

DESIGN OF A PORTABLE ELECTROMYOGRAPHY DEVICE FOR BACK HERNIATED PATIENTS

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Abstract: Up to 80 percent of people are affected by back herniation or another low-back disease in their life. Some studies have proven that there is a significant relation between paraspinal muscles and back herniation. In this study, a portable surface electromyography device was designed for measuring the muscular activity of paraspinal muscles from back herniated patients. The device's gain value is adjusted to 1000, it includes a band-pass filter and a 50 Hz notch filter to eliminate power source interference noise and other electrically noises. The device designed as an electrically isolated single channel, and it is linked to Matlab software via the serial port of Personal Computer.

1 INTRODUCTION

A superior cause of low-back pain is lumbar-disc herniation (LDH). LDH pain influences 70%-85% of people during their life and LDH is the most common reason which limits the activity in people younger than 45 years of age. (Hirose et al., 2008) In the USA, LDH is the second most common reason for visiting the physician, one of the most frequent reason of entrance to the hospital. Furthermore, the third most frequent reason of surgical interventions. (Andersson, 1999) Magnetic Resonance Imaging (MRI) is the commonly used imaging method in diagnosis of LDH. Because, approximately 30% of symptomless patients show a disc herniation on MRI. Moreover, Computer Tomography (CT) and myelography methods are rarely used for diagnosis. (Skinner, 2003) Electromyography (EMG) is used in LDH diagnosis to determine the neural injury in herniated region and to measure the level of injury if exists. (Çevikcan and Kara, 2007)

Electromyography (EMG) is a bio potential signal which represents the neuromuscular activities and occurs during the contraction and relaxation activity of skeletal muscles. These activities of muscles are controlled by the nervous system. (Reaz et al., 2006) Surface electromyography (sEMG) is a method used for appraisalment of muscles' activities noninvasively. sEMG signals should be detected as monopolar or bipolar. (Moore and Zouridakis, 2004) Some studies have proven that sEMG should be

used in research of paraspinal muscle activities. (Emley et al., 1992), (De Luca, 1993), (Kent, 1997), (Kuriyama and Hito, 2005)

In this study, our goal is the measurement of the paraspinal muscles' activities and the determination of the existence of back herniation with using the sEMG bio potentials of these muscles. This portable device offers a non-invasive, quicker, comfortable, low-cost and alternative system for diagnosis of back herniation.

2 GENERAL DESCRIPTIONS OF CIRCUITS

In this section, the main components of the device are described. Basically, whole device composed by five parts. In the first stage, low bio potentials are amplified and then for the safety of the patient isolation circuit is used. In the stages, amplified signals filtered and digitized with a high resolution analog to digital converter (ADC).

Lastly, the digital data is transferred to the personal computer (PC) by the microcontroller PIC18F452. General block diagram of the device is shown in Fig.1.

Raw sEMG data is collected with bipolar electrodes. The disposable bipolar electrodes are recommended by the European initiative, Surface Electromyography for Noninvasive Assessment of

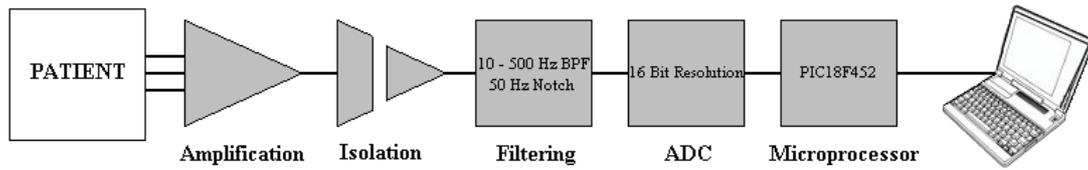


Figure 1: The block diagram of the device.

Muscles (SENIAM) who defines general agreements about the basic criteria about sEMG since 1996. (Merletti and Parker, 2004) Electrodes are connected to amplification block by using shielded cables to degrade the environmental noise effect.

2.1 Amplification and Isolation

Instrumentation amplifier (in-amp) amplifies the difference of the sensed low amplitude signals by bipolar electrodes. sEMG signal amplitude range changes between $100 \mu\text{V}$ to 5 mV and frequency range is between 10 Hz to 1000 Hz . For amplification, Analog Devices' (AD) low-power, low-cost and high accuracy in-amp AD620 is used. AD620 achieves a very high common mode rejection ratio CMRR (100 dB min when the gain is 10) and its low noise level, low input bias current and low power dissipation makes it suitable for biomedical instrumentation applications. This high accuracy in-amp's gain setting is adjusted by using just a single external resistor and its gain range changes between 1 to 10000. The gain of AD620 should be adjusted by using the equation (1). We chose G as 1000. (AD620 datasheet, 2004)

$$G = (49.4k / R_G) + 1 \quad (1)$$

AC-coupling is required in high-gain front-end amplifiers for biopotential measurements. A differential high-pass filter is designed without any grounded resistor to reduce baseline wander and to obtain the higher CMRR in front of the instrumentation amplifier. (Spinelli et al., 2003) The cut-off frequency of ac-coupling filter is 10 Hz .

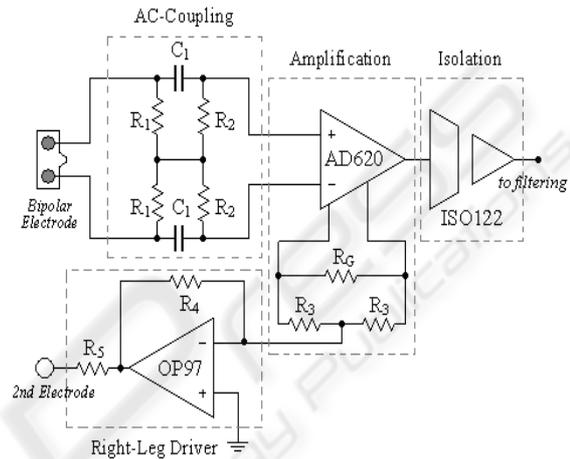


Figure 2: The circuit diagram of amplification and isolation block.

Using right-leg driver (RDL) circuit is another way of reducing the noise. Basically, RDL circuit inverts the common mode voltage which occurs during the recording of sEMG signals with respect to amplifier's common. Then, the inverted common mode voltage is applied to the body by attaching a second monopolar electrode to the patient's right leg. (Winter and Webster, 1983) AD's low power and high precision operational amplifier OP97 is used in the right-leg driver circuit.

Another important issue in biomedical instrumentation is the isolation of the patient from non-biomedical equipments such as computers, which could be connected to EMG device and have high power rates. Maximum accepted leakage current for biomedical equipments in Europe is $100 \mu\text{A}_{\text{RMS}}$ during instrument's normal working procedure. (Moore and Zouridakis, 2004) Galvanic isolation and optoisolation are commonly used types of isolation. For the isolation of our device, Burr-Brown's (BB) monolithic precision lowest cost isolation amplifier is used. Basically, ISO122 includes a galvanic isolation system and matched 1pF of isolating capacitors. ISO122 uses a novel duty cycle modulation-demodulation technique. The signal is transmitted to the other side of isolation

barrier by a 500 kHz duty cycle modulation technique. 0.020 % maximum nonlinearity ratio, 140 dB of isolation mode rejection (IMR) value and maximum $0.5 \mu A_{RMS}$ leakage current make ISO122 suitable for our system. (ISO122 datasheet, 1993)

The general block diagram of amplification and isolation stage should be seen in Fig. 2.

2.2 Filtering

To eliminate the unwanted signals such as, DC offset generated by the half-cell potential of the electrodes that DC-coupled in the input stage and motion artefacts, a band-pass filter (BPF) should be after the input stage of the device. (Moore and Zouridakis, 2004) According to the recommended sEMG amplifier bandwidth, an active high-pass filter (HPF) having 10 Hz cut-off frequency and an active low-pass filter (LPF) with a 500 Hz of cut-off frequency are designed. The circuit diagram of BPF is in Fig. 3.

In design of both filters, Linear Technology’s (LT) Quad Low Cost Precision Op Amp LTC1053 is used. HPF and LPF both have 4 poles and the types of filters are Sallen-Key. The responses of filters are Butterworth. We chose Butterworth because of its flattest response in the passband.

In the second stage of filtering, 50 Hz of notch filter is designed. LT’s Dual Precision Op Amp LT1013 is used for making notch filter. Fig. 4 shows the circuit diagram of notch filter.

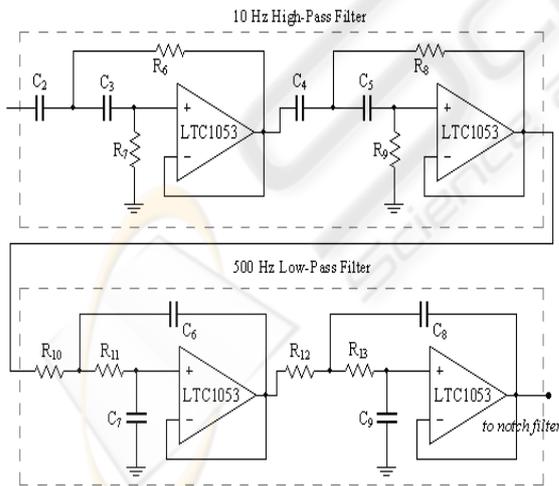


Figure 3: The circuit diagram of high-pass filter and low-pass filter.

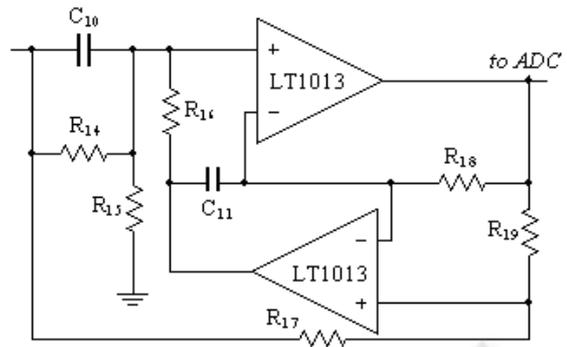


Figure 4: The circuit diagram of 50 Hz notch filter.

2.3 Analog to Digital Conversion and Microcontroller

After amplification, isolation and filtering procedures, the analog raw sEMG signal should be digitized with an ADC. BB’s low-power, serial 16-bit sampling ADC ADS7813 is used for digitizing. ADS7813 contains the 16-bit capacitor based successive approximation (SAR) ADC with a sample/hold, clock, reference and easy to use serial interface. The throughput rate of ADS7813 is minimum 40 kHz. The conversion time lengths maximum $20 \mu s$. Its integral linearity error is maximum +3 LSB and differential linearity error is +3, -2 LSB. ADS7813 includes single channel. But, it is suitable for multichannel applications. (ADS7813 datasheet, 2005)

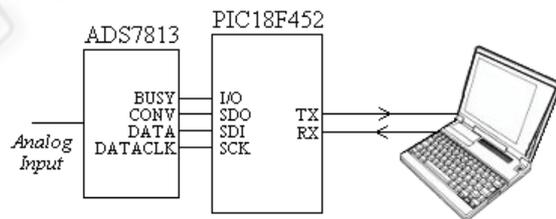


Figure 5: Relation of ADC, microcontroller and PC.

When transferring the 16 bit digital signals to PC, Microchip’s microcontroller PIC18F452 is used. PIC18F452 has the master synchronous serial port (MSSP) module including serial peripheral interface (SPI) suitable for interfacing ADS7813. PIC18F452 is chosen as master and ADS7813 as a slave. PIC18F452’s addressable universal synchronous asynchronous receiver transmitter (USART) is another serial I/O module. (PIC18FXX2 datasheet, 2006) UART module is used to send the signals to PC. Fig. 5 shows the relation of ADC, microcontroller and PC. PIC18F452 sends the

digitized signal via serial cable. Matlab's serial port I/O feature lets us to communicate with microcontroller. The sEMG signals are buffered to Matlab during the measurement and then other signal processing methods are applied. An example of raw unprocessed sample of sEMG signal should be seen in Fig. 6. This sample is taken from Thoracolumbar Fascia muscle of a volunteer healthy male. In the next stages of this study, we aim to evaluate sEMG signals collected with our device belong to patients with various signal processing techniques.

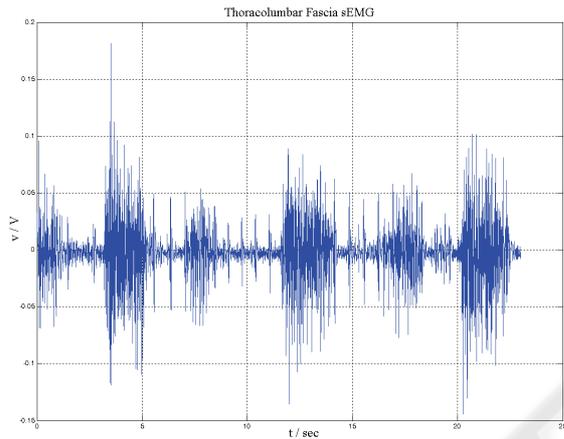


Figure 6: A sample of raw sEMG signal.

3 CONCLUSIONS

In this study, we described a non-invasive, low-cost and portable electromyography device for back herniated patients. Device includes a single channel and 16-bit resolution ADC. It has serial communication with PC and has a direct connection with Matlab software. In future, we aim to add a Bluetooth® module to make our device wireless and more portable.

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