ADAPTED TV REMOTE CONTROL

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ECE 445

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December 6, 2005

Project #7

ABSTRACT

The purpose of our project is to provide an alternative way to control the basic operations of a television. This would be useful for those with physical disabilities who may not have full functionality of their arms.

The user will be able to operate a universal remote control using an electro-oculogram (EOG) to amplify the voltages generated by their eye movements. These voltages will in turn drive the remote.

The basic setup of our project is to have 4 electrodes attach to the skin of the user. These are connected to the inputs of multiple operational amplifiers that are placed in series to obtain the correct output voltage. The outputs of the amplifiers are then connected to the remote between diodes that act as switches.

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1. INTRODUCTION

The basic setup of our project is to have 4 electrodes attached to the skin of the user. These are connected to the inputs of multiple operational amplifiers that are placed in series to obtain the correct output voltage. The outputs of the amplifiers are then connected to the remote between diodes that act as switches. These switches will activate the remote when the person is looking right to left (channel up), left to right (channel down) and up and down (power).

1.1 Purpose

We used our knowledge of biomedical instrumentation to design a project that provides an alternative way to control the basic operations of a television. This would be useful for those with physical disabilities who may not have full functionality of their arms. The user will be able to operate a universal remote control using an electro-oculogram (EOG) to amplify the voltages generated by their eye movements.

1.2 Specifications

Because we are using an EOG signal, the frequency of this biological component ranges from 0.1 Hz to 38 Hz. Due to this fact, we originally designed a low-pass filter with cutoff frequency of 45 Hz.

In order to receive a viable signal from the EOG, (that typically produces 5 mV) this signal was fed through a series of amplifying circuits. Each of these circuits used the same gain equation (Equation 2.1) to determine the amount of amplification.

1.3 Subprojects

Our design was broken into two separate modules. The two we implemented are listed below.

1.3.1 EOG module

The EOG module consisted of 3 AD622s in series for the horizontal eye movement and 2 AD622s in series for the lateral eye movement. The signal was amplified accordingly using the gain equation (Equation 2.1). This output was then fed into the diode module.

1.3.2 Diode module

The Diode module consisted of 2 1N749 diodes (4.3 V) connected between the EOG and the remote to act as switches for shorting out the contacts in order to activate the remote.

2. DESIGN PROCEDURE

2.1 Electrodes

The electrodes were used to obtain the voltage from the user's eye movements. Most electrodes have a gel that is used to lower impedance at the junction of the skin and electrode contact as well as an adhesive that is used to bind the electrode to the skin. The electrodes that we used (generously provided by Professor Raymond Fish) combined the two substances which is why the electrodes that we used were so small and thin. This provided problems because since the gel and adhesive were combined, the contact to the skin could not withstand the weight of the alligator clips that were used to transfer the voltage to the EOG circuit. A recommendation for later study would be to use stronger electrodes that do not combine the gel and adhesive.

Also, movement of the user's head affects the offset of the voltage. We believe this is because the movement alters the electrode's position on the skin and therefore changes the impedance of the electrode-skin interface. The solution for this would be to use stronger electrodes, as mentioned previously.

2.2 EOG Circuit

The outputs of the electrodes were put into two sets of operational amplifiers. The output of the laterally placed electrodes was placed into one series of amplifiers and the output of the vertically placed electrodes was placed into another series of amplifiers. To differentiate between looking left to right and looking right to left, we placed a differential amplifier at the end of the first series of operational amplifiers.

Originally we had a low-pass filter after the first AD622 that had a cutoff frequency of 45 Hz. We omitted this filter from the final schematic because the amplifiers reduced any significant noise. Any resulting noise was trivial and did not affect the behavior of our circuit.

2.2.1 Background of the EOG

The eye acts as a dipole, with the cornea being positive and the retina being negative. The EOG picks up the slight voltage generated by eye movement and amplifies it to a useable voltage. We are measuring the voltage when the eyes move horizontally and vertically. The EOG does not pick up torsional movements. When a person blinks, their eyes move upwards, creating a voltage. We want the voltage created by that blinking to turn the remote on and off, while the horizontal eye movements control the channel buttons.

All frequency content of the EOG is within 0.1 and 38 Hz.

2.2.2 Gain of the EOG Circuit

The equation that we used for the gain of each of the amplifiers is as given in the data sheet:

$$\text{Gain} = 1 + 50.5\text{k}\Omega/R_g \tag{2.1}$$

Using this equation, we found the gains for the three amplifiers for the horizontal EOG, and the two amplifiers for the vertical EOG. The gain of the inverting amplifier was kept at unity gain.

2.2.3 Output of the EOG Circuit

The resulting voltages out of the vertical and horizontal EOG circuits were around 4.3V, depending on the position of the eyes. When the eyes move from side to side, the voltage would go above 4.3 V, and would remain below 4.3 V when the user is looking straight ahead.

2.3 BJT Circuit

In our original design, we thought that current into the remote was going to be an issue. Therefore, we added BJT transistors after the EOG amplifying circuit to amplify the current to whatever the remote control required. The output of the EOG would first have to turn on a 4.3 V diode, which would act as a switch when the user looks left/right or up/down, and then the BJT would amplify the current out of the EOG circuit.

After testing the remote, we decided that the BJT circuit was not needed, and was left out of our final design. The actual current flowing through the remote was about 6 µA, which is negligible for our purposes.

2.4 PIC Microcontroller

We had originally designed our circuit to also use a PIC microcontroller because we thought that the remote could be controlled by blinking rapidly twice. This would have introduced a time-dependent module in our circuit. Ultimately we decided that controlling the remote in real-time would be more practical. Also, the amplifiers in the circuit delayed the voltage signal slightly. Blinking twice would have been difficult to detect.

2.5 The Remote Control

The circuit underneath the buttons on the remote control is shown in Picture D.5 (All figures and pictures are listed in the Appendix). From testing the remote, we determined that the action of pressing down the button shorts the two contacts on the circuit board. This action also generates a voltage potential between the two contacts of 3 V. So we needed a circuit to do the same thing between the EOG amplifier and the wires attached to the contacts on the remote control. Using the same idea from the discarded BJT circuit, we decided to use 4.3 V diodes as switches.

2.6 The Diode Circuit

The requirements for this circuit was for the two wires that connect to the remote have to be disconnected to each other for an EOG output voltage of less than 4.3 V (the user is not looking to the left or right), and the two wires should be shorted for a voltage greater than 4.3 V. This will act in the same manner as pressing down on the button on the remote. So, at the output of each of the EOG amplifiers (horizontal EOG, inverted EOG, and vertical EOG) the circuit shown in Figure B.4 was added.

3. DESIGN DETAILS

3.1 EOG Circuit

The placement of electrodes for maximum voltage output is illustrated in Picture D.1. From this setup, the wires from the electrodes were used as the inputs for the vertical and horizontal EOG amplifying circuits, as seen in Picture D.2 and Picture D.3. We used AD622 operational amplifiers to boost the voltage to a useable value. To differentiate between looking from right to left and looking from left to right, a LM741 differential amplifier was placed at the end of the horizontal EOG circuit. This output is separate from the original horizontal EOG and goes to the "channel down" button. The non-inverted output from the AD622 goes to the "channel up" button. The output of the vertical EOG amplifying circuit goes to the "power" button.

Originally, we had a low-pass filter that was to reduce noise picked up by the wires going from the electrodes to the EOG circuit. The filter was to be over the second amplifier in both horizontal and vertical amplifiers as shown in our original schematic, Figure B.1. The equation that we used to design the filter is as follows:

$$f_c = 1 / [2*\pi*R*C]$$

We chose our cutoff frequency to be 45 Hz, so the resulting resistor and capacitor values were 16.2 kΩ and 0.22 μF.

3.1.1 Gain of the EOG Circuit

The next step in the design process was to choose the gain of the amplifiers to give us the correct voltage to the diode circuit. The gain of the AD622 operational amplifier was given by this equation in the data sheet:

$$\text{Gain} = 1 + 50.5\text{k}\Omega/R_g$$

R_g is defined as the value of the resistor between pins 1 and 8 on the AD622.

	First AD622	Second AD622	Third AD622
Gain	15.6	99	2.1
R_g	3.56 kΩ	560 Ω	50 kΩ

This gives us a total gain of 3,243.2. The first (Figure C.2) and second amplifiers (Figure C.3) were used to raise the voltage to roughly the right voltage we needed , and then the last amplifier was used to fine tune the voltage (Figure C.4). The reason why three amplifiers were used was because although the amplifiers have the capacity to amplify a signal up to 1000 times, but a more practical gain is less than 100 times. Having a lower gain value ensures faster settling time, which is important in real-time applications like this project. Figure C.8 shows the settling time of the AD622 amplifier.

We chose the gain of the inverting amplifier to be unity because all we needed for it to do was invert the output. No extra gain was needed.

The vertical electrode voltages were found to be much larger than the horizontal voltages. For that reason, only two amplifiers were needed. The resistances that we used and the resulting gain are as follows:

	First AD622	Second AD622
Gain	10.9	99
R_g	5.1 kΩ	560 Ω

This gave us a total gain of 1097.1. As one can see, this gain is 0.338 the times of the horizontal EOG circuit.

3.1.2 Output of the EOG Circuit

The resulting voltages out of the vertical and horizontal EOG circuits were around 4.3V, depending on the position of the eyes and head. Figures C.5 and C.6 illustrate the range of voltages that can be expected out of the EOG circuit. When the eyes move from side to side, the voltage would go above 4.3 V, and would remain below 4.3 V when the user is looking straight ahead. The change in voltage is 3.13 V for the horizontal EOG and 0.938 mV for the vertical EOG.

3.2 Remote Control

For the core of our project, we used the One For All® Universal Remote Control. The circuit board on the inside is shown in Figure D.4. A layer of anti-soldering material (seen as the black substance covering the contacts) had to be carefully removed to expose the contacts for “channel up,” “channel down,” and “power” (Shown by Figure D.5 and D.6). For clarification for the aforementioned Figures, the button labeled “S05” is “channel up,” “S06” is “channel down,” and “S02” is “power.”

When the button is pressed on the remote, the two contacts underneath the button would be shorted. From testing the remote, we determined that the voltage across the two contacts was a constant 3 V. The oscilloscope readout of the remote while the two contacts are shorted is shown in Figure C.7.

Some challenges that we encountered while testing the remote were the anti-soldering material and the thin contacts. The anti-soldering material made it difficult to solder any wire to the board, but scratching off the material put the thin electrical contact at risk. We were not able to get any wires soldered onto the board, but holding two wires to the remote had the same effect. Recommendations for future projects would be to use thinner wires and drill holes in the board for more support for heavier wires.

The wires on the remote are connected to a diode circuit, which is the interface between the EOG and the remote’s circuit board.

3.3 Diode Circuit

The requirements for this circuit were that the two wires that connect to the remote have to be disconnected to each other for an EOG output voltage of less than 4.3 V (the user is not looking to the left or right), and the two wires should be shorted for a voltage greater than 4.3 V. Essentially, the diode circuit will act as a switch between the EOG and the remote control. The diode that we decided to use was a 1N7498 4.3 V diode. When the EOG meets its requirements, the remote will operate in the desired way. The schematic of Figure B.4 shows the new circuit that was used in place of the original BJT circuit. The reasoning behind the design is that when the EOG is greater than 4.3 V, the diode acts as a short. This will also short the diode that separates the two wires that connect to the remote, which will essentially act like the button was being depressed.

4. DESIGN VERIFICATION

The test that would determine if our project worked was that the LED on the remote would light up when the EOG voltage was greater than 4.3 V. To us, this would signify that the appropriate signal would be sent from the remote control.

4.1 Testing

We wanted to test three major parts of the design project. We required the EOG circuit to be robust to 60 Hz noise, and the signal also has to be useable by the remote. The interface circuit from the EOG to the remote also has to output the right signal to the remote given correct output of the EOG. Also, we tested the effect of offset from the electrodes and how it would affect our project.

4.1.1 Filter

The filter that we added to our EOG circuit was a just a resistor and capacitor in parallel with the second AD622 in both the horizontal and vertical EOG circuits. We tested the behavior of the circuit with the oscilloscope and found that the filter wasn't necessary. The amount of noise that was carried in the EOG signal was much smaller than the voltage swing when the user looks sideways or up and down. For example, shown in Figure C.4 is the output of the third amplifier in the horizontal EOG circuit. The effect of noise can be seen, but the voltage difference from looking to the side is much greater than the noise. Ultimately, the AD622 amplifiers provided enough filtering for our project.

4.1.2 EOG

We tested the output of each amplifier for the horizontal EOG to test the affect of noise as well as the gain. Figure C.1 is the raw signal taken from the electrodes. When testing with the oscilloscope, the differences in voltage from looking around were completely obscured by noise. After running the raw signal through an AD622 amplifier, the signal was cleaned up considerably and differences of voltage were easier to see (Figure C.2). Figures C.3 and C.4 show the gradual progression of the circuit to obtain voltages that can be used to drive the remote. The outputs of these amplifiers give the correct signal voltages to the remote. These amplified signals would have to be sent through an interface circuit before powering the remote.

4.1.3 Diodes

The schematic of the diode circuit, which acts as the interface circuit, is shown in Figure B.4. When testing the remote, we found that the voltage needed was 3 V (Figure C.7). The effect of the diode circuit would be to short the wires. We tested the circuit to make sure that it would turn on the LED of the remote. When we hooked up the EOG to the remote to test, the LED did turn on, so we were happy with the results of our diode circuit.

4.2 Conclusion

The separate modules performed within our specified parameters and we were able to combine them to get a working project.

5. COST

5.1 Parts

The cost of our project's parts was minimal compared with the cost of labor. The most expensive components of our project were the instrumentation amplifiers. The second most expensive part of our project was the remote (see Figure E.4), but even that cost can be minimized if one were to build a remote from scratch with limited functionality. The third most expensive item was the electrodes (Figure E.1), but the electrodes that we used are some of the cheaper brands. One trades quality with price with electrodes. A sturdy, functioning EOG that is robust to movement will require more expensive electrodes. The total cost of this project's parts was $79.90.

5.2 Labor

We estimated our future salary to be $50 an hour. Our original estimate of 180 hours was fairly accurate. The majority of those hours were spent in the lab and not on the design process. The bulk of the time spent in the lab was fine tuning the EOG to give us the correct output. We were able to work together on most of this project, so the hours for each partner were very similar. Using the equation below as the formula for estimating cost, the labor cost for our project was about $22,500 per person.

Ideal salary (hourly rate) x actual hours spent x 2.5 = Labor cost

This added together with the cost of our parts gives us the total cost of our project. The total cost of our project is estimated to be $45,079.90. The number of units that would have to be sold of this project in order to recover the research and development fees would be 563.

6. CONCLUSIONS

After finally overcoming many difficulties, we ended up with a working product. The EOG signal was strong enough coming through the op-amps and the diodes were working correctly. The led light up after the subject looked either right to left, left to right or up and down.

However, many things could have been improved with this project. First, if we had obtained sturdier electrodes, we would not have had to deal with many of the offset issues due to the alligator clips pulling the electrodes away from the skin. Also if we had known how to solder better or better techniques for holding down the wires, this would have eliminated single testing of the led and allowed for a better demonstration of a working product.

Some further tests would like to have been done on this project if time were available. First we would have shielded the wires coming from the electrodes into the AD622 to remove as much noise in the circuit as possible. Even though the amplifiers filtered out most of the noise, this additional filtering could have helped us with better control of the voltage or signal strength. This would be useful for other EOG projects that require greater accuracy of the voltage. Additionally, we would like to test different combination of gains used by the AD622s. We were curious if using a series of equal gains (32 for example) would cut down on the signal time and allow for faster data acquisition. If this were possible, blinks could have been implemented.

Some future modifications of this project could be easily added. One consideration would be wireless communication between the electrodes and the EOG module itself. This would cut down on the noise produced in the wires as well as improving the offset issues. Also we would like to use thinner gauge wire to help with soldering issues. Alternatively, we would build our own remote control with limited functions (only power and channel up and down) to save on these difficulties.

The cost of this project was relatively inexpensive. The only costly component was the instrumentation amplifiers themselves. If this project was to be mass produced, these devices would be obtained at a cheaper cost as well as a decrease in the amount of labor needed to produce the finished project.

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[3] National Semiconductor, “LM741 Operational Amplifier,” [Online Document], August 2000, [cited 16 October 2005], Available HTTP: http://www.national.com/ds/LM/LM741.pdf

[4] Microsemi Corp, “1N746 thru 1N759A, -1, e3 and 1N4370 thru 1N4372A, -1, e3 and DO-35,” [Online Document], 2005, [cited 20 November 2005], Available HTTP: http://microsemi.com/datasheets/SA5-7.PDF

APPENDIX A – BLOCK DIAGRAM

Diagram A.1 shows the block diagram for our original design. The internal blocks are independent modules that were designed, expect for the person and remote, which was obtained from Wal-Mart. In our final design, the filter was removed because it was deamed unnecessary.

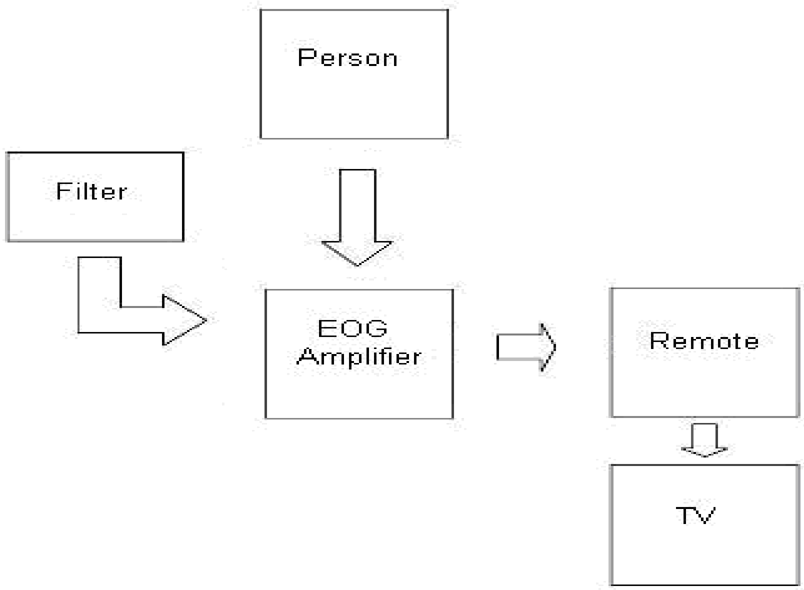


Diagram A.1 Block Diagram of Project

APPENDIX B – SCHEMATICS

Figure B.1 is the schematic used for our original design. Figure B.2 is the schematic used for the actual project. Figures B.3 and B.4 are the schematics of the EOG module and Diode module respectively.

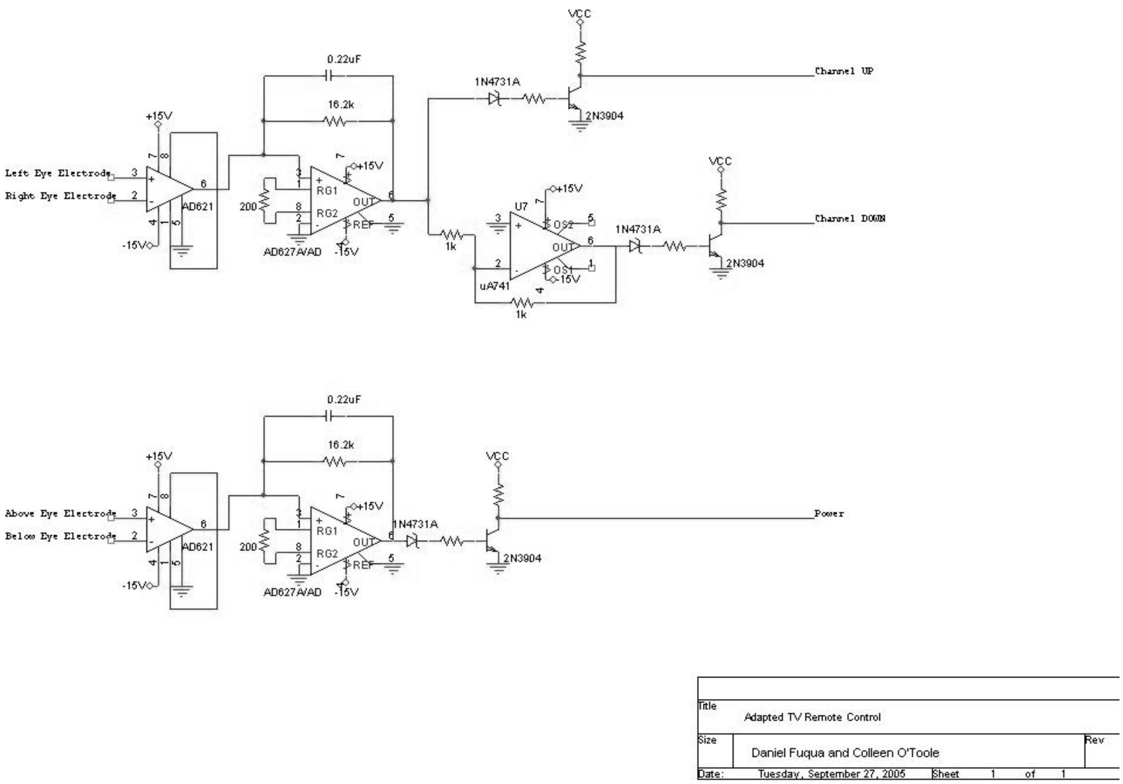


Figure B.1 Schematic of Original Design (LPF and BJT modules are shown)

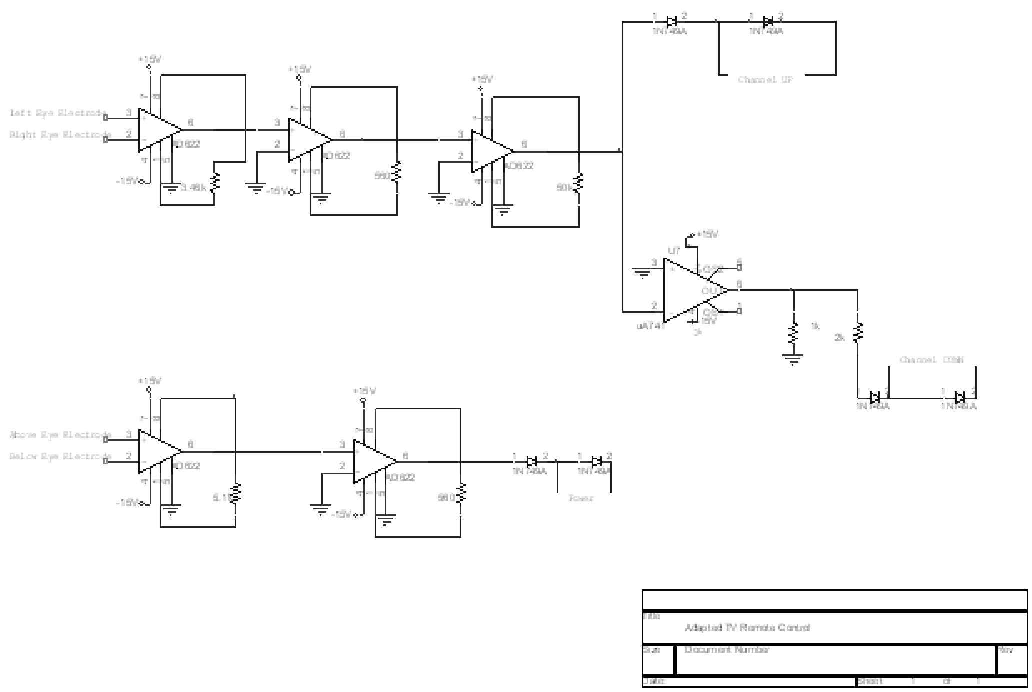


Figure B.2 Schematic of Final Design (Diode module is shown)

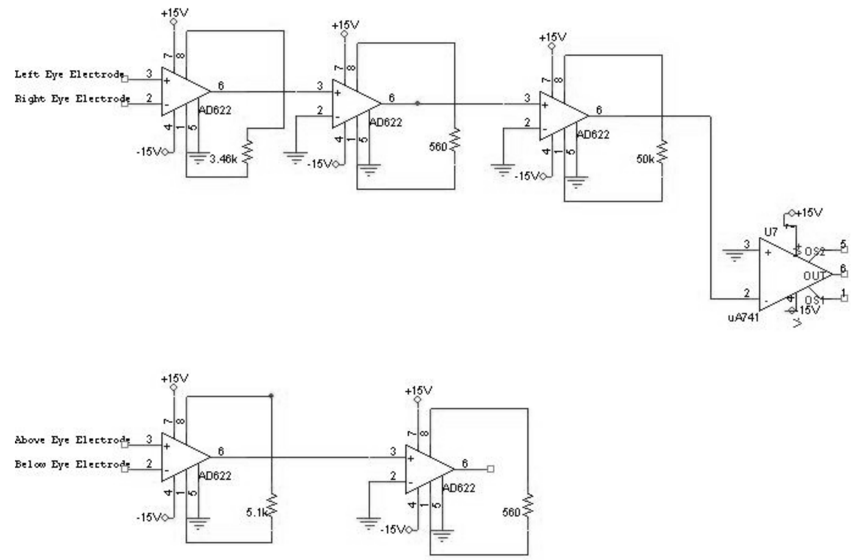


Figure B.3 Schematic of the EOG module

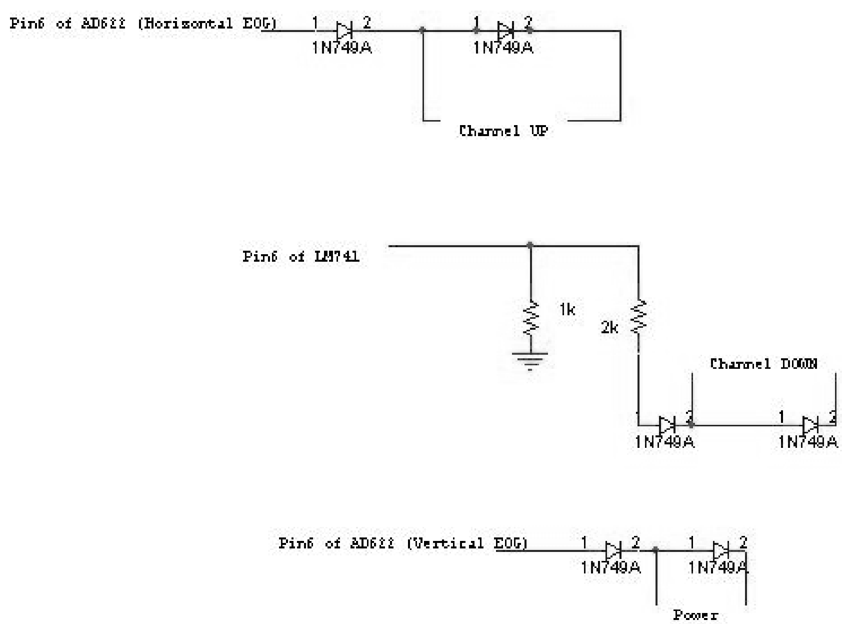


Figure B.4 Schematic of the Diode module

APPENDIX C – TEST DATA

Figures C.1 through C.4 show the voltage changes through each additional amplifier, as well as the input voltage across the electrodes. Figure C.5 shows the voltage from subject looking right to left across a 1kΩ resistor. Figure C.6 shows the voltage from the subject looking up and down across a 1kΩ resistor. This was done to determine the current supplied by the person which could be in turn used to drive some sort of load. Figure C.7 shows the voltage behavior of the remote control when the contacts are shorted.

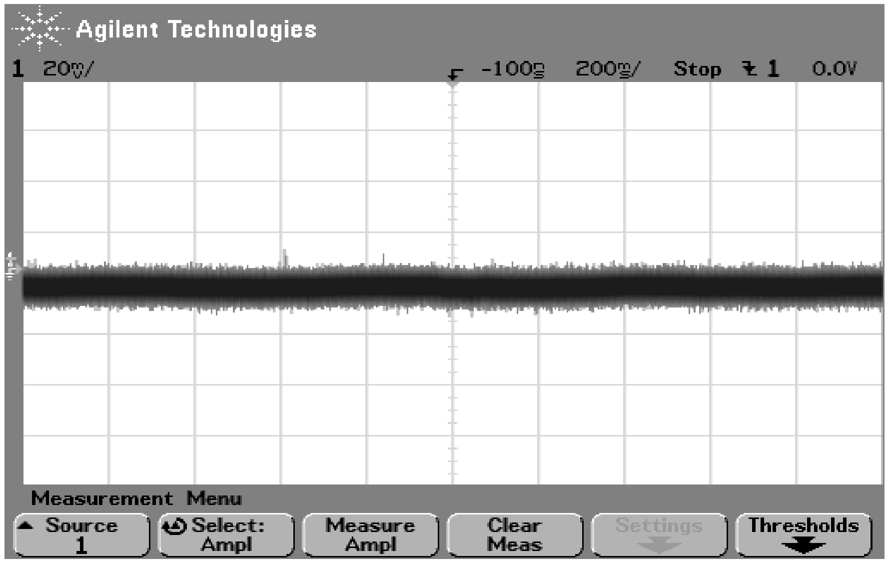


Figure C.1 Output of electrodes

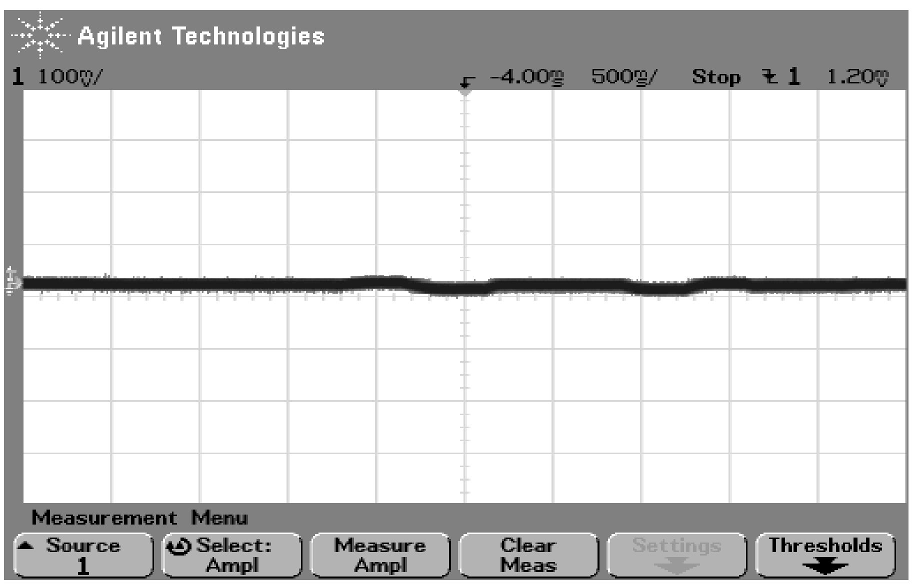


Figure C.2 Output of First Horizontal Amplifier

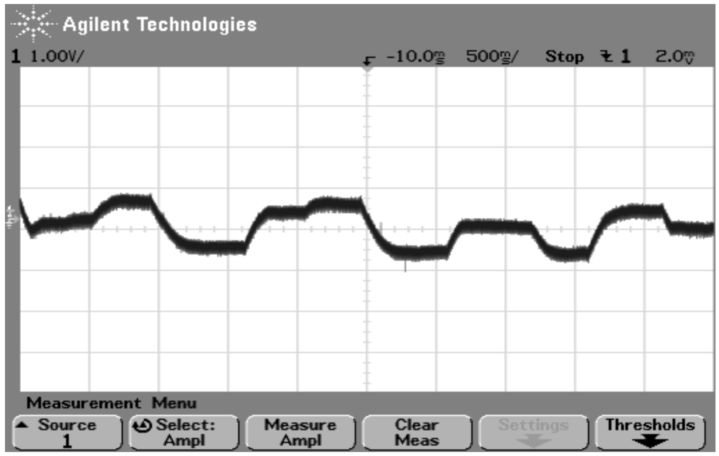


Figure C.3 Output of Second Horizontal Amplifier

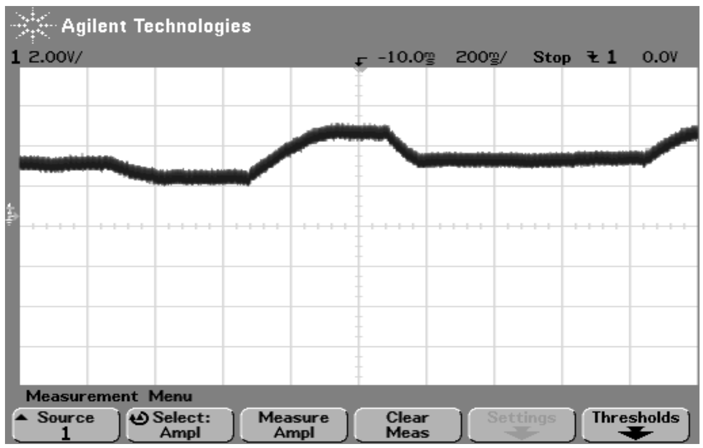


Figure C.4 Output of Third Horizontal Amplifier

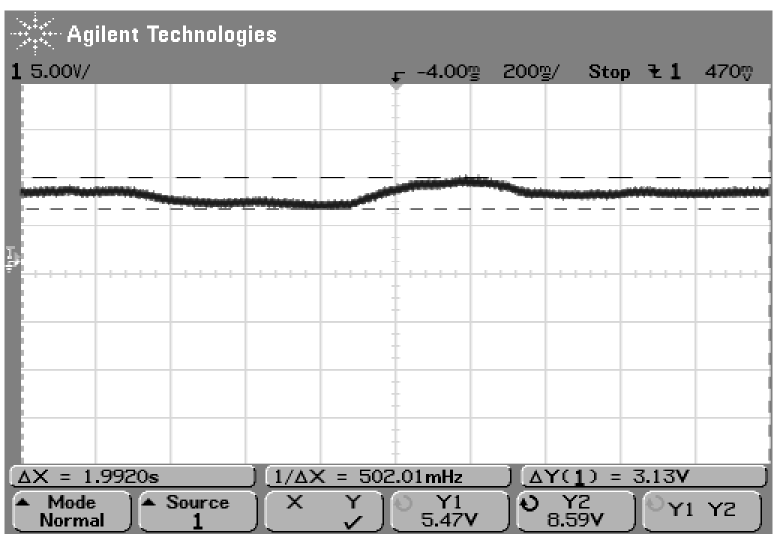


Figure C.5 Voltage across 1kΩ resistor looking right and left

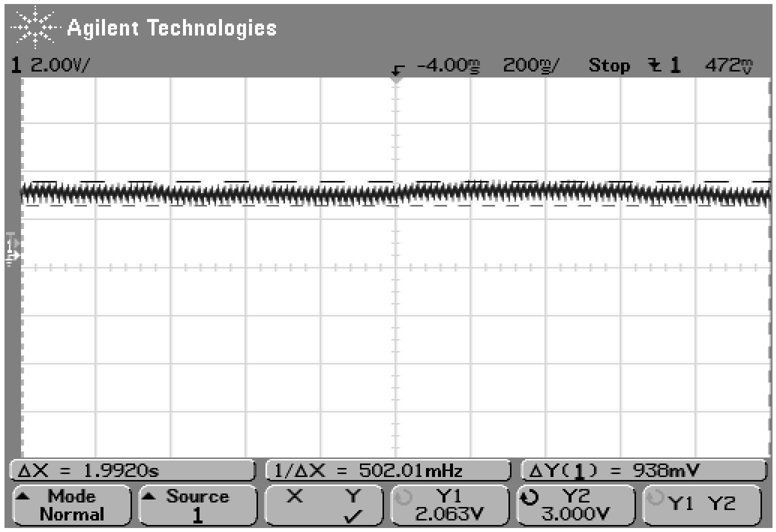


Figure C.6 Voltage across 1kΩ resistor looking up and down

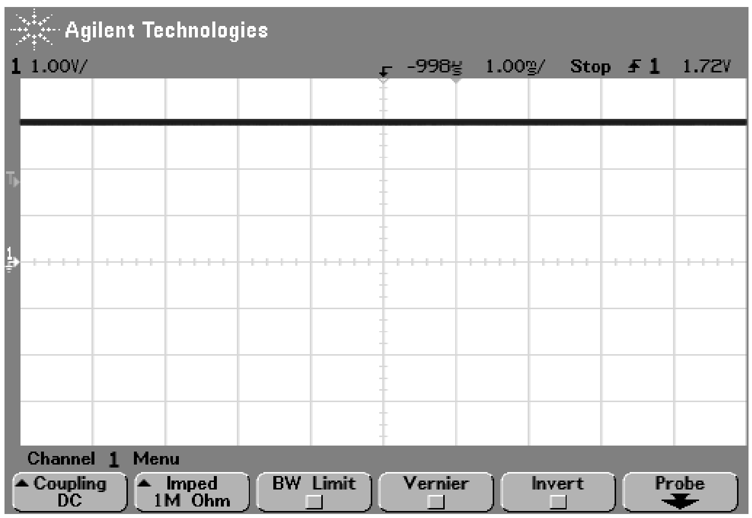


Figure C.7 Voltage across remote

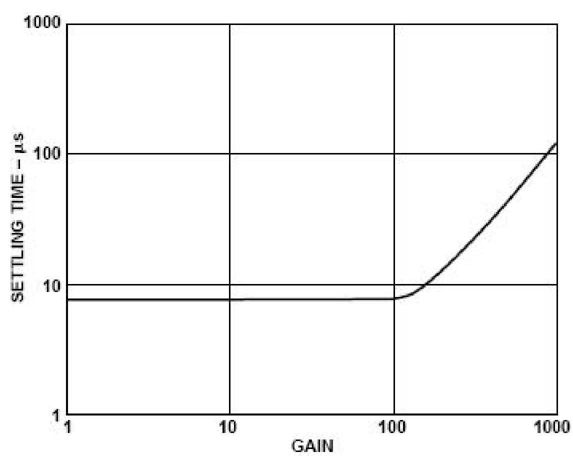
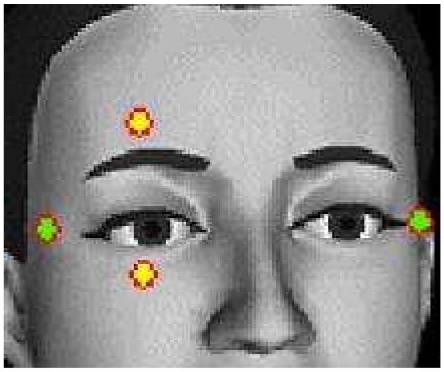


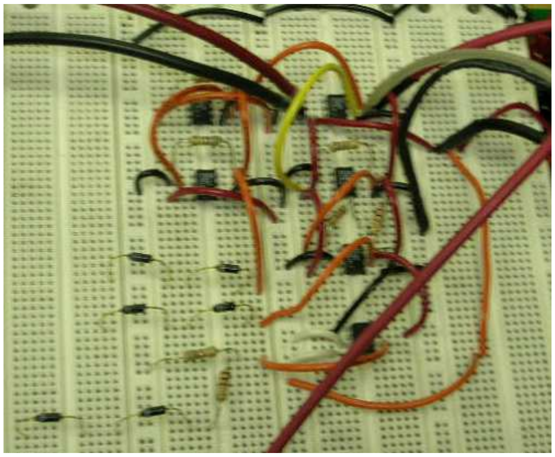
Figure C.8 Settling time of AD622

APPENDIX D – PICTURES

Pictures of the electrode placement can be seen in Figure D.1. Pictures of the circuit can be seen in Figure D.2 through Figure D. Pictures of the remote can be seen in Figure D. through Figure D.



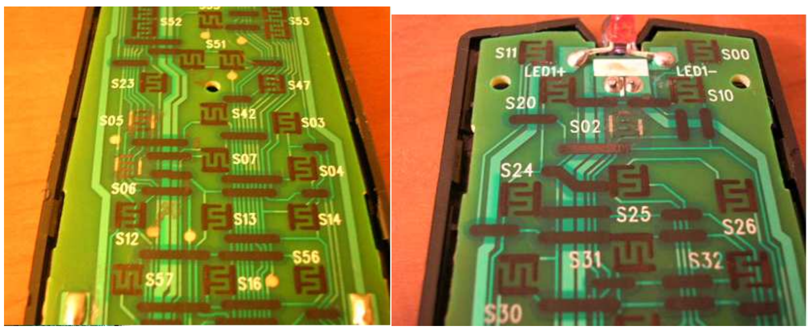
Picture D.1 Electrode Placement



Picture D.2 EOG module

Picture D.3 Overall Design

- **Picture D.4** One For All® Universal Remote URC-3021B00



Picture D.5 Remote contacts

APPENDIX E – PARTS AND COST

The parts and costs for the different modules are listed in Table E.1 through Table E.4. Each table includes the part number, manufacturer, description, cost, quantity, and total cost. The electrodes were listed as a separate module for simplification purposes.

Table E.1 Electrodes

Part #	Manufacturer	Description	Cost	Qty	Total Cost
EGECL5500	Kendall	Kendall Q-Trace Gold 5500	$7.00 for 100	1	$7.00

Table E.2 EOG module

Part #	Manufacturer	Description	Cost	Qty	Total Cost
25J500	OHMITE	500 OHM 5 WATT RESISTOR	$1.02	1	$1.02
25J10R	OHMITE	10 OHM 5 WATT RESISTOR	$.99	2	1.98
25J50R	OHMITE	50 OHM 5 WATT RESISTOR	$1.81	2	3.62
97-20K	MCM ELECTRONICS	20K-OHM 1/8W 5% CHIP RES	$1.83	2	$3.66
4308R-1-332-ND	BOURNS	3.3K BUSSED SIP RESISTOR	$.66	1	$.66
25J1K0	OHMITE	1K OHM 5 WATT RESISTOR	$.95	1	$.95
25J5K0	OHMITE	5K OHM 5 WATT RESISTOR	$2.62	3	$7.86
25J100	OHMITE	100 OHM 5 WATT RESISTOR	$1.29	2	$2.58
AD622AN	Futurlec	AD622	$4.90	5	$24.5
uA741	Fair Child	uA741	$.22	1	$.22
JK1	Graymark	Wires – various sizes (box)	$13.95	1	$13.95

Table E.3 Diode module

Part #	Manufacturer	Description	Cost	Qty	Total Cost
1N749A	Fair Child	4.3V, 0.5W Zener Diode	$.04	6	$.24
25J-2.0K	OHMITE	2K OHM 5 WATT RESISTOR	$.72	1	$.72
25J1K0	OHMITE	1K OHM 5 WATT RESISTOR	$.95	1	$.95

Table E.4 Remote

Part #	Manufacturer	Description	Cost	Qty	Total Cost
URC3021	One For All®	Universal Remote	$9.99	1	$9.99