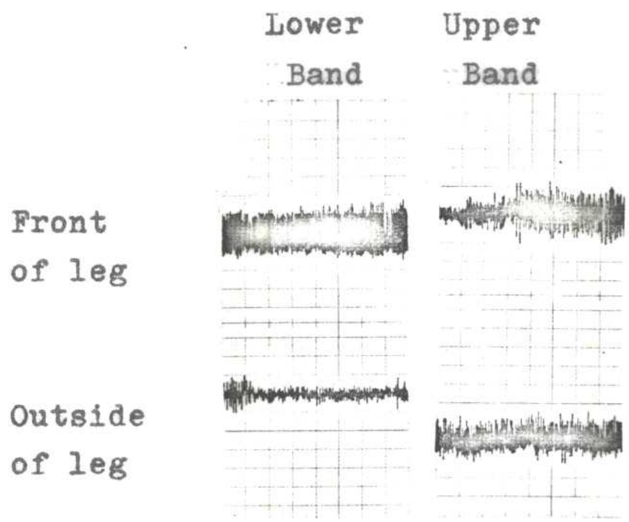


Figure 14: Recordings during abduction of the hip joint using a double band

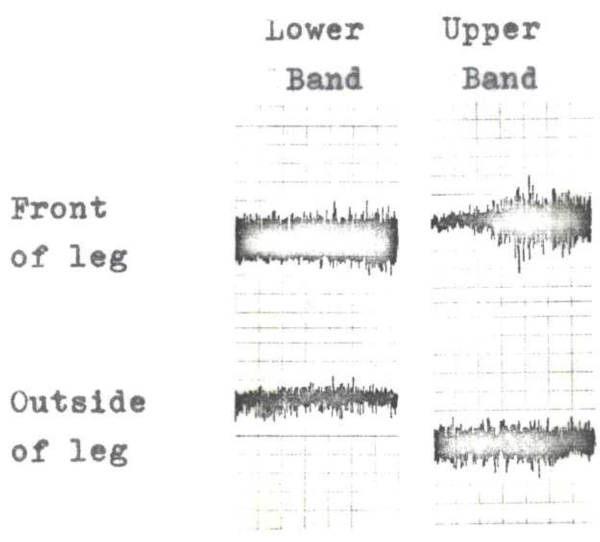


Figure 15: Recordings during adduction of the hip joint using a double band

was then flexed to its extreme in flexion, extension, abduction, and adduction (Results from this exercise are compared with Test 4 in Figures 8-11), and then shaken to determine if the band would slip from this quite conical limb. The initial position of the bags with respect to the skin was noted, and no detectable slippage occurred. This was repeated on a second amputee with similar results.

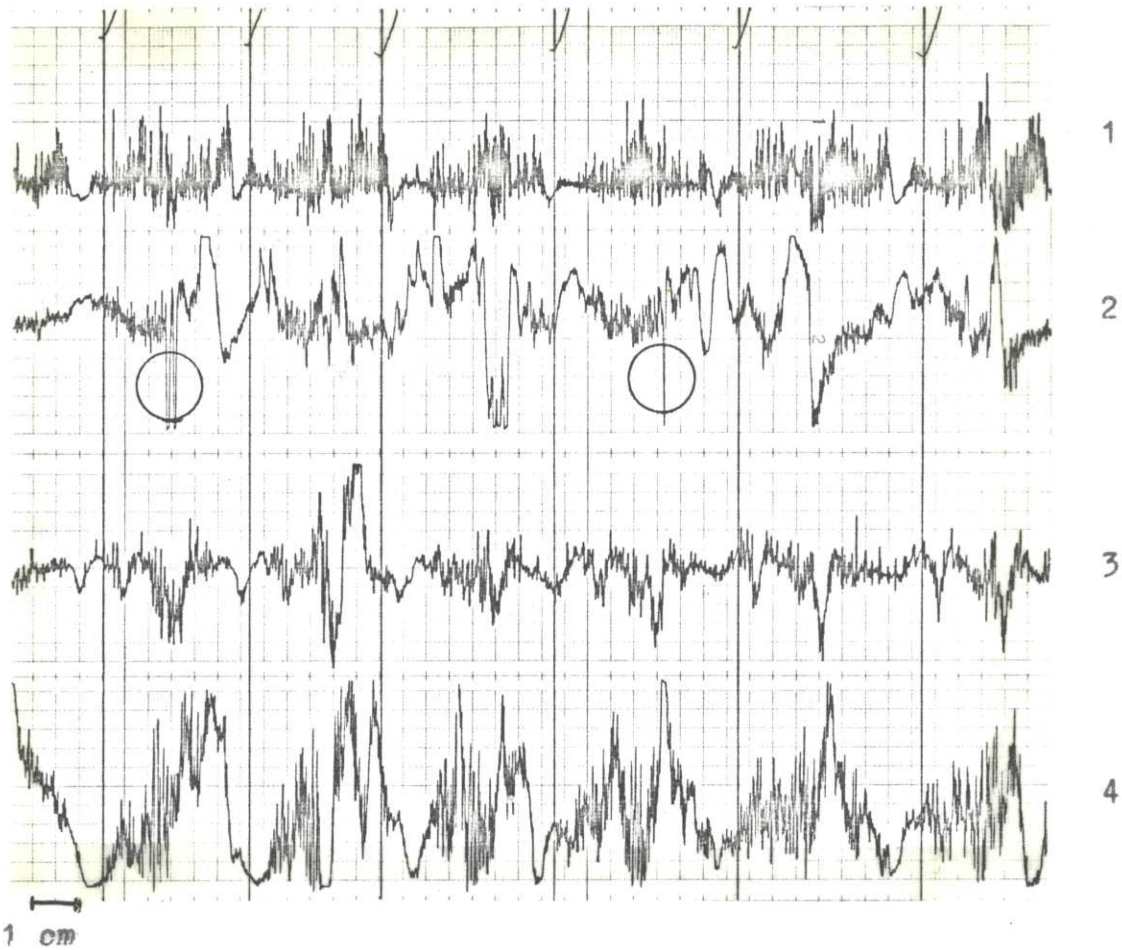
Test 7: Amputee Walking

The band was worn, on the stump of the amputee subject, complete with electrodes, underneath the socket of the prosthesis. The subject then walked while recordings were made. The signals recorded (See Figure 16) were cyclical about heel strike.

The low frequency components (1 to 5 Hz) and drifts in the DC level are due to slippage and pressure changes. The majority of the slippage is type (1) as explained in the Introduction. However, slippage (2) seems to be evident in the early parts of the recording from the front electrode. (See circled spikes in Figure 16) With continued wearing, there was less of these spikes, as if the electrodes were settling into a stable position.

An attempt was made to repeat this experiment on a second subject, but he used a suction socket, and the depth of the Jacobsen electrodes prevented the suction from holding.

Upon first placing the socket over the band with electrodes both subjects remarked on feeling "uncomfortable"



Recordings from 1) outside, 2) front, 3) inside, and 4) back of leg during walking. The band was worn under the socket of an AK prosthesis. The subject was a unilateral AK amputee.

Vertical lines denote heel strike.

Circles denote spikes probably caused by slippage between the electrodes and the skin.

Recording speed was 25 cm per second.

Figure 16: Amputee Walking

but with continued wearing, and walking for a few minutes, the discomfort lessened, and at the end of the session one remarked that he didn't notice it any more, and the other expressed marked preference over "having my leg taped up."

CONCLUSION

The band offers a marked improvment in the use of Jacobsen electrodes, and in terms of the criteria it was designed to meet, it is quite successful. There is still some problem with slippage, but I believe this to be minimal. If the elctrodes that it used were thinner, a band of this type could even be used for the measuring of MES under the suction socket of an amputee.

APPENDIX A

The surface musculature of the upper leg is given in the drawings on the next four pages. As is shown, a minimum of two bands is necessary in order to simultaneously cover all of the long muscles. However, only two bands are necessary if the electrodes are placed properly along their length.

Muscles under lower band:

Vastus Lateralis

Rectus Femoris

Sartorius

Vastus Medialis

Gracilius

Semimembranosus

Semitendinosus

Biceps Femoris

Muscles under upper band:

Gluteus Medius

Gluteus Maximus

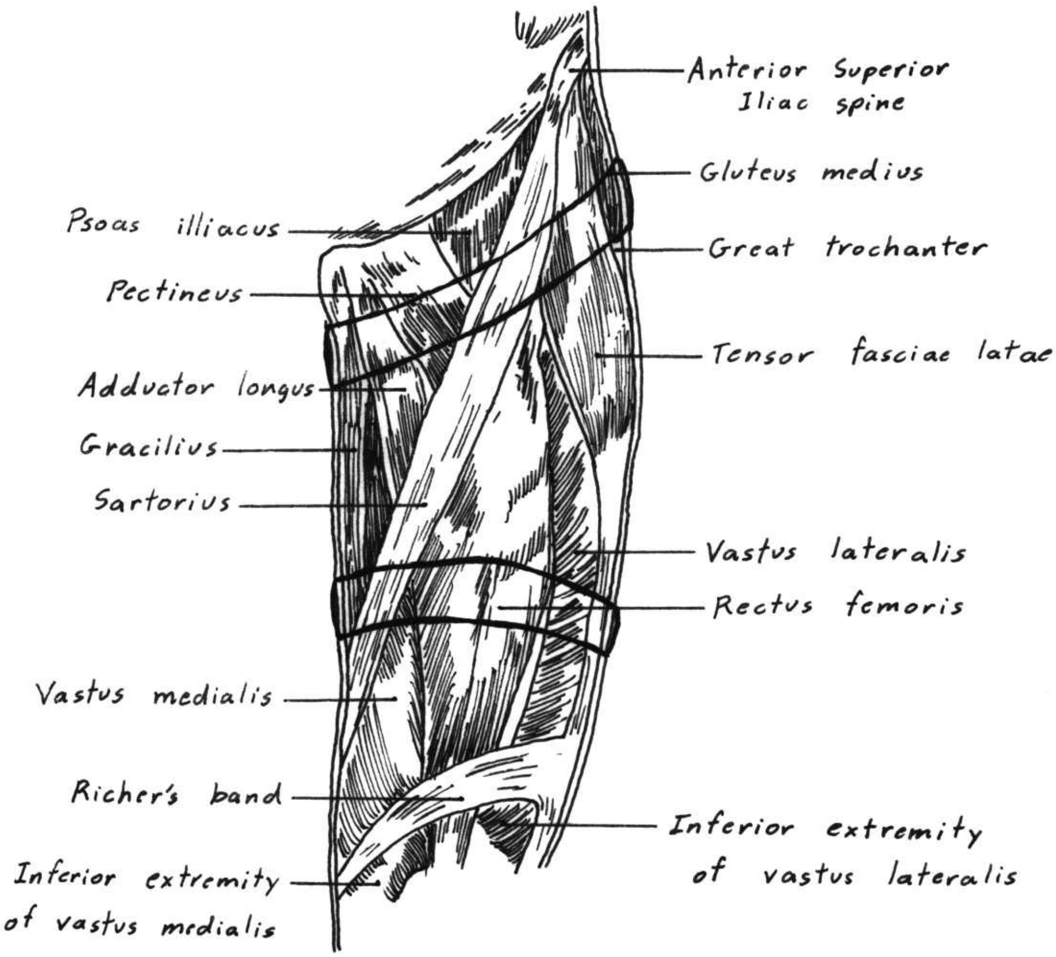
Adductor Magnus

Tensor Fascia Latae

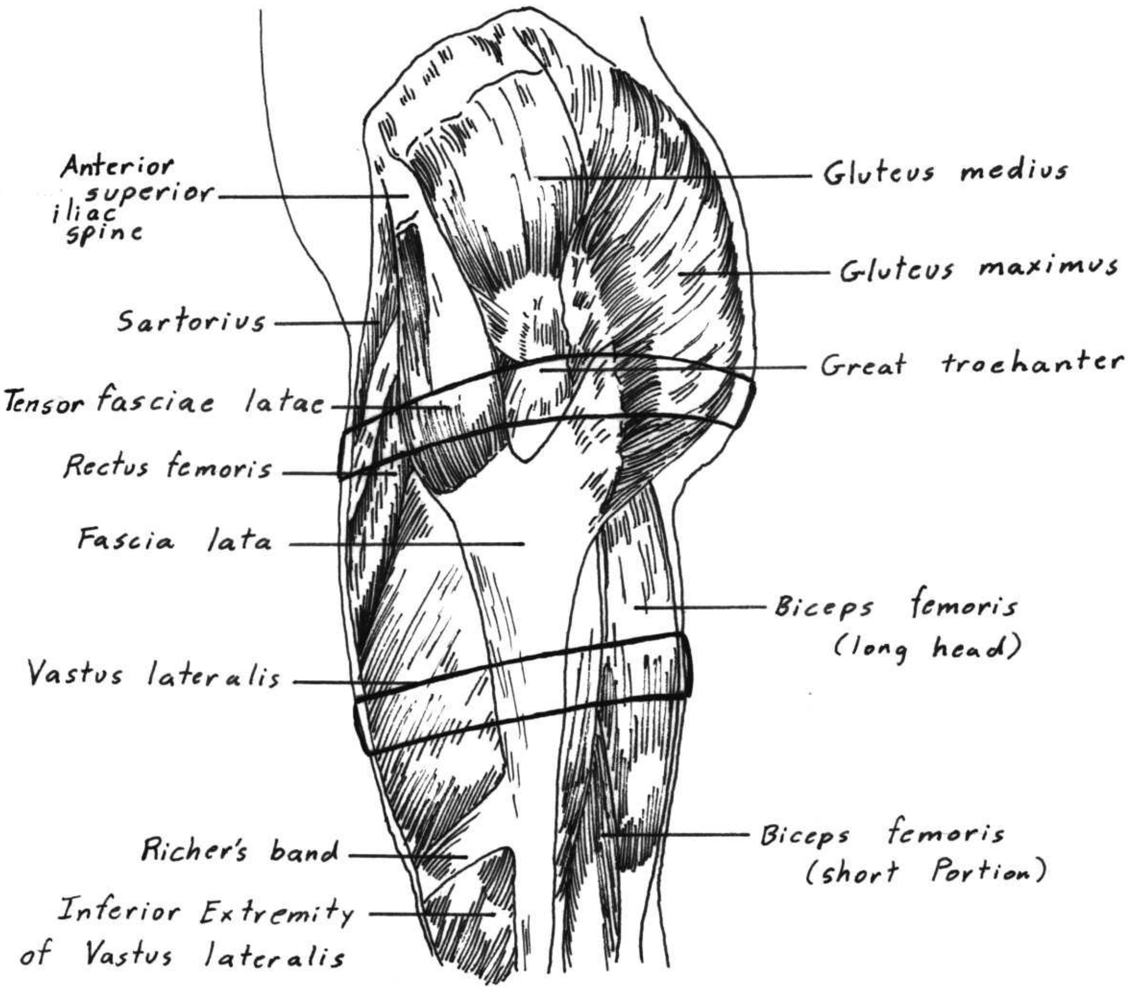
Psoas Illiacus

Pectineus

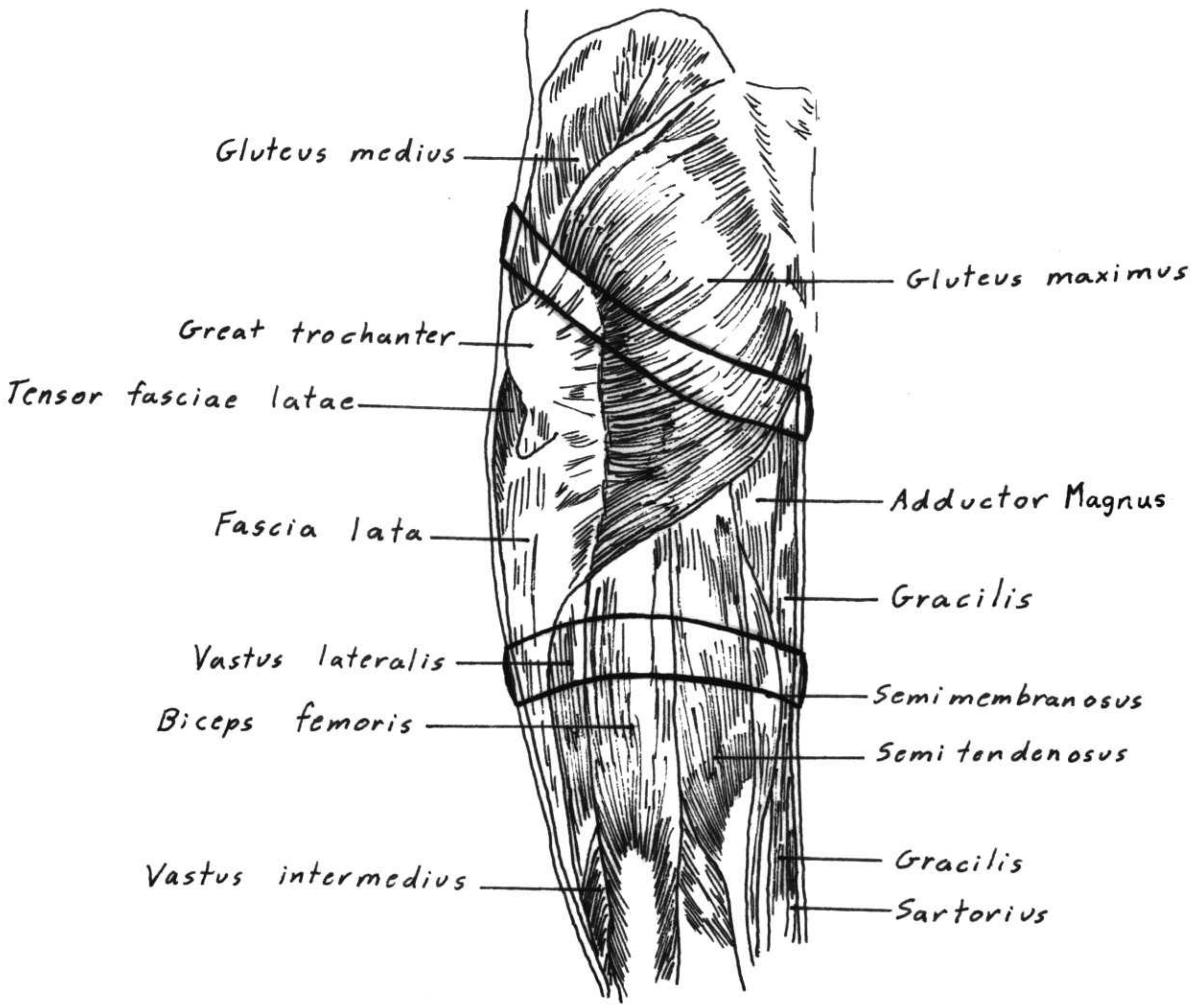
Adductor longus


Anterior Superior
Iliac spine
Gluteus medius
Psoas illiacus
Great trochanter
Pectineus
Tensor fasciae latae
Adductor longus
Gracilius
Sartorius
Vastus lateralis
Rectus femoris
Vastus medialis
Richer's band
Inferior extremity
of vastus lateralis
Inferior extremity
of vastus medialis

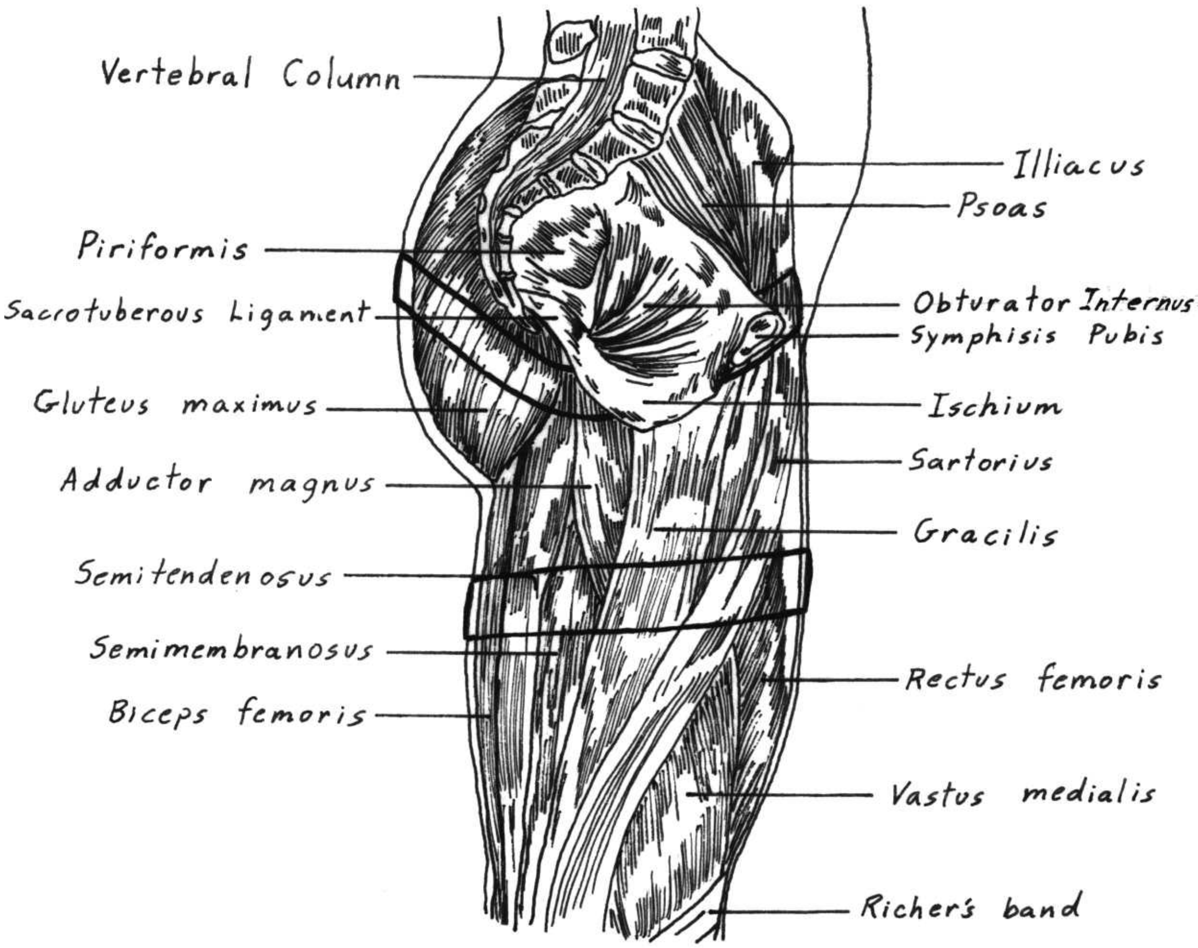
Front


Anterior superior iliac spine
Sartorius
Tensor fasciae latae
Rectus femoris
Fascia lata
Vastus lateralis
Richer's band
Inferior Extremity of Vastus lateralis
Gluteus medius
Gluteus maximus
Great trochanter
Biceps femoris (long head)
Biceps femoris (short Portion)

Outside


Gluteus medius
Gluteus maximus
Great trochanter
Tensor fasciae latae
Adductor Magnus
Fascia lata
Gracilis
Vastus lateralis
Semimembranosus
Biceps femoris
Semi tendenosus
Gracilis
Vastus intermedius
Sartorius

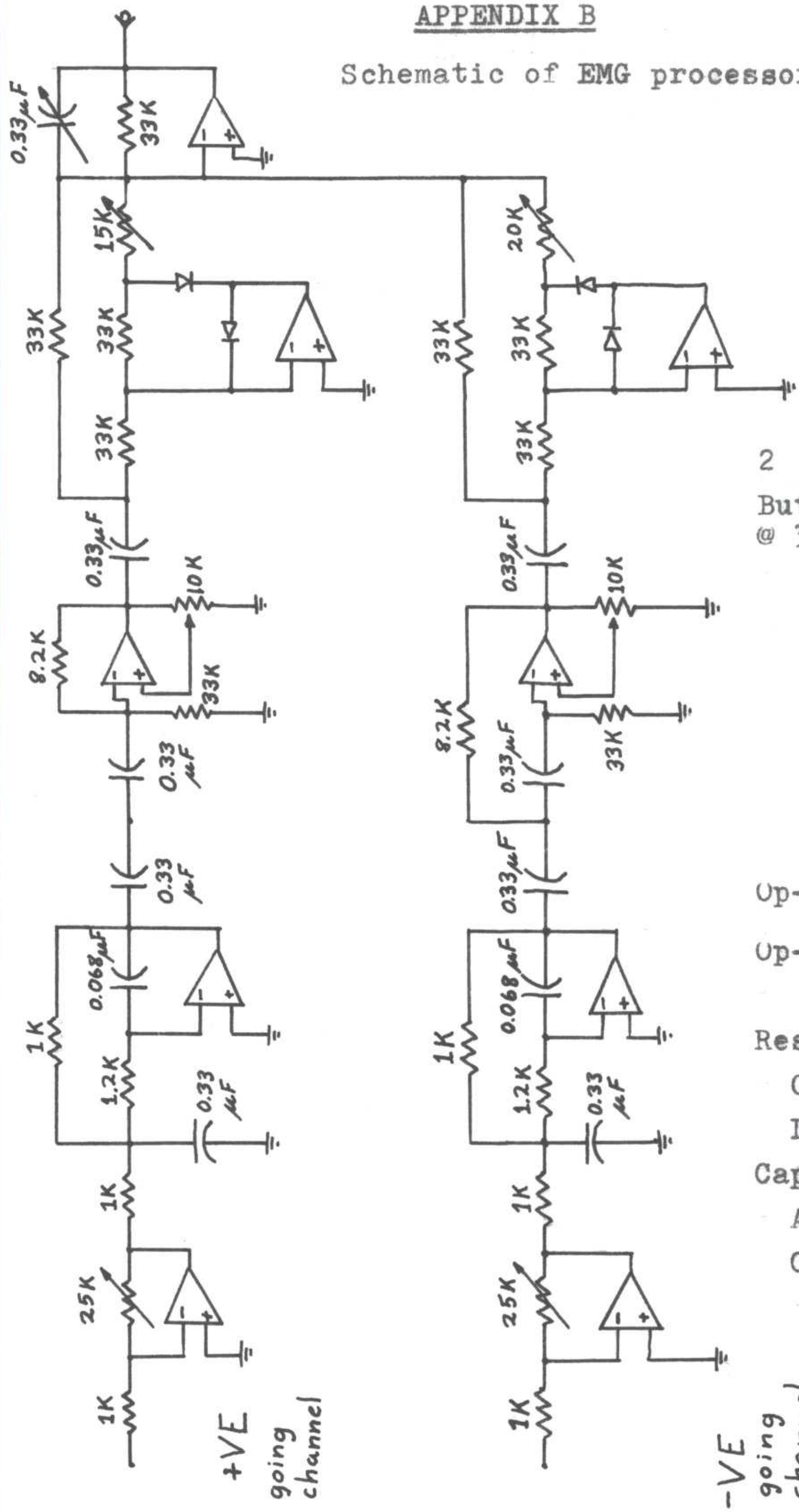
<u>Back</u>


Vertebral Column
Piriformis
Sacrotuberous Ligament
Gluteus maximus
Adductor magnus
Semitendenosus
Semimembranosus
Biceps femoris
Illiacus
Psoas
Obturator Internus
Symphisis Pubis
Ischium
Sartorius
Gracilis
Rectus femoris
Vastus medialis
Richer's band

Inside

APPENDIX B

Schematic of EMG processor



2 High Pass Butterworth @ 30 Hz

Op-amps 8-pin DIP

Op-amp Sockets 10-pin DIP

Resistors

OHMRE LITTLE DEVIL 59.

Capacitors

ARCO MCY or CENTRACASB CY