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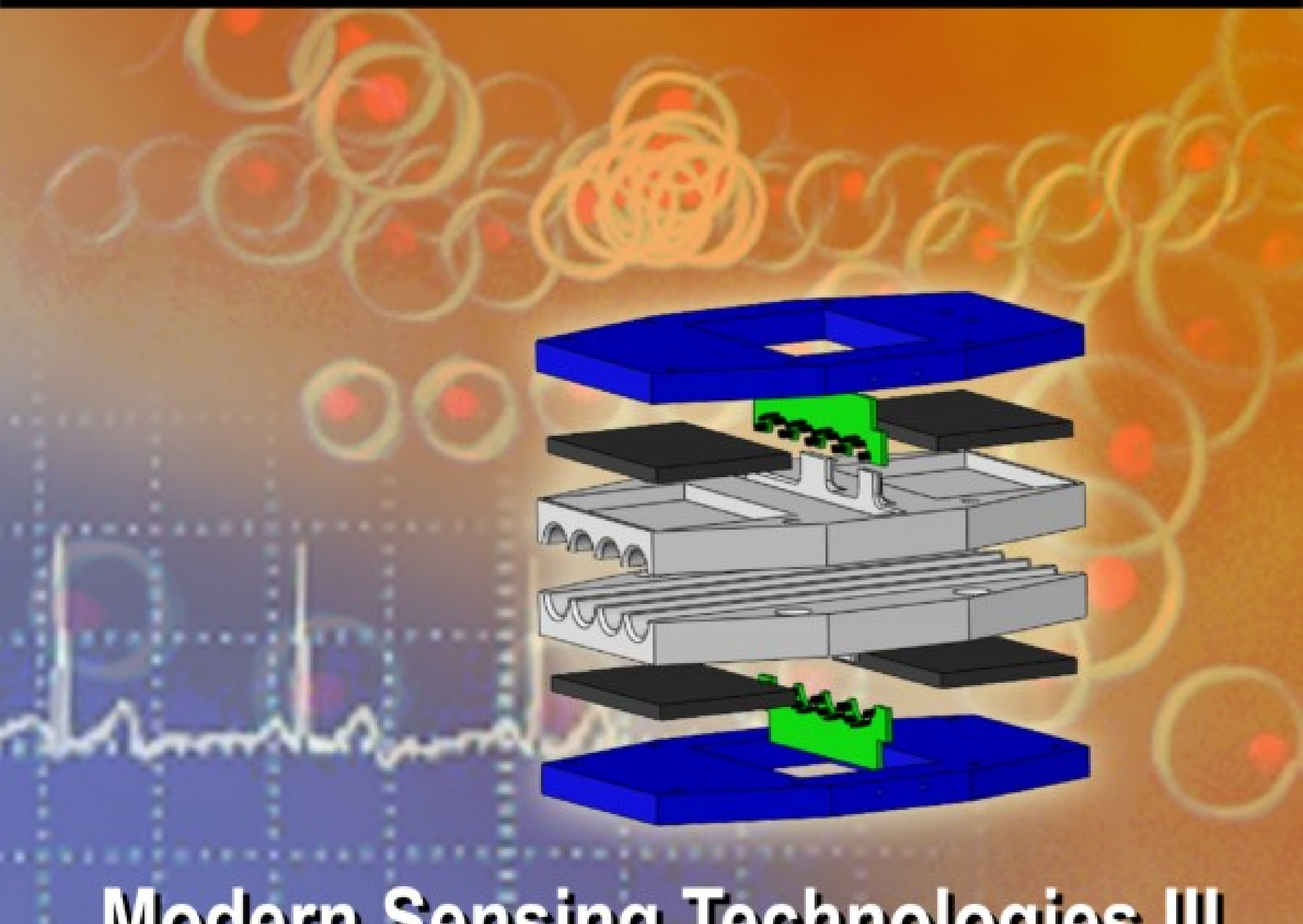

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- MPQSI: Multi Provider QoS/SLA Internetworking
- GRIDNS: Grid Networks and Services
- EDNA: Emergency Services and Disaster Recovery of Networks and Applications
- IPv6DFI: Deploying the Future Infrastructure
- IPDy: Internet Packet Dynamics
- GOBS: GRID over Optical Burst Switching Networks

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Measurement Using Conductive Polymeric Fibers in a Wearable Sensor Platform

Ram Manoj Sarda, Thomas Donnely, Mansour Taherinahzahdi and Michael Haji-Sheikh

Department of Electrical Engineering, College of Engineering and Engineering Technology, Northern Illinois University, DeKalb, Illinois 60115, USA

E-mail: mhsheikh@ceet.niu.edu

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Abstract: The purpose of this study is to design polymer fiber sensors which can be embedded into a t-shirt for electrocardiography. Recent inventors have envisioned this concept, but the feasibility of this idea needs to be investigated. The sensors used in this study are designed in way to make good contact with the skin without using gel or any other adhesives which can cause pain when removed and can annoy the user. The method of using polymer fiber sensors in a fabric for the purpose of electrocardiogram (ECG) signal detection was determined to be more feasible than the conventional silver/silver-chloride adhesive electrodes. This method of using polymer fibers as sensors for Electrocardiography is a novel method for this application. *Copyright © 2010 IFSA.*

Keywords: Electrodes, Electrocardiogram, ECG, Heart-rate monitor.

1. Introduction

There are different kinds of electrodes used for detecting an electrocardiogram (ECG) signal. The most common type of electrodes used for ECG signal detection are made with conductive gel or saline based adhesive electrolyte. This conductive adhesive material is necessary for a good electrical contact. However, the use of gel and saline leads to various problems. Some amount of gel is still left on the patient's skin even after the electrode is removed. It can also hurt the patient's skin when removed and may annoy the patient. Metal disk electrodes also make use of saline soaked pads to lessen the skin-electrode impedance. The metal electrodes gradually corrode due to saline and thus the functioning of electrodes is reduced. Any extra amount of saline that leaks out of the pads could cause an electrical short circuit between the electrodes which can lead to their improper functioning [1].

Some systems use a belt that is to be worn around the chest of an individual to detect the ECG signal. These systems are not comfortable and are not user-friendly. There are a few more problems with the existing systems that monitor the ECG signal. Most of the electrodes which are placed on the chest are rubberized electrode patches and these patches are held firmly by hook-and-loop type belt fasteners which are difficult to wear. It can cause damage to the skin and sometimes it may lead to bleeding which happens when it does not have proper contact with the skin [2].

With a goal of eliminating these problems, this paper focuses on replacing the sticky sensors, rubberized electrodes and belts with polymer fiber sensors by designing them and integrating them into a t-shirt to detect the ECG signal. This kind of fabrics can be made by employing knitting or weaving process. One of the yarns used to make the fabric must be electrically conductive. The fabric structure consists of various sensor regions. Each sensor region contains (i) a sensor element which is added to the fabric through the weaving process by providing a concentration of electrically conducting yarn at the position the sensor element (ii) a lead which is also made from electrically conducting yarn added to the fibre structure during the weaving process. It carries the information signal. The information signal carried by the leads can be seen on an output device [2].

A special t-shirt made by Pearl Izumi was chosen for ECG signal detection. The electrodes can be placed at any location of the t-shirt depending on the type of application. It is important to find fibers, which can conduct electricity like a metal or an inorganic semiconductor, for the ECG electrodes. Some conductive fiber materials have been successfully woven by the textile manufacturing equipment. Examples of these are metal-filled, carbon-filled, piezoelectric, and graphite. Metal wires are very heavy and not washable and easily breakable. Carbon filled polymer fiber or metal-filled plastic fiber has problems with mechanical properties degradation with increased loading and with repeated mechanical cycling. Additionally graphite fibers are too soft and brittle (also poorly conductive) and the piezoelectric fiber has very poor conduction. Conducting polymer fibers are the best suited for this purpose as they are strong, light weight, flexible and highly conductive [3].

2. Experimental Procedure

The conductive polymer used to construct this system is a polypyrrole material supplied by Martek. The conducting polymer used for extensive research is polypyrrole because it is the only conducting polymer which can be directly produced in the doped state. It has very high electrical conductivity. The films of polypyrrole produced just by one step electro-oxidation have conductivities up to 100S/cm and does not have the need for additional doping to produce electrical conductivity. It has excellent thermal stability in air which is a significant advantage over other conducting polymers. It can be thermally stable up to 250 degrees and shows very little degradation of its conducting properties below this temperature when compared to other polymers [4].

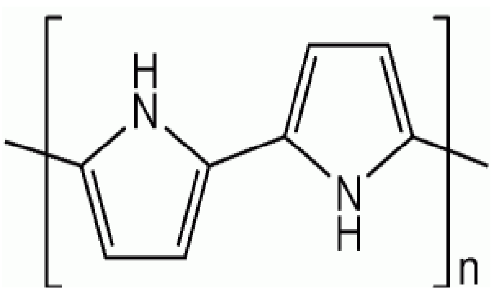

Fig. 1. Structure of Polypyrrole [4].

A recent patent [2] which is dependant on the development of fibers capable of being used as a sensor has been granted. This project is to investigate the feasibility of polypyrrole as a sensor for this application. Polypyrrole was initially discovered to be conductive in the early 1960's by R. McNeill [4]. To determine how many fibers and what size the patch roughly needed to be, an elastic medical bandage along with the conductive fibers is used. This structure in Fig. 2 gives a relative contact impedance.

Fig. 2. Test structure to determine the basic contact resistance of the polypyrrole to the researchers skin.

This structure only allows for a relative measurement due to the skin contact variability for various test subjects. Table 1 shows the results of multiple fiber impedance testing. The results show that to minimize the contact resistance between the fiber and the subjects skin, the patch will have to contain a large area of contact to the skin. It was then determined from this experiment that a woven configuration would be more effective. Fig. 3 shows the test configuration for the woven electrodes. It was determined from this investigation that the contact was good for two out of three of the subjects but the third subject needed to add a small amount of moisture to the contact pad to get a solid contact. Table 2 shows the skin contact resistance of the woven electrode in both dry and wet condition for the worst test subject.

Table 1: Impedance measurement with a few fibers.

Number of fibers	Skin-Electrode Impedance
1	0.13 Gohms
2	0.10 Gohms
3	0.084 Gohms
4	0.075 Gohms
5	0.063 Gohms

Fig. 3. Woven polypyrrole ECG pads.

Table 2. Impedance measurement with polymer fiber pads.

Type of Pad	Skin-Electrode Impedance
Dry pad	35 MOhms
Wet Pad	90 kOhms

The construction of the ECG shirt starts with a Pearl Izumi compression t-shirt. These shirts are designed to stay slightly compressive for the improvement of performance in endurance athletes. This platform was chosen to ensure a consistent pressure on the ECG pad. Practice with the silver/silver-chloride gel electrodes indicated that the upper left and right arm contacts were the most consistent. Fig. 4 is a photograph of the completed garment (inside out) with electrode pads sown into the shirt. To continue on the fiber wire idea, the leads to the amplifier was also made of polypyrrole. Fig. 5 is the ECG garment in the configuration that it is worn in. The Pearl Izumi used was a medium size, short sleeve shirt. These types of shirts are available in a large range of sizes and also available in women's sizes. This makes this particular shirt very desireable for this type of research.

Fig. 4. Construction of the electrode assembly (T-shirt inside out).

Fig. 5. Garment as worn with electrode labels.

The design and operation of the circuit used for the amplification of the ECG signal is discussed in the following paragraph. The basic circuit, which was taken as a reference, is shown in Fig. 6 [22].

U1, U2, U3, U4 are TL074 op-amps and U5 is AMP02 op-amp which is an instrumentation amplifier. A, B, C are the electrodes placed at the left leg, left arm and the right arm respectively. There were some changes made to the above circuit to obtain a better signal. The changed circuit makes use of just four operational amplifiers and uses an additional high pass filter. The following circuit is the one which is used for ECG signal amplification. This circuit needs to be modified to handle the additional impedance of the polypyrrole over the gel electrodes. The final circuit design used for this project is shown in Fig. 7. The circuit was then built using a National Instruments ELVIS breadboard set-up. The ELVIS bread-boarded set-up is shown in Fig. 8. This circuit was eventually built up using a two layer circuit board along with a wireless transmitter/receiver pair.

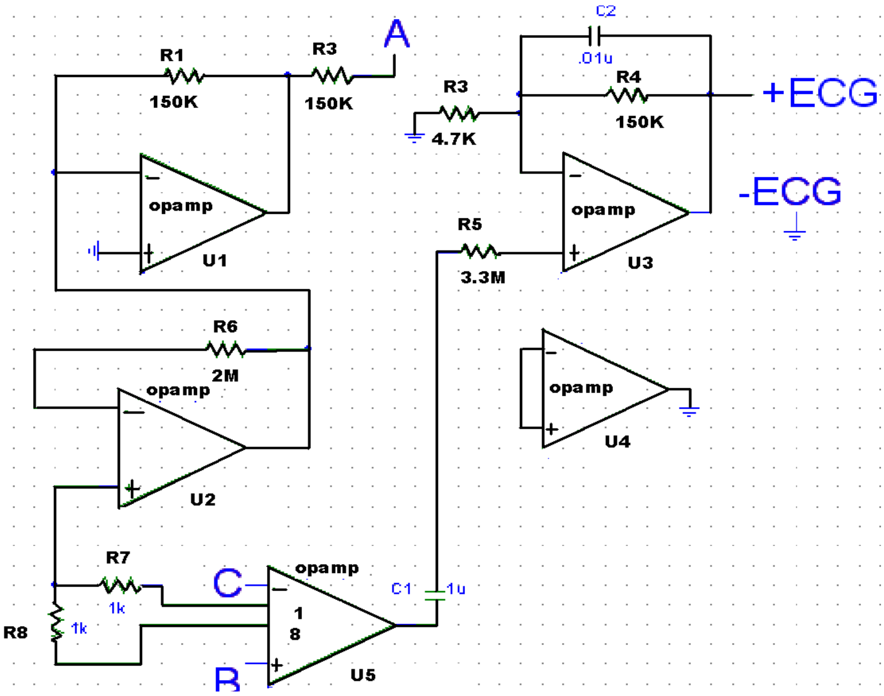

Fig. 6. Basic circuit used as a starting point for the amplifier design.[5].

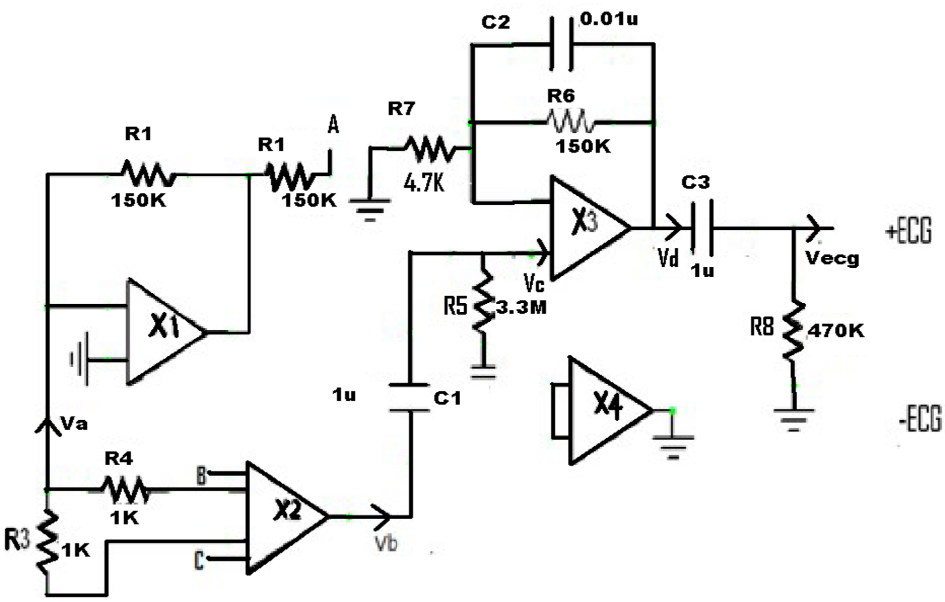

Fig. 7. Final amplifier design with modified High-pass and Low-pass filters.

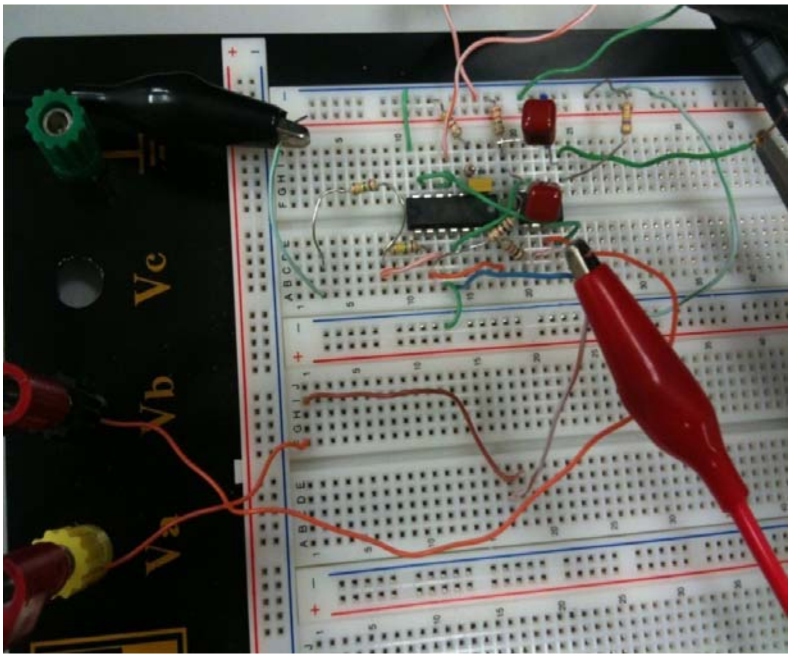

Fig. 8. Breadboarded amplifier.

3. Results

Silver/silver-chloride sensors were tested and compared to the polymer fiber sensors using the same amplifier circuit for both electrode configurations. Fig. 9 shows a screen image of the silver/silver-chloride sensor output. These sensors were part of a commercial ECG system. The silver/silver-chloride were very unreliable as sensors due to the constant loss of electrical contact to the clips. The contacts to the ECG harness would invariably break and the harness clip would have to be repositioned. Fig. 10 shows the output of the conductive polymer electrodes. This output is notable by the flat baseline. Fig. 11 shows the output of the polymeric electrodes and a description of the parts of the ECG.

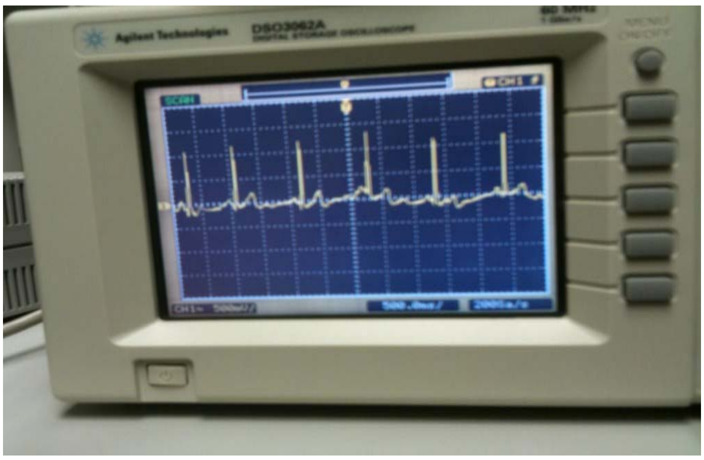

Fig. 9. ECG output of the amplifier using a silver/silver-chloride sensor. Some amount of baseline wandering was observed in the output signal due to improper contact of the electrodes.

Fig. 10. The ECG garment with polypyrrole electrodes amplifier output. A clean ECG signal with The gel electrodes were then removed and the subject put on the garment. The subject then used on drop of water on each electrode. The test subject was the highest impedance individual. Fig. 10 shows the result of this testing, minimal noise and minimal baseline wandering is observed.

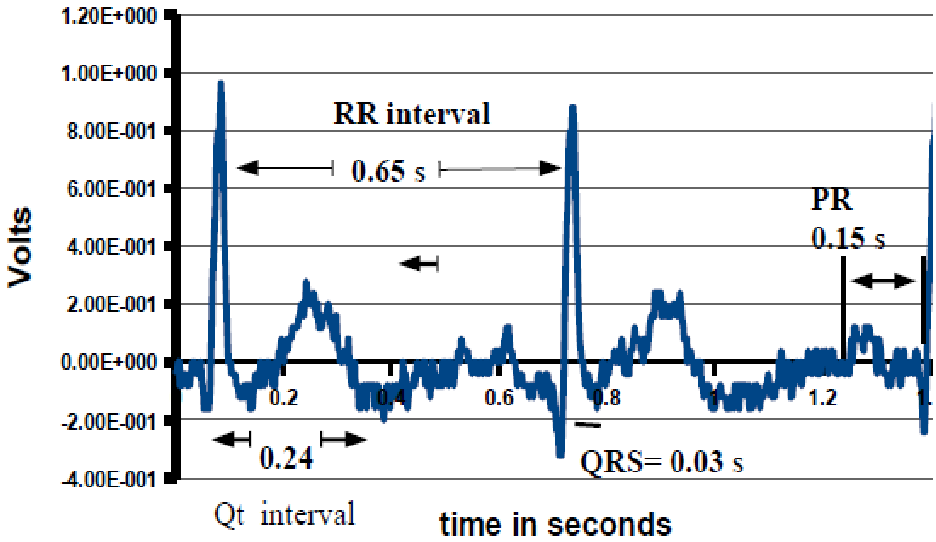

Fig. 11. ECG details using polypyrrole electrodes.

The RR interval, PR interval, QRS duration and QT interval and the heart rate can be measured by extracting a part of the signal and changing the time period to 200 ms for easy measurement as shown in the Fig. 11. This data is tabulated in Table 3.

Table 3. ECG Observations off of Fig. 11.

Parameter	Value
V_{pp}	0.98 V
Heart Rate	92 bpm
RR interval	650 ms
PR interval	150 ms
QRS duration	30 ms
QT interval	240 ms

The heart rate can be calculated by using the RR interval. RR interval is the time taken for a single heartbeat. So the heart rate, bpm (beats per minute) is calculated as

$$\text{Heart rate (for a min)} = 60 \text{ sec} * 1/RR$$
$$= 60 * 1/0.65$$
$$\text{Heart rate} = 92 \text{ bpm.}$$

An area of interest, with any method of ECG, is the effect of motion error on the integrity of the signal. A simple experiment was devised to demonstrate motion error. This effect is demonstrated in the ECG signal by the raising and lowering of the test subjects right arm. This movement should cause a shift in the baseline but should quickly recover if the signal is to be used with a moving subject.

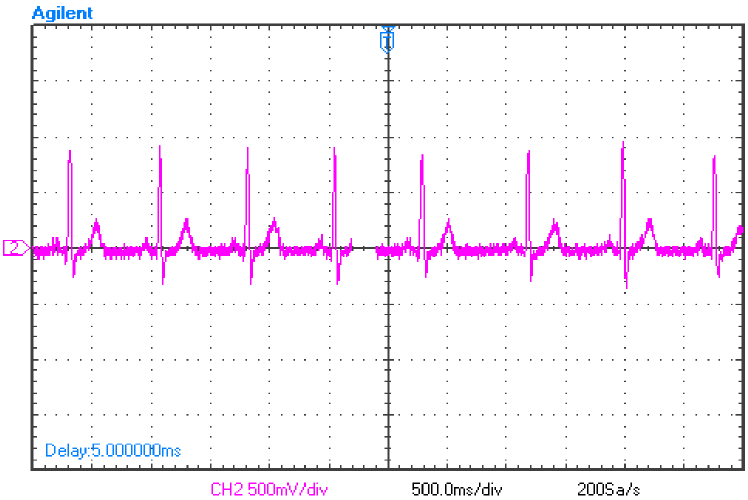

Fig. 12. The baseline ECG measurement show very little deviation.

Fig. 13 and Fig. 14 show the results of the baseline shift due to the subjects motion. The motion error quickly stabilizes as soon as the subject stops moving. This is due, most likely, to the constant pressure applied to the electrodes by the elastic material in the ECG shirt.

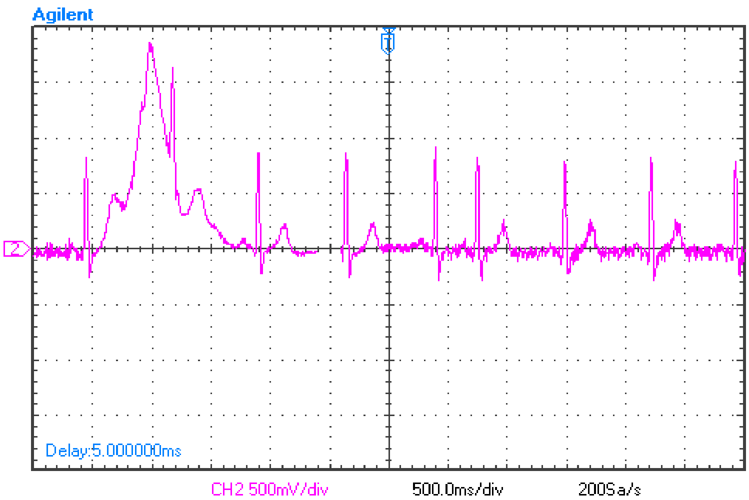

Fig. 13. The baseline shift caused by lifting the subjects right arm. This shift stabilizes within two beats. The unevenness shown in the heart rate is due to the vagaries in the capture program.

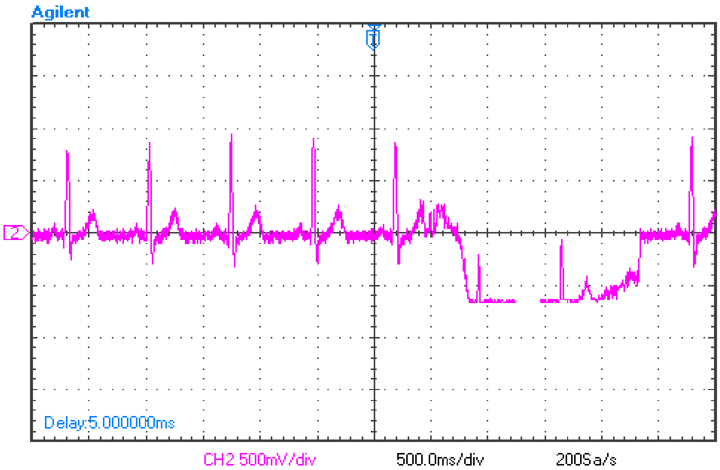

Fig. 14. The baseline shift caused by the lowering of the right arm. The time to stabilization is also within two beats.

4. Conclusion

The main goal of this experiment was to design a polymer fiber sensor array which can be embedded into a t-shirt for ECG signal detection. This design provides better contact and eliminates the use of gel and other adhesives which could cause problems to the user's skin. The hardware required for the amplification of the signal is also implemented using standard op-amps. The polymer sensor array provided a more reliable contact and less baseline wandering. During the evaluation, the gel electrodes consistently lost contact and could only used once. The polypyrrole is unfortunately a surface doping and can, in time, be washed off. Future research is being performed using various other conductive fibers.

Acknowledgements

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References

[1]. Conrad M. Swartz, Lake Forest, III, Electrode Application System and Method for Electroconvulsive Therapy, *United States Patent*, Patent No: 4, 870, 969, Oct 3, 1989
[2]. Vikram Sharma, Fabrics and Garments with Information Infrastructure, *United States Patent*, Application Publication, Pub. No. US2007/0089800 A1, April 26, 2007.
[3]. Qi, Baohua, Mattes, Benjamin R, Multifunctional Conducting Polymer structures, *US Patent*, 7463040, December 9, 2008.
[4]. R. McNeill, R. Siudak, J. H Wardlaw and D. E. Weiss, Electronic Conduction in Polymers I. The Chemical Structure of Polypyrrole, *Aust. J. Chem.*, 1963, 16, pp. 1056-1075.
[5]. Mark Austin, Development of a Complete Ballisto-Electrocardio System, Department of Electrical Engineering, ELE 521 Biomedical Sensors, Instructor: Dr. Abdel-Motaleb.

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Guide for Contributors

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Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
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- Frequency (period, duty-cycle)-to-digital converters, ADC;
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- Nanosensors;
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