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APPENDIX A: HUMAN MACHINE INTERFACES

As mentioned in the literature survey, the input for prosthesis control is divided into two categories, invasive and non-invasive types.

- Invasive methods involve the implant of devices underneath the skin, which requires surgery and the material selection for these devices are important as not to react with tissue [51].
- The second type is non-invasive methods, which are easy to attach to or remove from a patient as they are attached to the skin of the patient which requires no surgery.

A.1 INVASIVE HMI METHODS

This method is the more extreme method as it a more permanent solution and involves research in surgery methods. The material selection is important, as the human body may react to some materials, or loose functionality due to long term exposure to certain material or stimulation methods [51]. The various methods are summarized below:

A.1.1. TARGETED MUSCLE REINNERVATION (TMR)

When a person looses a limb by accident, the nerves up to the point of the amputation remains functional. There currently exist medical procedures to re-route these nerves to any muscle in the surrounding area that is close to the skin. This “targeted” muscle responds to the order given by the patient of the original muscle that got amputated. In total upper limb amputations, the pectoral-muscles of the patient are disconnected from their original nerves (denervated), and then reinnervated with the nerves of the amputated part of the patient. These reinnervated pectoral-muscles are mapped by comparing muscle activity to the original orders given to the missing body part by the patient. By removing excess fat below the skin over the pectoral-muscles, the muscle activity can be sensed by the either EMG method to control a prosthetic limb [51].

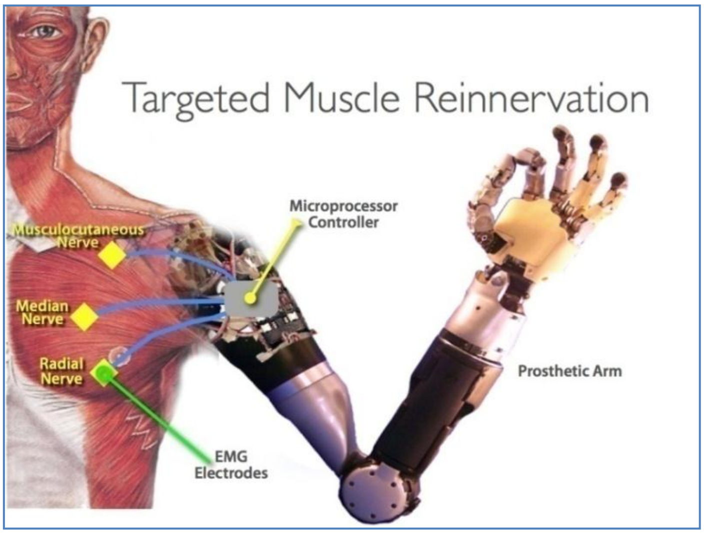

Figure 84: Targeted muscle reinnervation

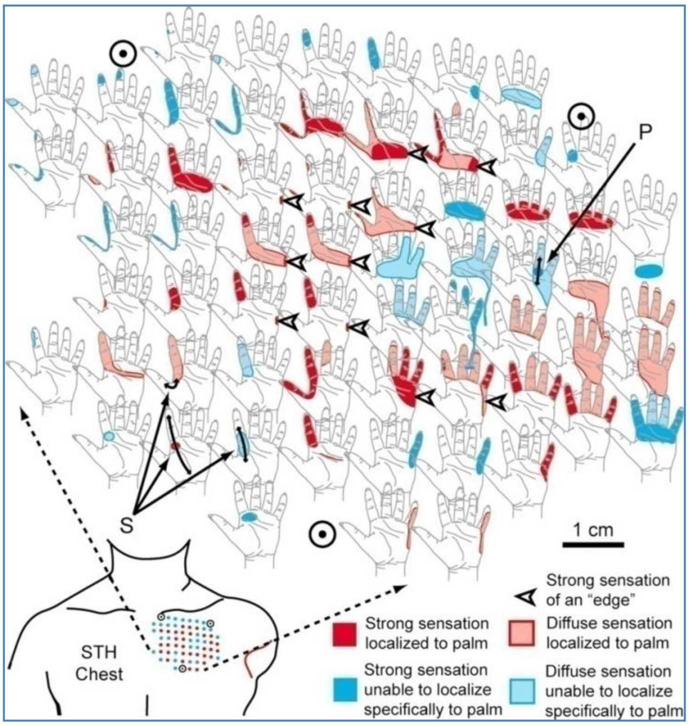

Figure 85: Example of the mapping of nerve to muscle activity

TMR has surgery involved in the muscle reinnervation procedure, but sEMG non-invasive method, which is preferred for its flexibility to cater for easy technology upgrades.

A.1.2. SENSOR IMPLANT

The majority of sensor implants measure nerve activity, with the exception of the EMG (or iEMG) sensor, which is a muscle activity sensor. The issues with invasive methods are the medical procedure required with the inserting of the devices, and the telemetry required for communication. [52]

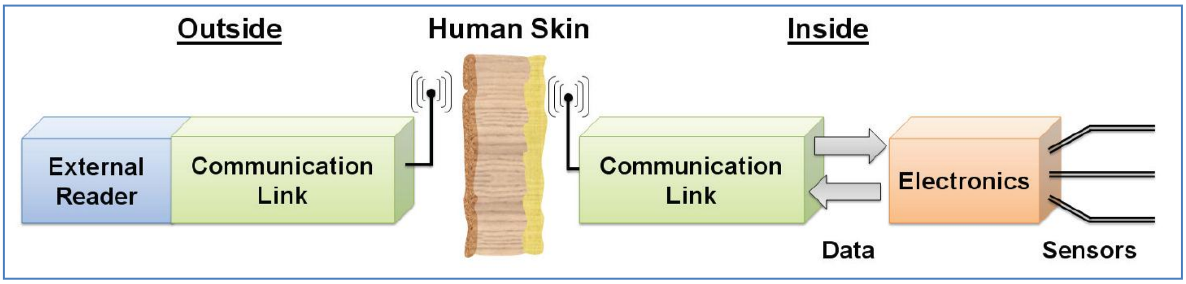

Figure 86: Basic communication channel for invasive bio-sensors [52]

EMG IMPLANT (INTRAMUSCULAR EMG OR IEMG)

An EMG signal is the electrical output of skeletal muscle activity. Each motor neuron from the spinal cord corresponds to a muscle fibre. This configuration is called the motor unit. The action potential that occurs in the motor unit, as an order to fire is given, are measured by measuring the muscle fibre with a pair of electrodes.

The EMG implant is a needle-like probe inserted into a muscle to measure its activity, but is not preferable long term method to use as it does minor damage to the muscle tissue, and a small shift in the EMG probes may alter the readings [45].

ELECTROCORTICOGRAPHY (ECOG) IMPLANT

Electrocorticography is an electrical sensor implant beneath the skull that measures brain activity similar to the non-invasive EEG method, but has much higher spatial resolution, the signal-to-noise ratio less, the bandwidth is larger. Another benefit with this method is that the patient adapt easier to this method as there is less training involved than using normal EEG methods.

Figure 87: Example of an ECoG implant electrode

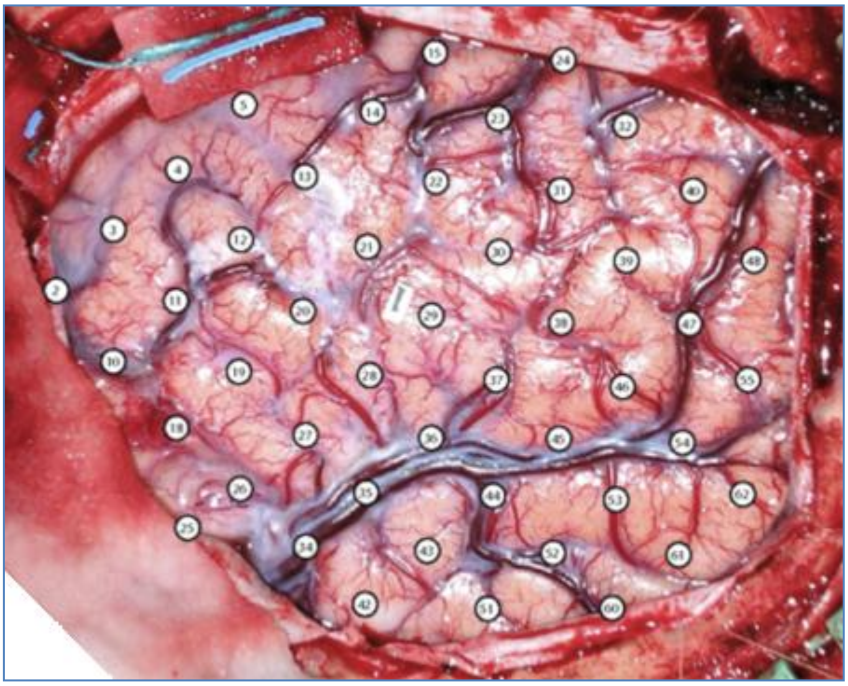

Figure 88: Placement of ECoG array on the patient’s brain

A.2 NON-INVASIVE METHODS

Technology improves at a rapid rate. With non-invasive methods, no surgery is involved to replace/upgrade technology in patients. There are fewer complications in the material selection process, as skin doesn’t react to a lot of materials, lowering the risk of a patient’s body rejecting the device. Engineers are able to perform research without medical personnel involved to perform medical procedures required for implants.

A.2.1. ELECTROENCEPHALOGRAPHY (EEG)

EEG is the measurement of brain electrical activity in patients' brains. An EEG recording consists of signals within their six different frequency ranges up to 100+ Hz. An EEG sampling frequency is around 256 Hz. Engineers extract limb movement from the Mu and Beta waves by analyzing Event-Related Synchronization (ERS) and Event-Related Desynchronization (ERD) within the information [49]

Patients with early stages of certain diseases such as amyotrophic lateral sclerosis (ALS) can be helped with EEG method of prosthesis control [49]. Unfortunately, EEG signals can be contaminated by non-cerebral related signals, called artefacts [50].

A.2.2. SURFACE ELECTROMYOGRAPHY (SEMG)

EMG is the recording of electrical activity within a patient's muscles. sEMG is a method that makes use of external electrodes placed on a muscle to measure the motor unit action potential trains (MUAPTs) inside the muscle. Although sEMG signals reveals less information than using the invasive iEMG method [26], all the drawbacks of the iEMG are eliminated by the sEMG method [45].

A.2.3. MAGNETOENCEPHALOGRAPHY (MEG)

This is the recording of the magnetic field produced by the brain activity inside a patient's scalp. It produces a 3D image of the brain activity, and is considered accurate as the skull and brain-tissue don't influence the magnetic field readings. This is a complex procedure, and the equipment is expensive and large, thus not practical.

A.2.4 NIRS AND FMRI

The altering levels of haemoglobin in blood flow inside the brain (called the haemodynamic response) are monitored, by both these methods [51]. Near-infrared reflectance spectroscopy (NIRS) is more practical than functional magnetic resonance imaging (fMRI) as the equipment is smaller in size and cheaper, but these techniques could have an input lag of up to seven seconds [51], which is impractical, as the patient would become frustrated with the delay in action of the prosthesis.

APPENDIX B: HARDWARE DESIGN

The next section includes the detailed hardware design for the sEMG sensor platform.

B.1. SEMG PLATFORM SCHEMATIC

B.1.1. Electrodes

The sEMG electrodes include two pairs plus one reference electrode. Its function is to measure differential potential difference across muscles. The reference electrode is placed on a bony joint for a ground reference.

Refer to drawings and assembly in Appendix C.1.

B.1.2. Differential Amplifier

Dual-channel sEMG amplifiers are included into the circuit. INA114AP instrumentation amplifiers are used. They have a fixed gain of G = 501 (EMG signal of around 500uV amplified to approximately 250mV). Their outputs are connected to the high-pass filters.

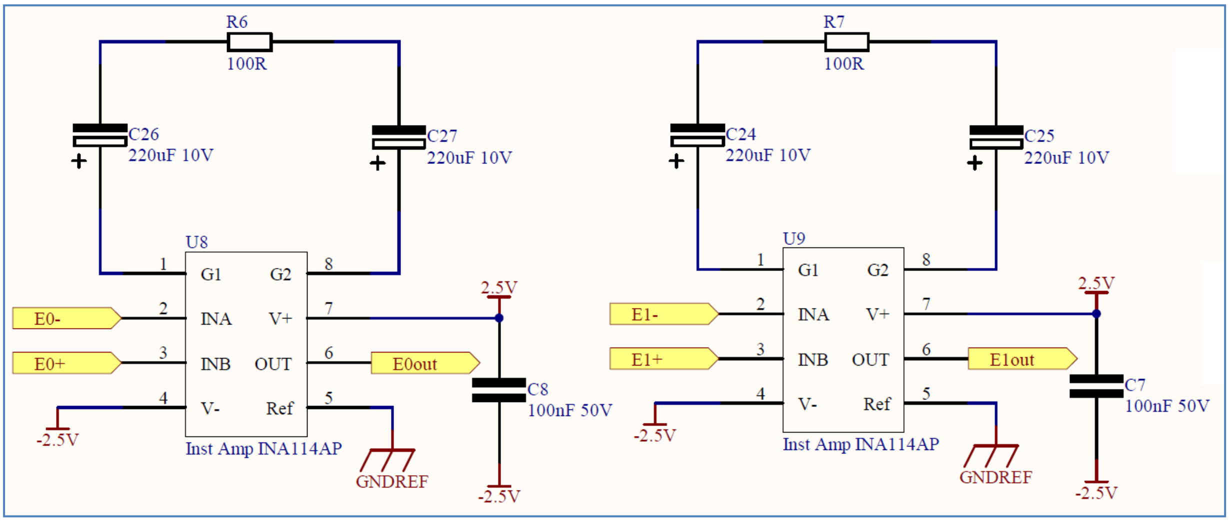

Figure 89: Differential amplifier circuit

From the INA114AP instrumentation amplifier, the amplifier gain

$$G = 1 + \frac{50k\Omega}{R_G}$$

where R_G is the feedback gain resistor. For an amplifier gain of approximately 500, R_G is chosen as 100Ω resistor. The addition of the two capacitors is to allow AC gain, but blocking DC gain.

B.1.3. High-pass filter

Dual-channel high-pass filters removes the DC-offset in sEMG signals. The high-pass filter outputs are connected to the low pass filters.

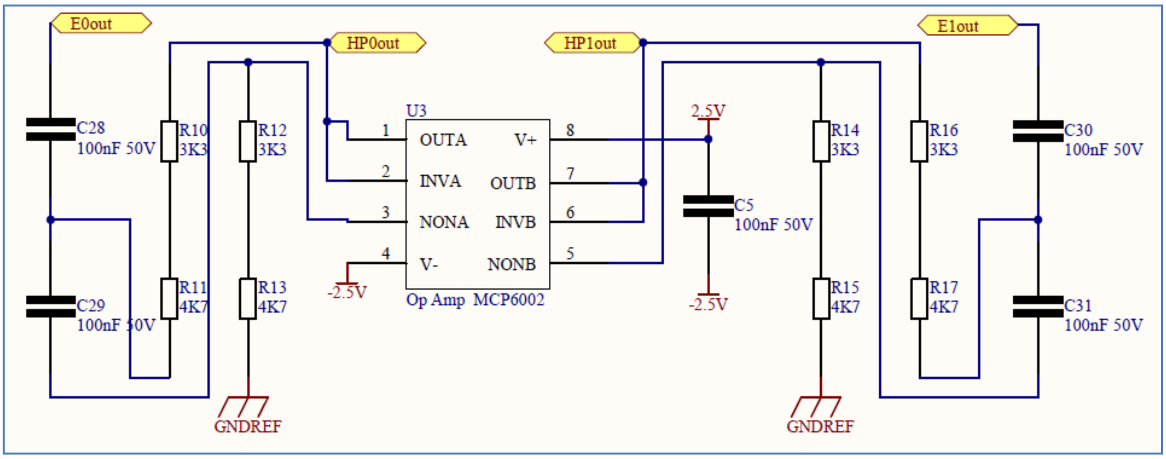

Figure 90: High-pass filter circuit

B.1.4. LOW-PASS FILTER

Dual-channel low-pass filters serves as 500 Hz anti-aliasing filters. Their outputs are connected to the AGC

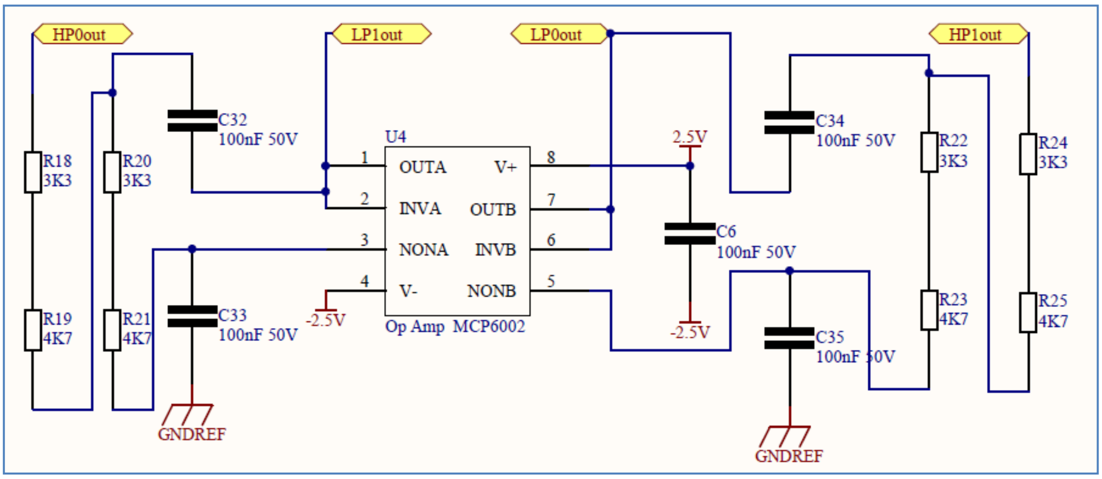

Figure 91: Low-pass anti-aliasing filter circuit

B.1.5. GAIN CONTROL

Dual-channel digital controlled gain control used for calibration of sensors. Their outputs are connected to the final stage amplifiers.

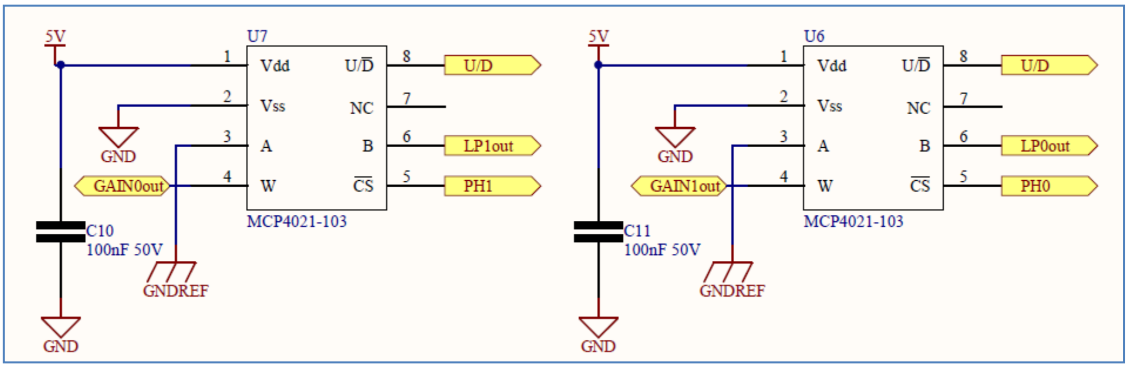

Figure 92: Digital gain control circuit

B.1.6. FINAL AMPLIFIER

The final stage amplifier is a dual-channel amplifier with a fixed AC gain of 20, and DC gain of zero.

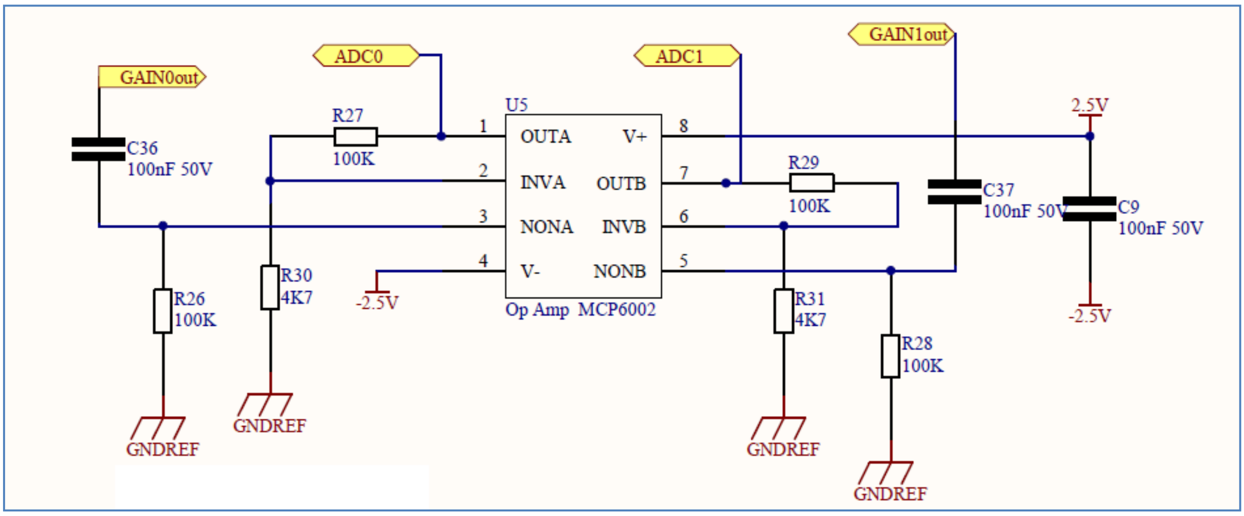

Figure 93: Final gain stage

B.1.7. ADC

The ADC is built into the microcontroller. The dual channel outputs from the final amplifier stage are connected to AN0 and AN1.

B.1.8. MICROCONTROLLER AND USB INTERFACE

IThe microcontroller controls the AGC, and acts as a serial emulator to create an interface with a PC.

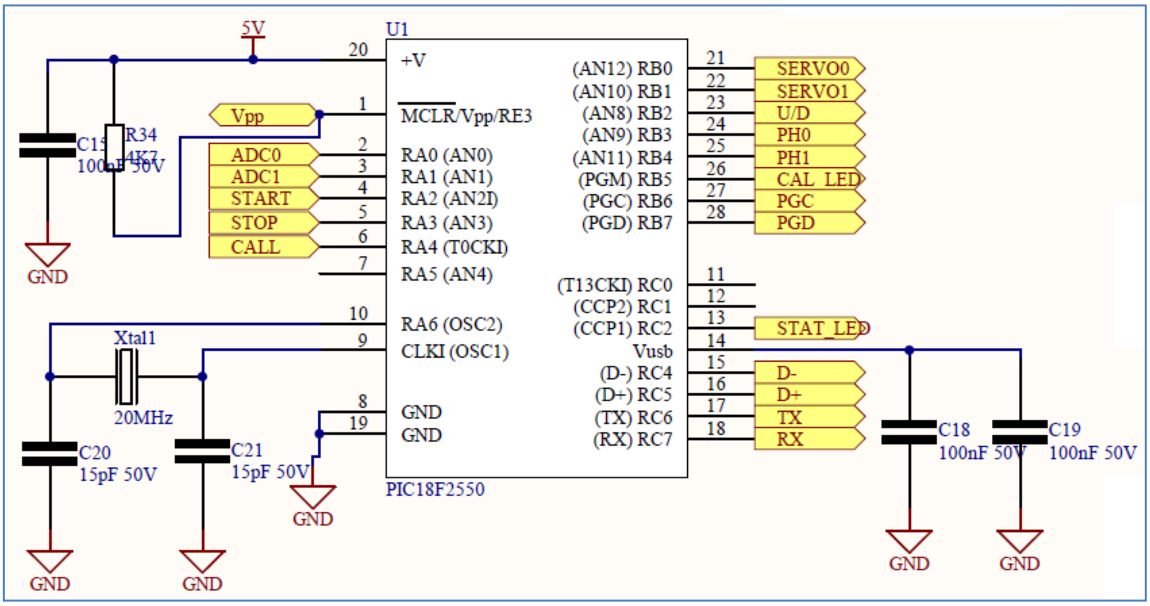

Figure 94: Microcontroller connection diagram

B.1.9. ANALOG POWER SUPPLY

The analog power supply splits the 5V and GND up into dual rail +2.5 V and -2.5 V.

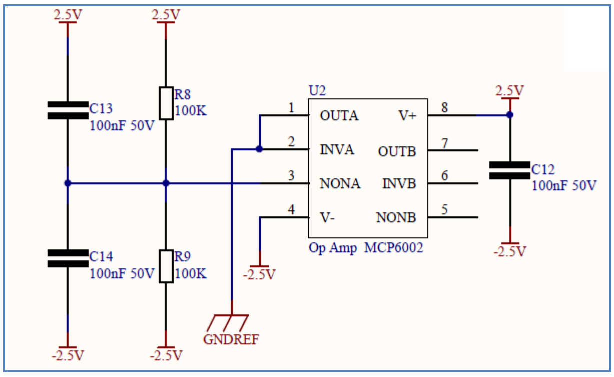

Figure 95: 2.5 V reference circuit

B.1.10. DIGITAL POWER SUPPLY, EMI FILTERING AND CONNECTORS

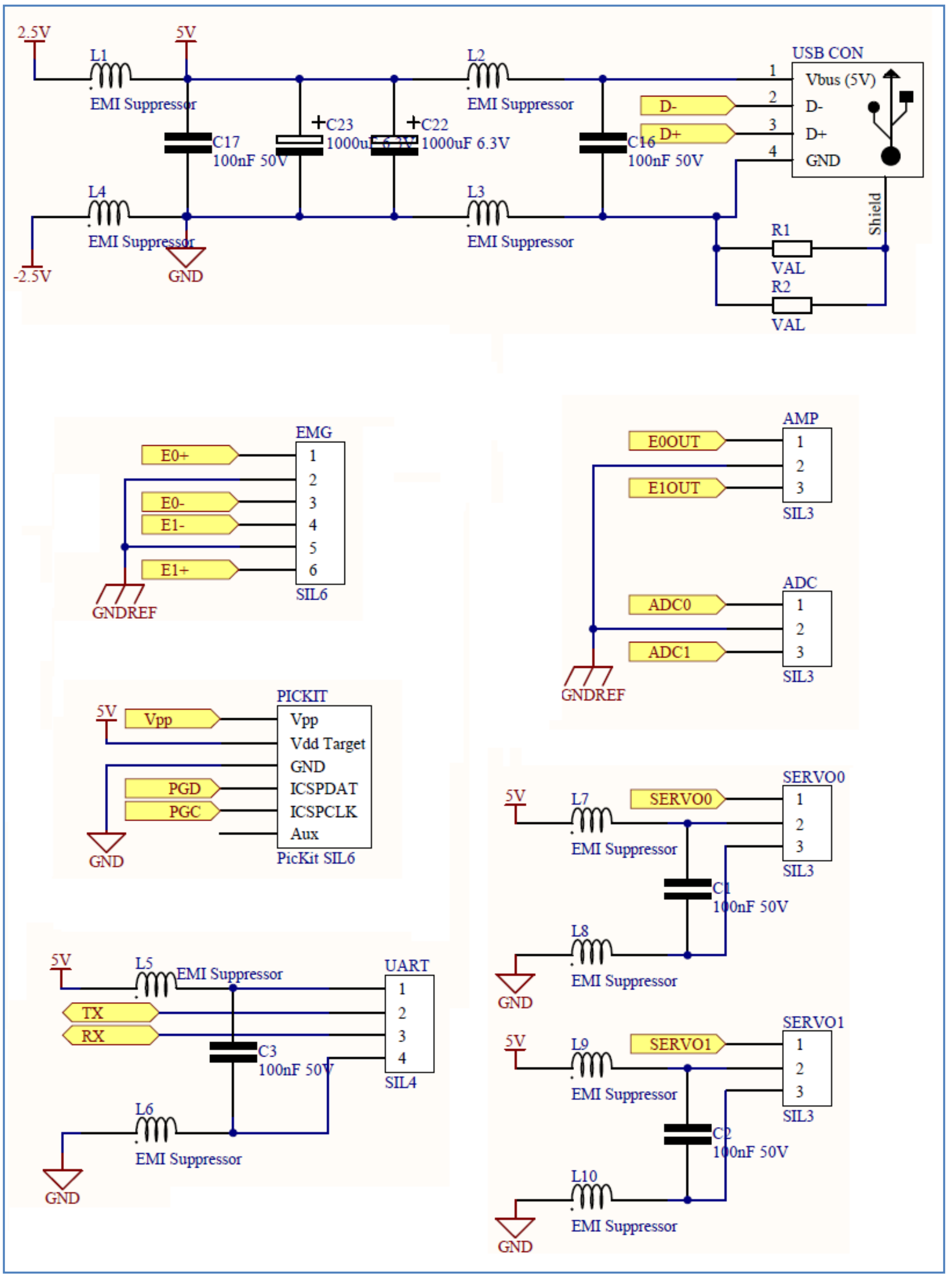

Figure 96: Connectors and EMI filtering circuits

B.1.11. PERIPHERAL DEVICES

The following peripheral devices are available on the sEMG platform:

- 2 Servo Channels
- UART

B.1.12. USER INPUT/OUTPUT

The following User inputs and outputs are available on the sEMG platform:

- LEDs
- Pushbuttons

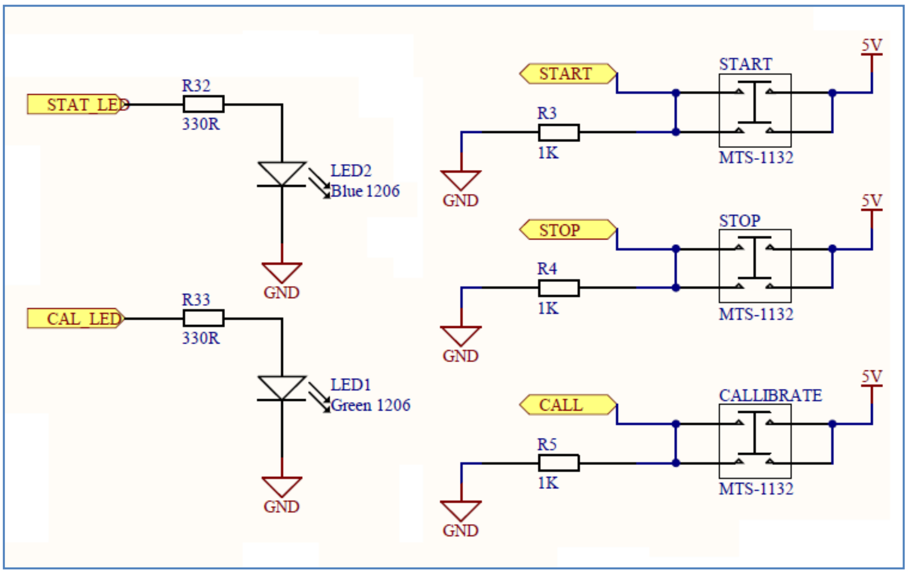

Figure 97: LED and push button connections

B.2. PCB LAYOUT

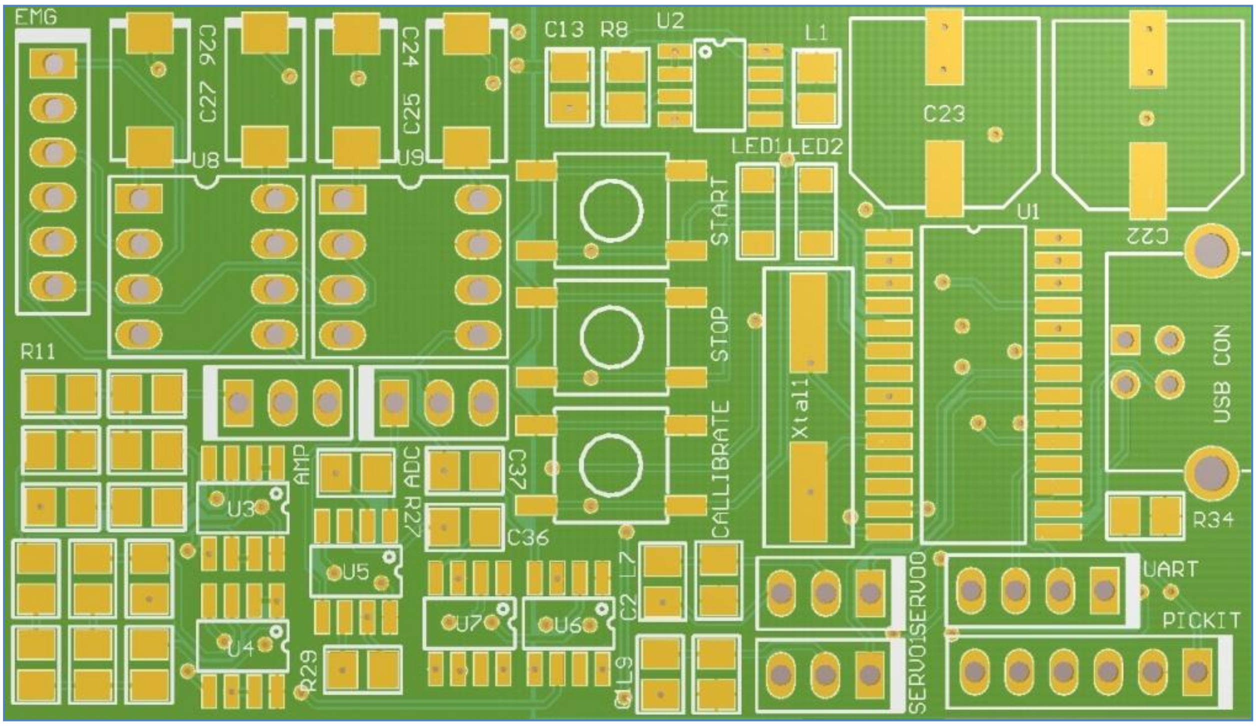

Figure 98: PCB layout top view

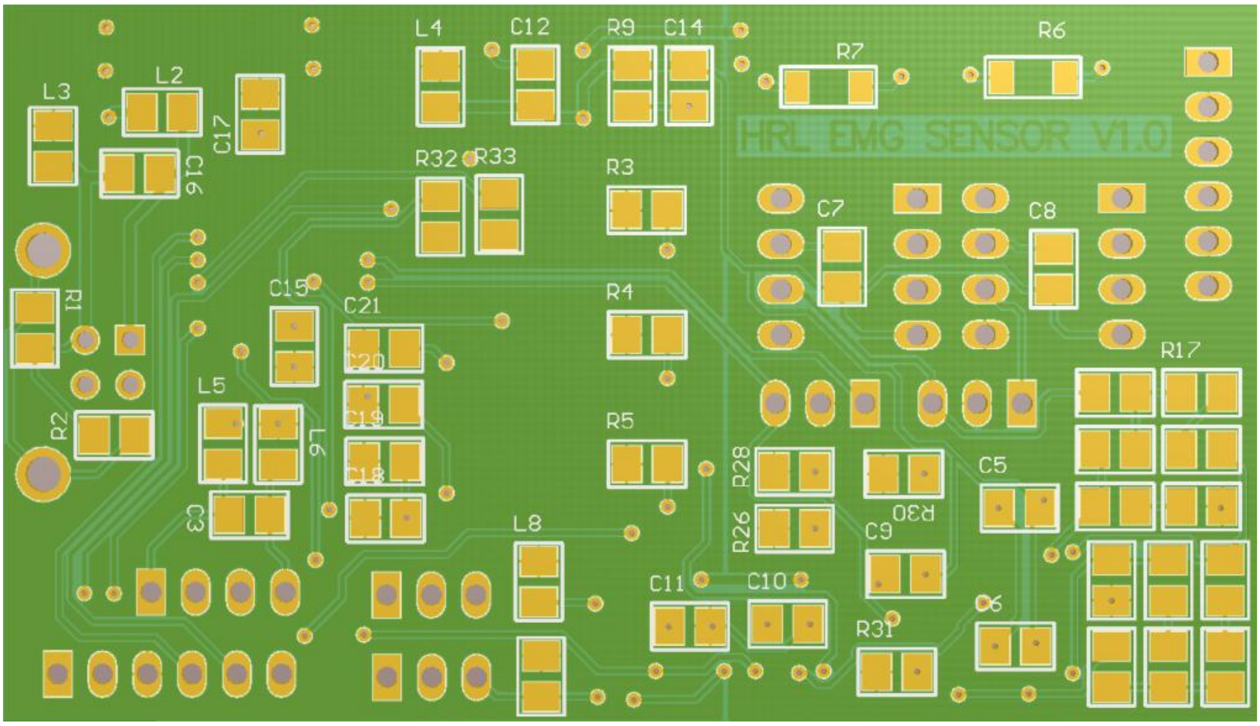

Figure 99: PCB layout bottom view

APPENDIX C: DATA DISK

This appendix lists the folders included on the data disk.

C.1. SOLIDWORKS® DRAWINGS

The drawings and assembly for the electrode wrist band are included in this folder.

C.2. ALTIUM® SCHEMATIC AND PCB LAYOUT

The project folder for the PCB design is included in this folder.

C.3. FIRMWARE FOR PIC18F2550 MICROCONTROLLER

The C18 project files can be found in this folder.

C.4. SIMULINK® FILES

The Simulink® files used to demodulate the measured data can be found in this folder.

C.5. PHOTOS

Photos of the PCB sensors and evaluation platform are included in this folder.

C.6. VIDEOS

A demo of the proportional control can be viewed in this folder.

C.7. DOCUMENTATION

The project proposal and dissertation can be found in this folder.

C.8. REFERENCES

All references available in .pdf format are included in this folder.