PORTABLE 3- CHANNEL REAL-TIME EMG ACQUISITION DEVICE FOR USE WITH MYOELECTRIC PROSTHESES

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Abstract

A multi-channel portable EMG amplifier and acquisition device is proposed. The device is intended to be used with myoelectric prostheses, therefore there is an emphasis on the multichannel real-time acquisition, portability, current consumption and connectivity features.

The goal of the design is to implement the latest low-power high speed technologies available on the market today.

The device is not yet intended to run the EMG signal algorithms, but to send the raw signals to the PC where it will be more convenient to process the data for the research purposes.

This document covers the EMG signal all the way from the muscle through the amplifier, the Driven Right Leg (DRL) noise suppressor, filtering, digitalization and PC communication.
The article includes complete schematics, analysis and tests of the device.

1. INTRODUCTION

The EMG signal, recorded from a surface electrode is comprised of the action potentials of many single motor units SMU (fig. 1). The resultant signal has a frequency range from 25Hz to several thousand Hertz and amplitude in the range of 20-2000 uV [1][2].

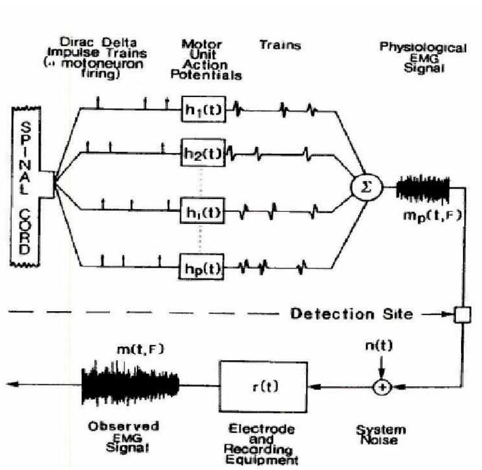

Fig. 1

The amplifier must be designed to cover this frequencies and amplitudes.

According to Nyquist-Shannon theorem, which basically says that the sampling frequency must be at least two times higher the then the highest frequency sampled. If this theorem is not respected, aliasing will occur. The above requirement has important consequences to the design because we must choose a cut off frequency high enough not to lose valuable signal but low enough to avoid a very complicated and expensive design.

The core of the design is the microcontroller. It must be chosen very carefully so that it is powerful enough to be able to process the data at the chosen sampling rate but at the same time to be with as low as possible current consumption. High power consumption will need bigger batteries hence the design will became bigger and heavier.

There are several communication possibilities for the design. In recent years many manufactures developed small and easy to implement OEM modules for different type of communication – USB, Wireless, Bluetooth and GSM modules. For this design a Bluetooth module is chosen because, we need a wireless communication with enough speed and a distance no more then 10-20 meters, which is perfectly covered by the Bluetooth module.

Below a general block scheme of the design is shown.

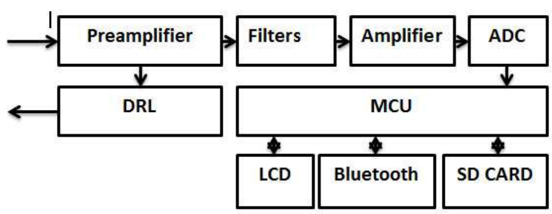

Fig. 2 (Block scheme of the device)

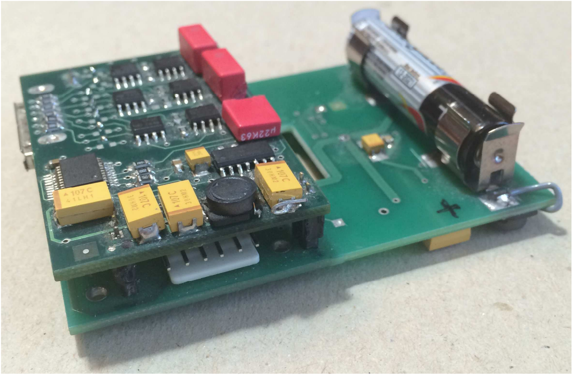

Fig. 3. The device prototype

2. AMPLIFIER

A three-channel amplifier has been designed to measure the EMG signal. The block diagram depicted in Figure 2 shows the different stages. The amplifier consists of: preamplifier, Driven Right Leg (DRL), filter, second amplification stage.

2.1. Preamplifier

The preamplifier is based on the AD627 instrumentation amplifier by Analog Devices. This IC has very good CMRR, very low offset voltage, and very high input impedance. Also it is a micro-power and has rail to rail operation which can allow us to use lower voltage levels.

The gain of the amplifier is determined by the formula:

$$Gain= 5+(200k\Omega/Rg)$$

$$Rg=200k\Omega/(Gain/5)$$

A gain of 10 have been chosen for this stage.

A group of resistor and diodes clamped to the supply rails is used to protect the inputs from static discharge. The resistor and the 56 pF capacitor form low-pass stability filter.

During testing of the initial device a problem was discovered. Due to the very high input impedance of the AD627, when an electrode inadvertently falls the amplifier saturates in all channels through the DLR schematic. To solve this problem and to assure redundancy of the system TLC 2252 micropower opamps were added before the instrumentation amplifier as a simple voltage follower.

2.2. Driven Right Leg (DRL)

The biggest noise origin in the EMG bandwidth is the electrical network interference. It produces a common mode voltage in the patient body and sometimes this voltage is higher than the useful signal. The DRL system is based on a feedback circuit that drives the common-mode voltage back to the patient body, amplified and phase reversed by 180°. This feedback improves the CMRR by an amount equal to (1+A) where A is the closed loop gain of the feedback loop.

In this design the common voltage is collected by from the two resistors of the Rg group. Then through a voltage follower, which purpose is to protect the gain circuitry, it goes through an inverting amplifier which reverses it to 180°. And then it goes back to the patient. A current limiting resistor is added to protect the patient. A typical DRL implementation is shown on fig. 4 [5].

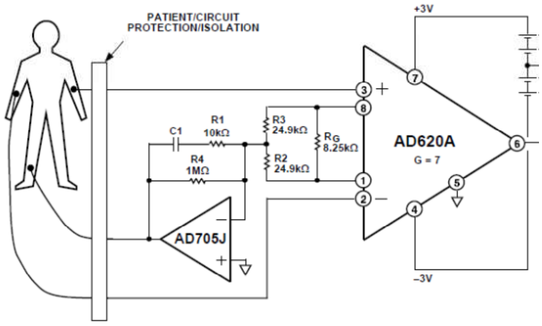

Fig. 4

2.3. Filters

After the preamplifier the next stage is the groups of high-pass and low pass filters.

The frequency range of the amplifier is chosen to be 25Hz – 500Hz. This range is chosen to eliminate the low frequency noise witch is mostly below 25Hz. The upper cut off frequency is chosen so that the signal will include the most of the EMG signal and to ease the signal processing.

Simple RC filters are chosen for this stage. First it is the high-pass filter and then the low pass.

$$Fc = ½ \pi RC$$

For High Pass We have:

C = 0.22 uF and R = 33 kΩ Fc = 22 Hz

For Low pass we have:

C = 0.056 uF and R = 5.6 kΩ Fc = 507 Hz

2.4. Second Stage Amplifier

The second stage amplifier is a non-inverting amplifier with a gain of 50.

In this stage we translate the signal to single-supply with a zero-point at 1.65V.

MCP609 is used for the design. It is a micro-power rail to rail op-amp, designed for single-supply purposes. Additional filtering is added at the gain setting network and at the output of the amplifier.

2.5. ADC

A dedicated multichannel ADC - ADS7844 schematic is used. It is a micro-power 8-channel ADC with SPI communication. The maximum sampling rate is 200 kHz.

Most of the present day microcontrollers have ADC integrated into them by using them instead of a dedicated ADC presents several problems. First it is the power supply decoupling. To improve the noise suppression usually the power lines in the analog schematic is decoupled through a LC network to supress the noise from the digital schematics. Using the MCU ADC will add noise to the analog schematic.

Another problem is design commonality. If we change the microcontroller we need to redesign also the analog part of the schematic to use the new MCU ADC.

Since the upper frequency of the amplifier is set to 500 Hz and according to the Nyquist-Shannon theorem, the minimum sampling rate per channel is 1000Hz. To further improve the digitalization a sampling rate of 2000Hz is chosen.

The amplitude range of the signal is from 0 V to 3.3 V.

The general parameters of the amplifier are:

Frequency response: 25 Hz – 500 Hz

Total Gain: 500

Dynamic range: ±3.3 mV

3. DIGITAL PART

The digital part of the device consists of: MCU, LCD for displaying critical data, the Bluetooth transceiver and a SD card holder for logging data.

3.1. Microcontroller

There is a wide variety of options for the Microcontroller. The chosen MCU for this project is the Microchip PIC24FJ128A306 [4]. It is a 16-bit MCU with 128 kB of Program memory, 8 KB of RAM, NanoWatt Technology for extreme low power consumption and up to 32 MHz of operation speed.

The main reason to choose this MCU for the project are:

- The very low power consumption;
- High speed;
- Low profile;
- The availability of the Peripheral Pin Select function;
- The available Development tools MPLAB and MICROCHIP C16 C-compiler.

3.2. Bluetooth transceiver

Bluetooth was chosen for the design. It will give freedom of movements for the device and has enough range.

There are many manufacturers of Bluetooth transceivers, which function as a simple serial port over Bluetooth. There is no need to develop specialized applications and drivers for communications, because it is transparent to the MCU and the host computer. Based on popularity and known quality the SENA PARANI BCD-210 was chosen [6]. The module is first configured with the tool ParaniWin where the speed and authentication options are set.

Fig. 5. Parani BCD210DC

3.3. LCD Display

A low profile monochrome LCD display is chosen – DEM12864L from Display Elektronik Gmbh. It features a Chip on Glass technology and 128x64 resolution. It has very low power consumption.

3.4. SD Card

A SD card slot is provided to collect a log data. The SD card is working in SPI mode.

3.5. Power supply

Power is provided by a single AAA battery which, because of the low power design is enough for at least 10 hours of operation.

A very efficient voltage convertor IC is used – MAX1676.

4. EXPERIMENTS

To test the device a Software EMGLAb was developed.

The device is tested on different muscles with real-time signal processing.

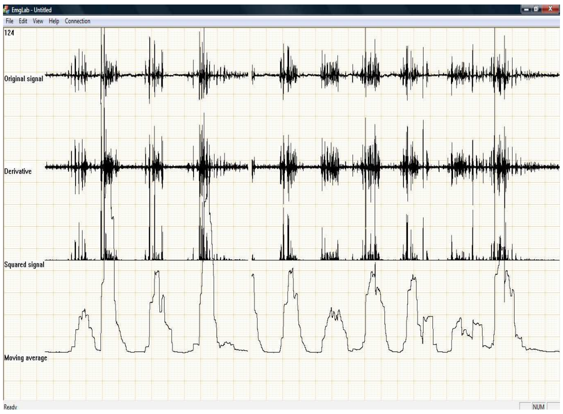

Fig. 6. Rectus femoris muscle

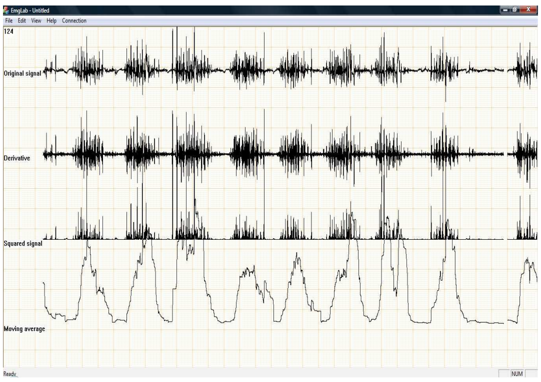

Fig. 7. Rectus femoris during walking

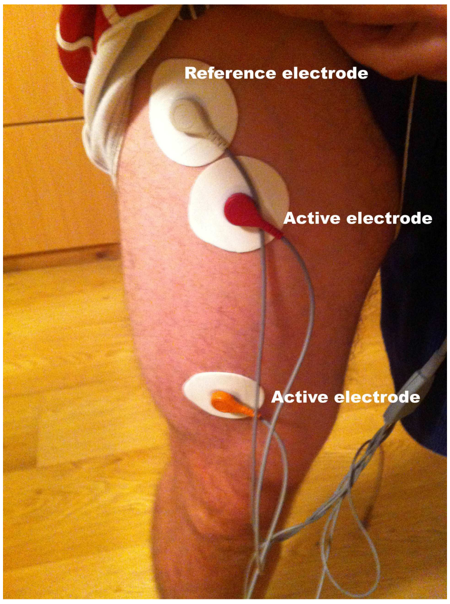

Fig. 8. Electrode placement for the Rectus femoris experiment

5. CONCLUSION

The device extracts very well the EMG signals from the muscles. The light weight and small size make it transparent the test patient, which gives us very accurate experimental results for the patients gait and movements.

This gives us an opportunity to develop models for recreation of missing muscles based on the data for other muscles.

References

[1] Rangaraj M. Rangayyan "Biomedical Signal Analysis" Wiley-Interscience

[2] Joseph Bronzino "The Biomedical Engineering Handbook" CRC Press

[3] Webster J, "Medical Instrumentation – application and design" John Wiley & Son

[4] MICROCHIP PIC24FJ128GA306 Datasheet http://www.microchip.com/wwwproducts/Devices.aspx?product=PIC24FJ128GA306

[5] Analog Devices AD620 Datasheet http://www.analog.com/en/products/amplifiers/instrumentation-amplifiers/ad620.html

[6] Sena Industrial Parani BCD210 Datasheet http://www.senaindustrial.com/products/industrial_bluetooth/bcd210.php

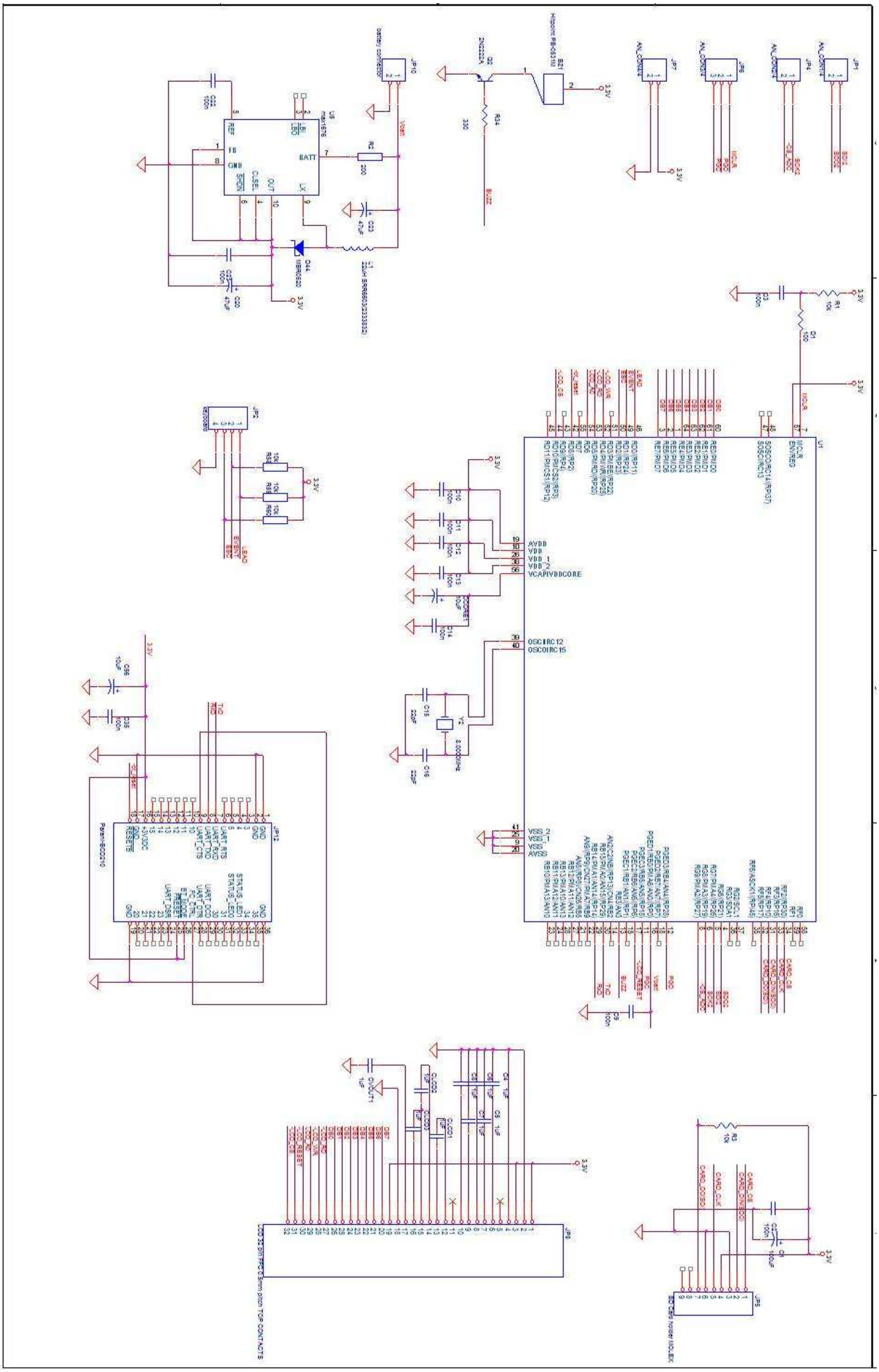

Fig. 9. Digital part of the device

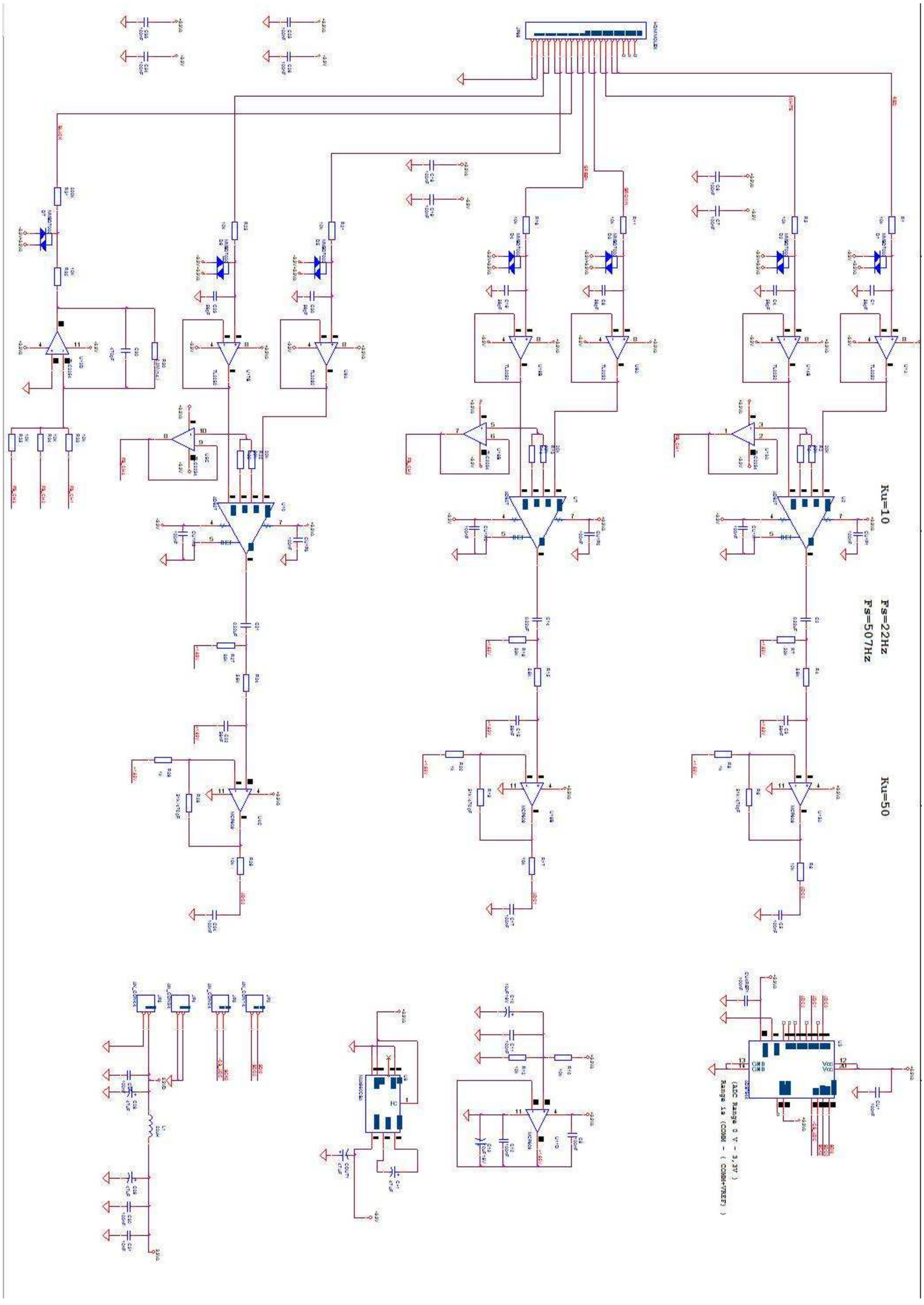

Fig. 10. Analog part of the device