Al-Mustaqbal University

College of Engineering & Technology

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Lecture Title: EEG Construction, Example.

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3. Collecting the EEG data: This section comprises of a detailed summary of collecting the EEG data and transmitting it wirelessly using an Arduino UNO and XBee. It explains how the microcontroller was programmed to collect the data and then transmit it to another XBee.

2.1 Constructing the EEG Circuit

This section explains in depth how to construct a simple EEG circuit that will help in monitoring the EEG signal on an oscilloscope. The circuit is constructed in a way that it can be used for measuring both EEG and ECG (measure of the heartbeat). It uses three EEG electrodes, two for measuring the change in voltage across the scalp and one is used as the ground terminal. This project uses a minimum of three electrodes. In order to be able to use more than three electrodes, several such EEG circuits need to be constructed and linked together. Constructing this circuit is very reasonable economically.

2.1(A) Hardware parts required to construct the EEG circuit

Following is the list of all the parts needed to construct a simple EEG circuit with a brief description of each part.

1. 1x Instrumentation Amplifier:

AD620ANZ: The datasheet for the AD620 given by Digi-Key Corporation states that [7], the AD620 is an instrumentation amplifier with low cost and high accuracy. It requires only one external resistor to adjust its gain from 1 to 10,000. It has a 8-lead SOIC and DIP packaging which is smaller as compared to the discrete designs and offers a lower power value of 1.3mA maximum supply current. This makes is a perfect fit for battery-powered and portable applications. AD620 has accuracy up to 40 ppm, a low offset voltage of max 50μV and a max offset drift of 0.6µV/ºC. This makes it ideal for being used in precision data acquisition systems. Also, its low noise, low input bias current and low power makes it perfectly suited for being used in medical applications, for example EEG, ECG and noninvasive blood pressure monitors. The AD620 can be used as a pre-amplifier because of its low input voltage noise. An instrumentation amplifier can also be built using three operational amplifiers, but it very rare that it would give a result as good as the AD620ANZ.

The connections diagram for the AD620ANZ is shown in figure 2.1 below.

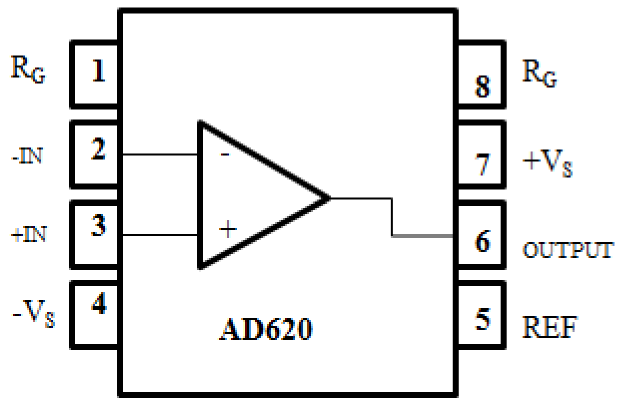

Figure 2.1 Pin Diagram of AD620 Instrumentation Amplifier [7].

2. 2x Operational Amplifier:

TL084IN: As mentioned in the datasheet for the TL084 [8], it is a high-speed JFET input quad operational amplifier. It is a monolithic integrated circuit incorporating high voltage JFET, and bipolar transistors. It has a high slew rate, low input bias and offset current, and a low offset voltage temperature coefficient. The pin connections diagram for TL084 is shown in figure 2.2 below.

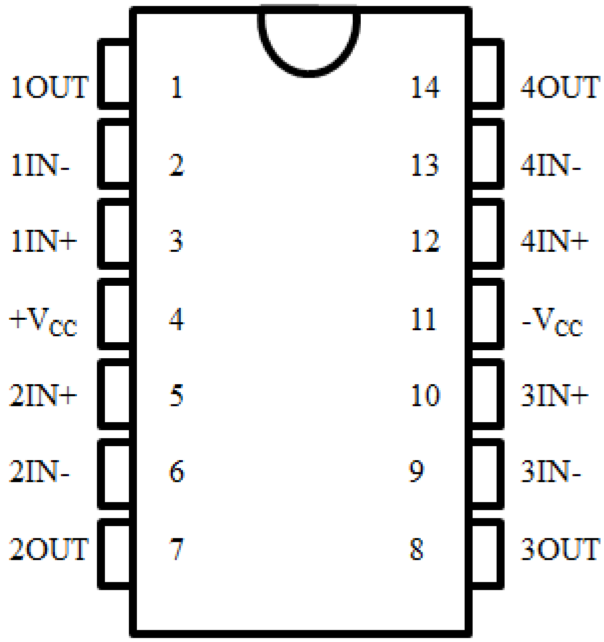

Figure 2.2 Pin Connection Diagram for TL084 Op-Amp [8].

3. 1x Notch Filter- UAF42AP-ND:

"The UAF42 is an universal active filter which can be used to configure a large range of low pass, high pass, and band pass filter" [9]. "It uses an inverting amplifier and two integrators having a classic state-variable analog architecture" [9]. The integrators consist of 1000pF capacitors on the chip, cut down to 0.5%.

4. Capacitors
5. Resistors
6. 3x EEG Electrodes:

This circuit design uses three EEG electrodes, two for measuring the voltage across the scalp and the third one is used as a ground electrode. The disposable cup EEG Ag/AgCl electrodes with a cup size of 10mm are used. The disposable cups ensure the safety of the people and eliminate the time spent in cleaning and disinfecting the electrodes.

7. 1x Breadboard:

A large enough breadboard is need to wire the entire circuit on.

8. Connecting Wires:

Several connecting wires of various sizes are required to make connections in the circuit on the breadboard.

9. 2x Arduino UNO:

An Arduino UNO is the microcontroller which is used to collect the EEG signal data and then transmit it to another arduino. It consists of 6 analog inputs, 14 digital input/output pins, a 16 MHz resonator, a USB connection, a power jack, an ICSP header, and a reset button. It is a self-sufficient microcontroller and simply needs to be connected to a computer with a USB cable, power it with an AC-to-DC converter or use with a battery. An arduino can receive inputs from a variety of sensors and thereby control the surroundings such as lights, motors, and other actuators. It can be programmed using the Arduino programming language. The figure 2.3 below shows an image of the Arduino UNO used in this project.

Figure 2.3: An image of the Arduino UNO.

10. 2x XBee PRO:

A pair of series 1 XBee's are programmed on the Arduino and then used to collect the EED data on one Arduino and then transmit it to the other arduino. It is a radio module which is used for over-the-air communication at a baud rate of 250kbits/s. An XBee is perfect for applications that need a low latency and predictable communication timing. It provides a rapid and robust point-to-point, peer-to-peer, and multipoint/star configuration communication. It can be used instead of a pure cable in case of simple serial communication or in a complex hub-and-spoke network of sensors. The XBee multipoint RF modules increase wireless performance and make development much easier. The figure 2.4 below shows the picture of the series 1 XBee used in this project.

Figure 2.4: An image of the series 1 XBee.

2.1(B) Compiling the Hardware together to form the EEG circuit

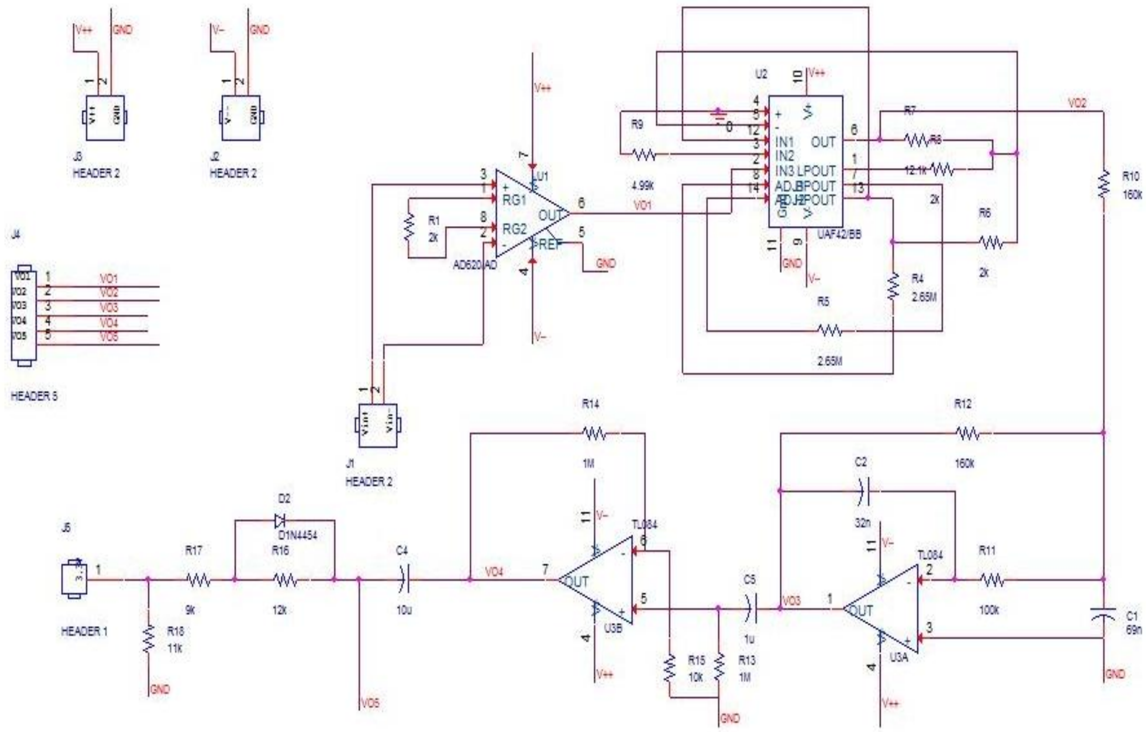

Figure 2.5 Schematic diagram of the overall EEG Circuit.

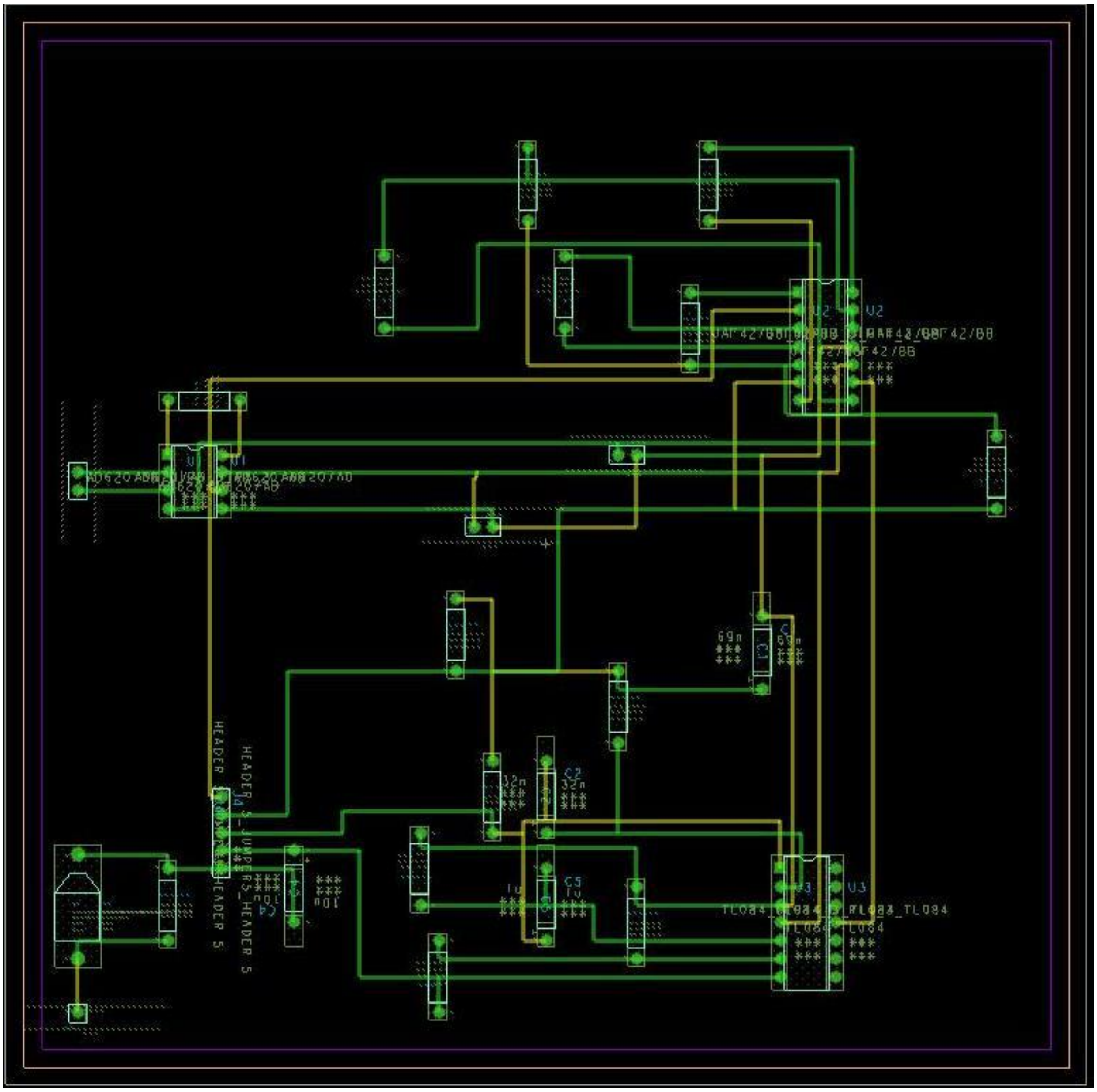

Figure2.6: PSpice model of the EEG Circuit.

Given above in figure 2.5 is the final schematic diagram of the EEG circuit, formulated on P-Spice. This circuit has been slightly influenced from the ECG circuit given in the DIY Instructables [10]. "The instrumentation amplifier is used in the beginning of the circuit after which each box is a simple op-amp, used to construct the 60 Hz notch filter, the high-pass filter, low-pass filter and the gain stage" [10].

The circuit is powered with a 12V Power supply from the frequency generator. To power the op-amps with a -12V to +12V power supply connect positive terminal of the frequency generator to the positive terminal of the breadboard and the negative terminal of the frequency generator to the negative terminal of the bread board. The positive and negative terminals are also shorted and that is connected to the ground terminal of the breadboard. The main goal of this circuit is to retrieve EEG data by reducing the noise enough to obtain a good signal into the computer. The signal will then be further passed through a digital low-pass filter to negate as much noise as possible. This is done by designing a digital low-pass filter on Matlab. The filtered data is then processed on matlab using SVM, which gives the accuracy of the data.

The EEG circuit is divided into several stages for compilation simplicity. Given below are the division on the circuit into stages and an explanation of each stage:

1. Stage 1- Instrumentation Amplifier stage:

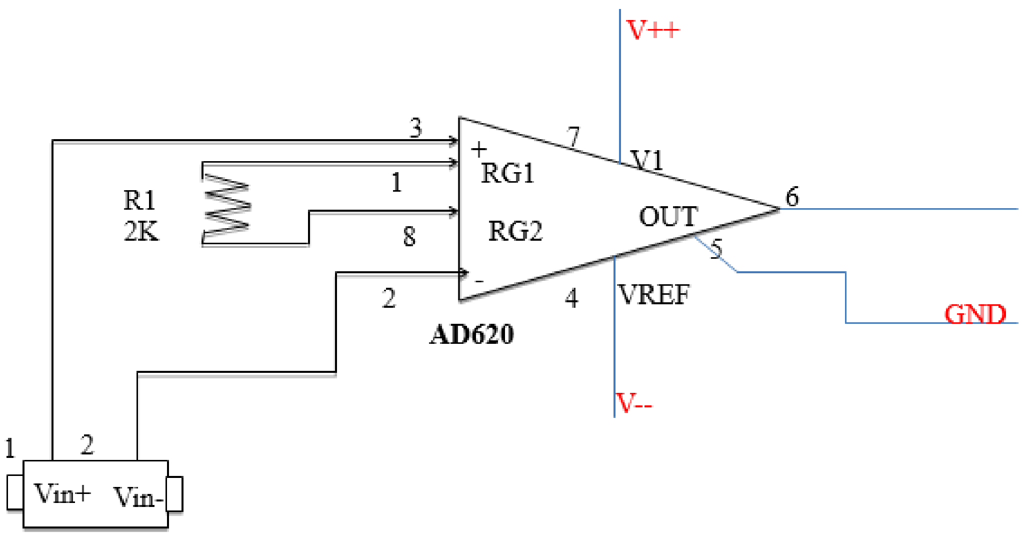

Figure 2.7: Connections for the Instrumentation amplifier.

The positive and negative EEG electrodes are connected to the two input pins (pin 3 and pin 2 respectively) of the AD620ANZ Instrumentation Amplifier. “The output is the difference between the two input voltages multiplied with a gain value of” [10] 25.7 V/V (G). However, the instrumentation amplifier is not perfect which results in a slight change in the output when the inputs are offset the same by some amount. Considering an example from the DIY Instructables [10], an ideal instrumentation amplifier with inputs 3.1V and 3.2V will give an output of 0.1V*G, whereas the real one will be influenced by the common offset, and will marginally change the output. This change in the output value is not significant enough and can be neglected.

The value of the resistor connected across pins 1 and 8 determines the gain of the instrumentation amplifier. The datasheet for AD620 is attached in the abstract [7], from which the formula for calculating the gain can be seen (G= 49.4k Ω/R1 + 1). In order to observe the EEG signal a gain of about 25V/V is required. Hence, using the formula we can calculate the value of the resistor (Rg= 2k Ω) which gives us a gain value of 25.7 V/V. Pin 7 is given the 12 V power supply from the frequency generator and pin 5 is grounded. It is possible to build an instrumentation amplifier using op-amps, but it is advisable to use an AD620 instead to get a good reading.

2. Stage 2- 60Hz Notch Filter:

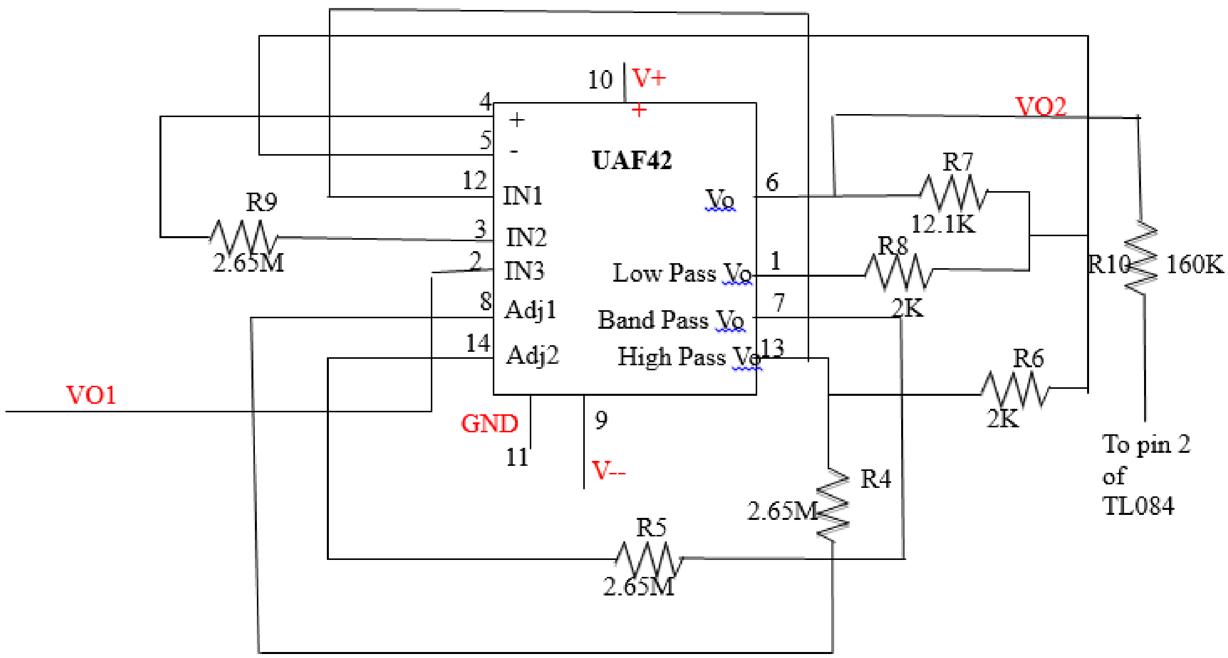

Figure 2.7: Connections for the Notch Filter.

"The biggest source of noise in the system will be centered at 60Hz" [10], whether you use an external power supply or batteries. Due to this reason a notch filter has to be incorporated in the circuit. It will negate as much interference as possible before we apply further gain to the circuit. A second notch filter can be built at the end of the circuit too to final cut off any more interference that may have been added to the circuit. The notch filter at the end can also be replaced by a digital notch or low pass filter for simplicity of the circuit and also to get better results.

3. Stage 3- 31Hz Low Pass Filter

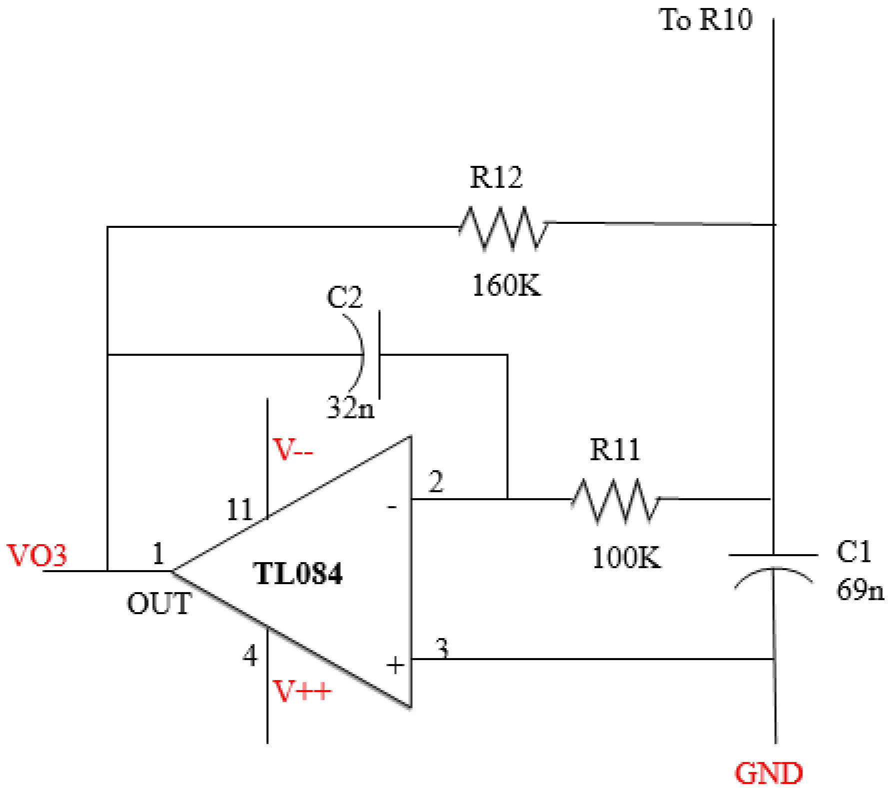

Figure 2.8: Connections for the 31Hz Low Pass Filter.

"A low pass filter is built to filter out the frequencies that are above the alpha/beta/gamma frequency range" [10]. Not filtering out these frequencies can lead to a good amount of noise in our final output. It has a cut-off frequency of 31Hz.

4. Stage 4- Gain Stage:

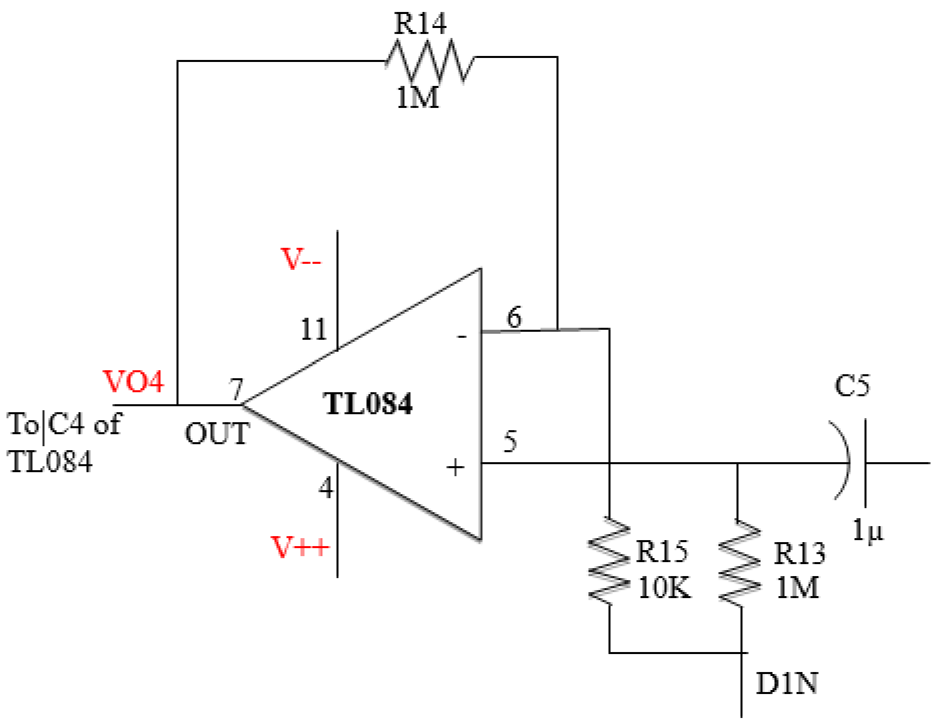

Figure 2.9: Connections for the Gain Stage

"This section of the circuit has a quick high pass filter with a cut-off frequency of 1Hz (Fc= 1/2*pi*R13*C5) in the beginning" [10]. The high pass filter is built to get rid of some extra unwanted noise. However, the main purpose of this circuit is to adjust the gain of the EEG circuit using the 1M potentiometer. "The potentiometer is variable resistor, with the input connected to the first pin and the output to the second pin and on turning the wiper the resistance varies between 0 to 1M ohms" [10]. Adjust the potentiometer such that when viewing the EEG signal without any body movement the voltage should not fluctuate off-screen. The amplitude of the signal need not be at its highest value but at the same time it should not be too small that it causes an error while digitally reading it on the computer. It is also important to make sure that gain is not too high causing the signal to get clipped, as in such a case there is a possibility of losing some important information. The gain of the EEG Circuit excluding the instrumentation amplifier is calculated to be 200.

5. Stage 5- Clamper Circuit:

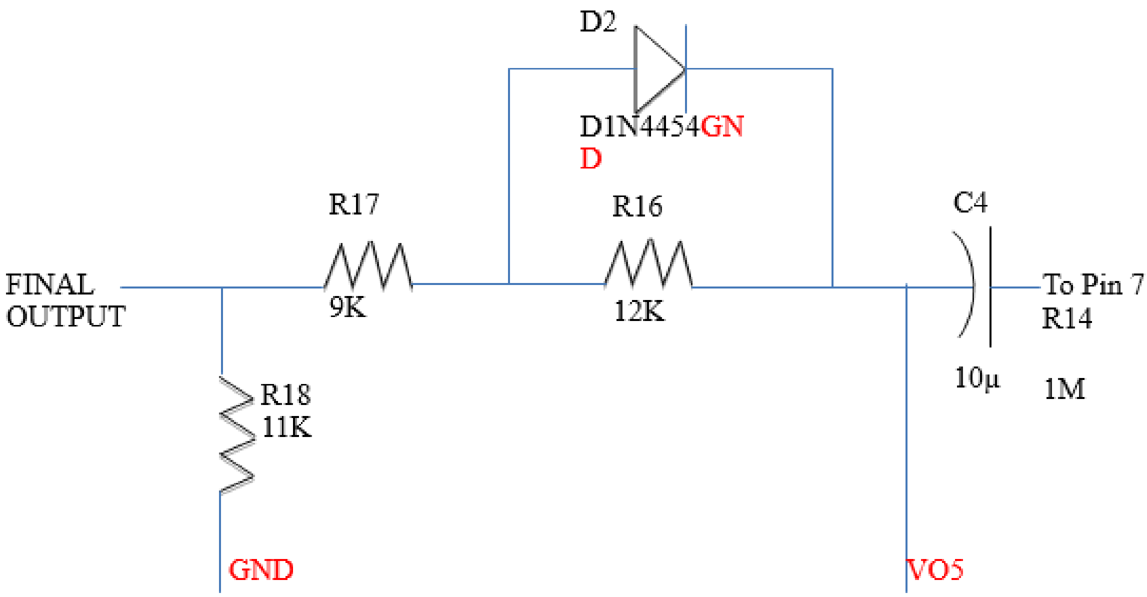

Figure 2.10: Connection diagram for the Clamper Circuit.

The voltage of the signal obtained at the end of the gain stage has some values below 0 Volts which cannot be read by the arduino. The Arduino UNO reads all values below 0 Volts as zero, this can completely change the signal causing the loss of some important EEG data. Hence, a clamper circuit needs to be added to the end of the EEG circuit as it shifts the entire signal up such that all the peaks are above 0 Volts. The output from the clamper circuit is the final EEG signal that is seen on the oscilloscope.

Once the entire circuit is built it needs to be tested before proceeding to the step of collecting EEG signals. The results from testing each stage of the circuit is explained in detail in the results and discussion chapter (chapter 4).

2.2 Collecting the EEG Data

After observing the signal on the oscilloscope, the EEG data is collected using the arduino and XBee. The XBee is programmed using the Arduino to collect samples of the EEG signal. The sampling frequency is 838Hz precisely, which is very close to 1K Hz, a very good sampling frequency. The Arduino code used to program the XBee is given in the Appendix.

Firstly, the baud rate of the XBee is set to 115200 and the same baud is set in the code too. The sampling frequency is set to 838 Hz and the sampling time is set to 3.5 seconds. So, each set of data contains 3000 (838*3.5) samples of data. This code collects 100 such sets of data with 10 sets collected continuously. After every 10 sets of data the reset button on the arduino needs to be pressed to start the next set of data collection. It takes 35 seconds to collect 10 sets of data. For this thesis, 250 sets of data were collected while thinking of the left and right directions respectively. Such 250 sample sets were collected twice using two different collection techniques.

In the first technique, 250 data sets of thinking right were collected all together, with and interval of 2-3 minutes after every 50 sets. A 10 minute break was taken then taken, after which 250 data sets of thinking left were collected again with a 2-3 minute break after every 50 sets. The second technique followed almost the same procedure except that after every 50 sets of data collected the thought was changed. For example, if 50 sets of thinking right were collected first, then 50 sets of thinking left would be collected after that with a 2-3 minute interval in between. The software used to collect the signal is called HyperTerminal. Its saves the data into a notepad file with commas separating each value and every set of data starting from the next line.

The next step after collecting all this data is to process it and check its accuracy. The SVM algorithm is used to process the data. A detailed explanation of this algorithm is given in the following chapter.

The reason for collecting the data using two different techniques is to check how each technique affects the accuracy of the SVM algorithm. This would give an idea as to what technique should be used to collect the data to be finally processed. An IRB approval is taken to test this device on people and data is collected from 8 different people, asking them to think both left and right.