MYOGRAM CIRCUIT FOR ON – OFF CONTROL

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ABSTRACT. Myogram on and off controller is important for improving or assist weak or the elderly people. One of the most important aspects of the controller development is to determine the on and off time with respect to the body movement. In this project, high accuracy signal filtering, high gain amplifier, signal converter, microcontroller and electrodes are used for circuit simulation and development to obtain muscle signal (Electromyogram). A good quality amplifier is used in the circuit to achieve high accuracy performance of the process. Safety precaution is important in biomedical equipment to avoid accident to the user. In order to prevent accident, an isolating circuit has been included in this project to protect the user. To ensure the user-friendliness in the development of this device, non-invasive electrodes are used in this project instead of invasive electrodes. It performed well even when exerted with only a small amount of power.

KEYWORDS: Electromyogram (EMG) circuit, surface Electromyogram (sEMG), amplifier

INTRODUCTION

Electromyography (EMG) is a diagnostic test performed to assess the health and functionality of an individual’s muscles (Konrad, 2005). Small electrical currents is generated by muscle fibres prior to the production of the muscle force (Stoykov et al, 2005). The muscle force will generate electromyogram signal which can be measured by applying conductive element. Electromyogram signal so-called potential difference is in the range of µV to mV. A good quality amplifier is needed to obtain the signal due to extremely small range of potential difference (Hao et al, 2011).

Previously, EMG test was only performed to diagnose patients who have unexplained muscle problems. Nowadays, EMG is used for biofeedback or ergonomic assessment, laboratories research including biomechanics, motor control, neuromuscular physiology and etc (Chen et al, 2009). An on-off controller can be developed to assist weak or elderly people by using myogram theory. In this project, myogram circuit will be simulated and developed to get muscle signal for controlling purpose. Finally, the performance of developed myogram controller is asserted to ensure it is fully functioning.
DESIGN AND MODELLING

EMG on-off controller circuit can be separated into several parts which are preamplifier, noise filtering, signal rectification, signal converter, microcontroller and isolation circuit. As shown in Figure 1.

![Figure 1: Overall concept of EMG On – Off Controller](image)

The basic functional unit for excitation and contraction in vertebrate skeletal muscle is the motor unit. The terminals of the motor axon are connected to a set of fibers by a chemical synapse. An ionic equilibrium between the inner and outer spaces of a muscle cell forms a resting potential approximately -80mV to -90mV. The difference in potential which is maintained by physiological processes results in a negative intracellular charge compared to the external surface. A surface electrical recording of the spiking activity derived from one or more motor units is called electromyogram. The spiking activity can be detected by using electrode which is attached on the skin and connect to a recording device. Electrodes are conductors through which electric current is passed. To obtain accurate data measurement of EMG signal, the placement of the electrode on muscle should be on the correct position.

The EMG signal obtained from the muscle through the electrode is extremely small from 50µV to 20mV. Therefore, a good amplifier is needed to amplify the small voltage to the preferred voltage such as 10mV peak-to-peak for control purpose (Sedra and Smith, 2003). In order to avoid signal acquisition mingled with noise, pre-amplifier gain was not set to maximum (Maheshwari and Anand, 2006). Figure 2 shows the pre-amplifier circuit and the overall gain can be obtained by using Equation 1.
Signal obtained from the muscle will have a lot of noise and offset voltage. These unwanted signals will affect the signal analysis. A filtering circuit is required to eliminate offset voltage (Ullah et al, 2011) and also to smooth the muscle signal (Kitchin and Counts, 2006). The offset voltage can be caused by the skin impedance and the chemical reactions between the skin and the electrode (Day, 2001). EMG raw signal is not favorable in signal digitalization. Therefore, signal filtering is required for smoothing the fluctuated EMG signal to obtain the average ongoing EMG activity.

There are two types of rectification that can be done including half wave rectifier and full wave rectifier. Full wave rectification is required in EMG signal rectification to retain the negative signal. The negative value of the signal will also represent movement of the myogram. In this project, high quality rectifier is used rather than normal rectifier. General rectifier can affect the EMG signal to be not accurate or block. Isolation is important to avoid current drawback from the load to human. Current more than 10 mA can cause painful shock, muscular paralysis, extreme breathing difficulties and etc. When the current achieved 100mA or more, it may cause burns and death (Yeo et al, 2011). Figure 3 shows the myogram on – off control flow chart.

\[
A_v = \frac{V_{out}}{V_2-V_1} = 1 + \left(\frac{R_4}{R_1}\right)
\]
RESULTS AND DISCUSSION

Myogram On – Off control circuit was tested using available equipment such as oscilloscope, digital multimeter and etc in order to obtain the accurate results. In order to ensure accurate EMG value, placement of the electrodes must be at the correct position. Two positive electrodes must be placed at the area consist of muscle and not too far from each electrode. Negative electrode must be placed near to the elbow area for reference purpose. Figure 4 shows the electrode placement on the hand.
In order to obtain an average gain for muscle signal, a pre – experiment was carried out to obtain muscle signal from 10 people. Table 1 shows the myogram voltage when muscle is fully strained. Average muscle voltages obtained from 7 male and 3 female students is 301.22mV.

Table 1: Myogram voltage during muscle fully strain

<table>
<thead>
<tr>
<th>No</th>
<th>Voltage (mV)</th>
<th>Voltage (mV)</th>
<th>Voltage (mV)</th>
<th>Voltage (mV)</th>
<th>Voltage (mV)</th>
<th>Average (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>325</td>
<td>302</td>
<td>308</td>
<td>296</td>
<td>303</td>
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<td>304</td>
<td>305</td>
</tr>
<tr>
<td>3</td>
<td>304</td>
<td>313</td>
<td>311</td>
<td>296</td>
<td>283</td>
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<td>276</td>
<td>286</td>
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<td>302</td>
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<td>327</td>
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<td>275</td>
<td>260</td>
<td>267.6</td>
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<td>320</td>
<td>348</td>
<td>334</td>
<td>323</td>
<td>318</td>
<td>328.6</td>
</tr>
</tbody>
</table>

Pre-amplifier circuit testing result done is as shown in Figure 5. In this project, high performance amplifier is needed to give excellent result.
Figure 5: Output muscle signal of Pre-amplifier

From the observation, output signal was in the negative position due to offset voltage occurred. Active signal filter is required to eliminate the offset voltage to obtain accurate signal. The EMG signal will return to its original position after the active signal filter. At the same time, output signal will be rectified to obtain the positive values to allow the signal to be processed in the microcontroller. Precision rectifier is used instead of general rectifier due to potential difference of the muscle signal is low (St-Amant et al, 1996). A smoothing active filter will be used to smooth the fluctuated EMG signal. Smoothing filter will reduced the noise of the signal. Finally, output signal of the smoothing filter will be amplified to achieve a standard voltage which allows processing by the microcontroller. Figure 6 shows the comparison of EMG raw signal and output signal.

From the observation in Figure 6a, the input EMG signal consisted of noise and offset voltage. In Figure 6b, the output EMG signal when the muscle is in the relax condition but, it still consists of at least 1V to 2V of signal. It is due to synaptic of the muscle are transmitting the chemical reaction all the time. When the muscle was strained, it will achieve the maximum voltage which is suitable to be used for processing in the microcontroller. When the circuit deals with the high voltage equipment, isolator will be needed in order to protect our life and protect the circuit as well. An emergency switch was ready to be used during any emergency. It will automatically cut off the connection between the electrodes and the circuit to prevent any connection during the rescue. Table 2 shows the available action for the circuit.
Figure 6: Comparison of EMG raw signal and output signal

Table 2: Available action for the circuit

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Voltage</th>
<th>Action</th>
<th>Muscle (2)</th>
<th>Voltage</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relax</td>
<td>0 – 2.99</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Strain</td>
<td>0 – 2.99</td>
<td>No</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Strain</td>
<td>3 – 5</td>
<td>Safe Stage</td>
<td>Relax</td>
<td>0 – 2.99</td>
<td>No</td>
</tr>
<tr>
<td>Strain</td>
<td>3 – 5</td>
<td>Safe Stage</td>
<td>Strain</td>
<td>0 – 2.99</td>
<td>No</td>
</tr>
<tr>
<td>Strain</td>
<td>3 - 5</td>
<td>Safe Stage</td>
<td>Strain</td>
<td>3 - 5</td>
<td>Switch Trigger</td>
</tr>
</tbody>
</table>

From Table 2, muscle action produce voltage that is less than 3V will not activate the circuit to perform any action. However, the muscle action produces voltage more than 3V will activate the circuit in waiting stage. During this stage, processor will be waiting for the
confirmation signal from user to trigger on or off the device. If the voltage is more than 3V, the circuit will trigger the device switch.

CONCLUSION

There are some issues in the design of this project. The first issue is the selection of the EMG signal gain. EMG signal of each individual will be different and it gives problem to select the actual gain to amplify the signal. To achieve good output signal, 1000 of gain value was suggested by researcher and academician. However, the highest gain cannot be applied directly in the pre-amplifier circuit.

To achieve accurate result, suitable circuit or electronics must be used. In this project, an active filter is used instead of a passive filter and this is an important decision to be made. Besides that, signal rectification is one of the major problems to be considered during the circuit design. Full wave rectification is used instead of half wave to avoid the signal from being lost. This is due to the negative values of the EMG signal will also represent part of the muscle data.

There are some limitations in this system which included the system inability to update on time or no interrupt procedure as this will require a lot of wire to be connected between the system and the human and etc. To achieve less component and reduce the size of the board, current technologies can be applied. Wireless electrodes are friendlier to be used and it is suitable for use in anywhere. In order to reduce the size of the circuit board, the component on chip can be fabricated to develop a single chip.

ACKNOWLEDGEMENTS

The authors thank the technicians (Mr Borhan and Mr Seri) and School of Engineering and Information Technology for assistance and facilities rendered. The first author wishes to express gratitude to his friends and beloved parents for their endless support during the project.

REFERENCES


