Low-Cost Prototype Design of Biomedical Sensing Device for ECG and EMG Signal Acquisition System

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***Abstract*—This short paper briefly shows a prototype Acquisition System Design (ASD) for Biomedical Sensing Device (BSD). This BSD is designed for detecting both of electrocardiogram (ECG) and electromyogram (EMG). To reduce the hardware cost, a view of ASD is discussed and then a system specification is carefully determined for block function sharing scheme, *i.e.*, the gain of instrumentation amplifier, band-stop and band-pass filters, adjustable gain-stage amplifier, and microcontroller. The results show that the board size of the proposed BSD was only 5×5 cm^2 and the power consumption was 31.9 mW. A lithium battery (280 mAh) is used to supply 3.7 voltages for this BSD, and can let it work lasted 32.5 hours, ideally. The total cost of the proposed BSD is 39.72 USD.**

***Keywords*—Arduino; electrocardiogram; electromyogram;**

I. Biref Introduction

Wireless e-health monitoring device is a very modern application and will play a key component connected with the homecare services [1, 2]. The electrocardiogram (ECG) and electromyogram (EMG) signals are, respectively, useful for a doctor to discern the symptoms of heart and neuromuscular diseases.

In Lai *et al.*'s ECG ASD [3], the kernel is consist of Field-Programmable Gate Array (FPGA) to generate a "Nios" processor. Recently, Arduino platform [4] has been a very hot hardware and is an easy-to-learn development tool. Another ECG ASD based on Arduino DUE platform is proposed in [5]. It embedded an ARM Cortex-M3 MCU to develop complex data compressing algorithm but required more cost. That is why it scales down the design specification in [6]. Due to Arduino platform's highly intensive integration and compatibility, the open-source hardware and firmware are widely applied to designers for developing innovative ideas and prototype designs.

In this work, a single architecture and compact design is proposed to both ECG and EMG signal detections, because the Analog Front-end Circuit (AFC) for the ECG and EMG has many similar processing blocks (PBs). In general, there are 5 basic processing blocks of AFC which includes: 1) Instrumentation amplifier (IA); 2) Right-Leg Driven (RLD) circuit; 3) Band-Pass Filter (BPF); 4) Band-Stop Filter (BSF); 5) Adjustable Gain-stage Amplifier (AGA). Table I and II summarize the specifications of ECG and EEG.

Table I. Gain Ratio Selection of ECG and EMG detection

Type	Signal Range	Desired Range	Gain Ratio
ECG	0.1mV-1mV	0v-3.3V	1833.33
EMG	0.05mV-2mV	0v-3.3V	1692.30

Table II. AFC Specification of ECG and EMG

Type	IA	BPF	BSF	AGA
ECG	15	0.1-100 Hz	60 Hz	122
EMG	10	0.05-1000 Hz	60 Hz	170
Proposed	10-20	0.05-1000 Hz	60 Hz	<101

II. System Design and Realization Results of the Proposed Biomedical Sensing Device

The overall system design of the proposed BSD is shown as Fig. 1. There are total 8 PBs included 5 PBs for AFC, atmega328 micro control unit (MCU) [7], Bluetooth 2.1 block (RN-42) [8], and power supply block. Under the data transmission mode, the MCU embedded a 10-bit Analog-to-Digital converter (ADC) samples 500 (or 2,000) times per second and can transmit the digital ECG (or EMG) codes to Android smart phone through RN-42, immediately.

In the AFC design, INA333 [9] has a low-power and 100-dB-of-CMRR advantages. To implement BPF, RLD, BSF, and AGA, all of the operation amplifiers are using MCP6074 [10], which have a rail-to-rail output and 72-dB CMRR. The regulator is using NCP752 [11] to convert the input voltage, which is supplied by lithium battery, from 3.7 to 3.3V. The BPF of ECG is only ranged from 0.1 Hz to 100Hz according to Table I, and hence we need to design an extra 20-tap low-pass digital filter with a folded structure to achieve the stopband specification. Figures 2 and 3 demonstrate the proposed analog BPF and BSF, respectively, and the realization result of the proposed BSD is shown in Fig 4.

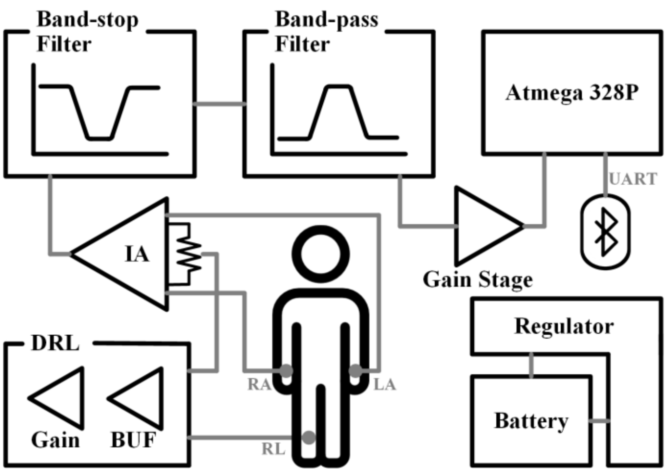


Fig. 1 Overall system design of the proposed BSD.

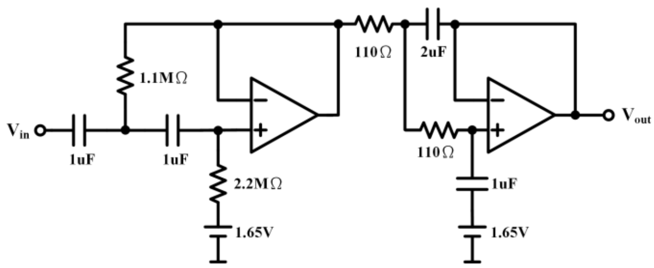


Fig. 2 Schematic diagram of the proposed BPF.

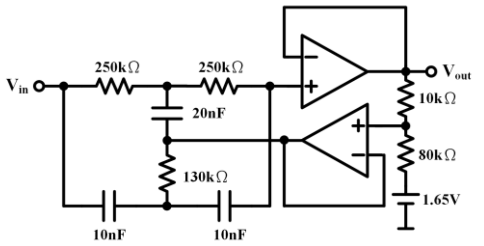
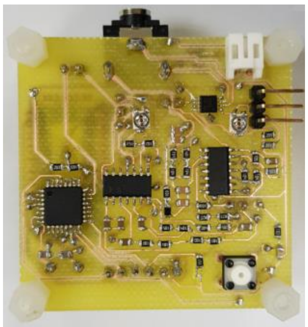
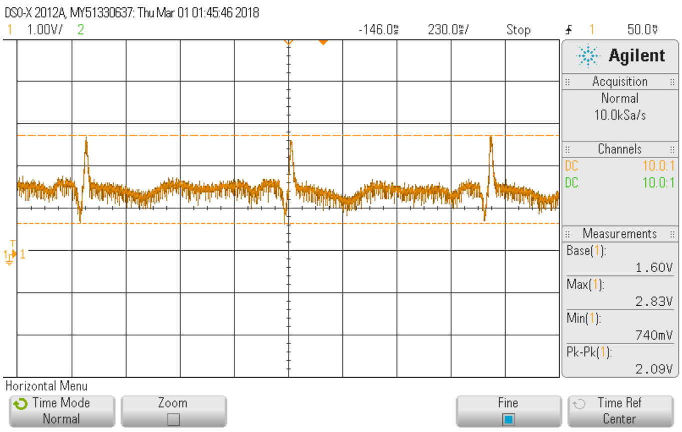


Fig. 3 Schematic diagram of the proposed BSF.

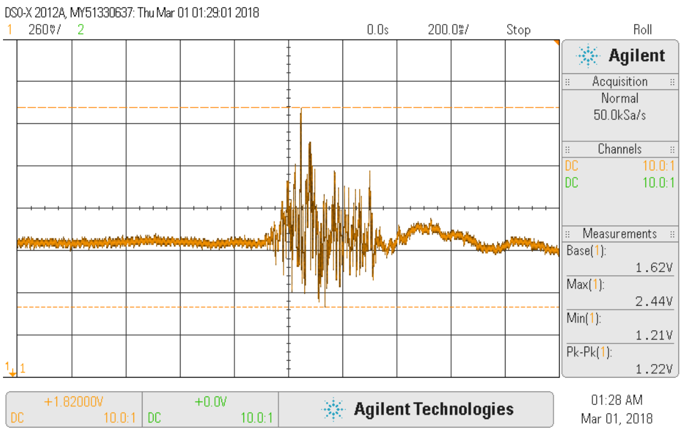
(a)



(b)



(c)



(d)

Fig. 4 Realization results of the proposed BSD. (a) top view; (b) bottom view; (c) the AFC detection result of ECG signal; (d) the AFC detection result of EMG signal.

Table III shows the detailed cost of implementing the proposed BSD, and the most expensive module is for Bluetooth 2.1 (RN-42). The total cost of the proposed BSD with RN-42 is 39.72 USD. However, the Bluetooth 2.1 module can be easy instead of Bluetooth 4.0 BLE (HM-10) [12] to reduce hardware cost and reduce the power consumption. Hence, the total cost of the proposed BSD with HM-10 would only take 15.72 USD.

TABLE III. EQUIPMENT COST OF THE PROPOSED BSD

Component Name	Quantity	Unit Price	Total Cost
Bluetooth 2.1 (RN-42)	1	30	30
Bluetooth 4.0 (HM-10)	1	6	6
Atmega328	1	1.9	1.9
MCP6074	2	1.43	1.43
INA333	1	4.23	4.23
NCP752	1	0.56	0.56
Crystal oscillator	1	0.05	0.05
Headphone plug	1	0.5	0.5
Button	1	0.02	0.02
Potentiometer	2	0.2	0.4
Resistor	33	0.01	0.33
Capacitor	15	0.02	0.3
Total Cost of the proposed system (USD)			39.72

III. CONCLUSION

This short paper has presented a low-cost prototype design of biomedical sensing device. The results show that the proposed design can clearly acquire the ECG and EMG signals and the board size of the proposed BSD is design within 5×5 cm^2. It would be suitable for future integration of various ECG applications.

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