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Design and Comparative Analysis of ECG Data Acquisition System using Low Power Microcontroller

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Abstract

Electrocardiogram (ECG) is the most commonly used bio-medical signal for diagnostic purpose. It can be used to diagnose heart disease, identify cardiac arrhythmias, and evaluate effect of drugs. Earlier the ECG systems were designed to be used in hospitals and clinics, but now there is an increased demand for the ECG machines that can be used as a lifestyle product for routine health monitoring. For example, we already have systems that are being used in homes for blood pressure and glucose level measurement. Therefore, user- friendly, affordable and portable ECG system that can be managed by the user is a great research area. The size, cost, performance, recording time & energy efficiency of medical equipment design has undergone a great transition along with a timeline. With the advancement in low power embedded hardware technology & Signal processing platforms, more efficient ECG system designs have started to emerge. This paper presents a review of the resent work on the design of portable & low power ECG systems. Further inspired by some of the related work [3-6], this paper also presents to design & development of a wearable & ultra-low power ECG data acquisition system using MSP430 microcontroller. The power consumption of the given design is then compared with other designs discussed in the literature review. The comparison shows that our design consumes the lowest power among these.

Keywords: *Analog front end unit, Electrocardiograph (ECG), Long-time monitoring, Ultra-Low Power, MSP430 Microcontroller, MATLAB, Portable size*

1. Introduction

Energy Efficient [1-3] medical equipment design is the major research area in the field of bio-engineering. With the development in medical science, the scientists are shifting towards the energy efficient medical equipment design; ECG machine is the commonly used medical equipment. If any medical equipment is consuming less power than the traditional counterpart, then the whole medical system will be more greener or energy efficient. The main challenges on the development of a low-cost wearable ECG system design of an ultra-low-power microcontroller, which can acquire, process, and display digitally and can be transmit the ECG signal to a remote doctor via a personal gateway in real-time.

2. Related Work

Ira Mahajan [3] has designed an ECG data acquisition system using an integrated analog front end (AFE) ADS1292 chip and P89V51RD2 microcontroller. ADS1292 AFE Chip has 24-bit 2-channel ADC for patient monitoring. It has a very small form factor that reduces the size & power requirements. ECG waveform is displayed on the oscilloscope.

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Thakor, Prof. Kher and Prof. Patel [6] have worked on development of innovative wearable and ambulatory system that is able to monitor the physio-pathological parameters of the patient's daily activities. The ECG signal is amplified by the instrumentation amplifier (INA 321 from Texas Instruments). The amplified ECG signals are then converted into digital signals using ultra-low power microcontroller (MSP 430FG439) and stored in the SD card. It also uses an accelerometer for the suitable monitoring of human movements likes gaits, sit to stand transfers, postural sway and falls etc. It has five power-saving modes that make the battery saving operated instrumentation.

Suhas Kale and C. S. Khandelwal [5] has written on physiological parameters such as ECG, pulse-rate, temperature measurement using ARM7 LPC 2138 processor and waveform showed on the GUI-MAT-LAB window. It also has a facility to send SMS to a doctor if any vital parameter goes to abnormal range. Team viewer Software and low cost hardware components transmit the ECG data to the physician regardless of patient's location for monitoring, diagnosis and patient's care at a low cost. The body parameters are processed by ARM processor and displayed on the LCD and on Patient's side, wave-forms can be seen on personal computer using MAT-LAB GUI window. Also same data can be viewed by the physician on the PC.

3. ECG System Design

The Block diagram of proposed ECG system design is given below.

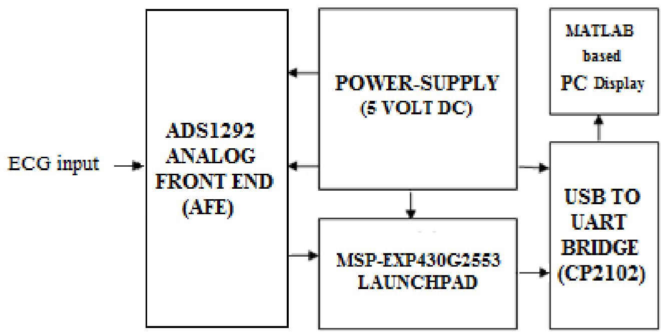

Figure 1. Block Diagram of ECG System Design

The ECG system is implemented as a combination of these design modules:

- ECG machine
- Display system

3.1 ECG Machine

The ECG machine is designed using these components.

- Analog Front End (AFE) chip
- MSP430 microcontroller Unit
- USB to UART Bridge (CP2102)

3.1.1. Analog front end (AFE) Chip

In order to deal with extremely weak ECG signals (0.5 mV to 5 mV) acquired from the human body we need an analog front end chip [3]. It consists of components such as Instrumentation amplifier, filter, multiplexer, 24-bit analog to digital converter, oscillators, control register & serial peripheral interface (SPI).

3.1.2. MSP430 Microcontroller Unit

MSP430 Microcontrollers further enhances the performance of the ECG systems. The ultra-low power consumption of MCUs extends the battery life of machines [9]. MSP430 board has associated circuit components such as MSP430 controller IC, MSP430 interface IC, SPI, capacitors, resistors, *etc.*, we have interfaced the ADS1292 AFE Chip with MSP430 board and assign the ports as input and output for ECG signal receiving by the ADS1292 AFE Chip and the outputs give to the MSP430 board. The MSP430 LAUNCHPAD board receives the input signal and gives output to the USB to UART Bridge (cp2102).

3.1.3. USB to UART Bridge (CP2102)

The CP2102 is a highly-integrated SMD chip called USB-to-UART Bridge Controller we can say to update the solution of RS-232 designs, making minimize the size of components and save the PCB space. The output of MSP430 BOARD makes as input for the USB to UART Bridge (CP2102).

3.2 ECG System Display

For ECG system display, we used the PC with Mat-lab software. Mat-lab software is an effective for acquisition and processing of ECG data [2]. For the ECG waveform display, here we used the Mat lab window as graphical form called “GUI” window and PC. The ECG signal receives from output of CP2102 Bridge chip and comes to the com-port of the computer. MATLAB port synchronizes with USB to UART Bridge (CP2102) port and receives the ECG data and display the ECG signal in MATLAB window.

We have easily described a whole ECG system design with a flow-diagram given in Figure 4 below.

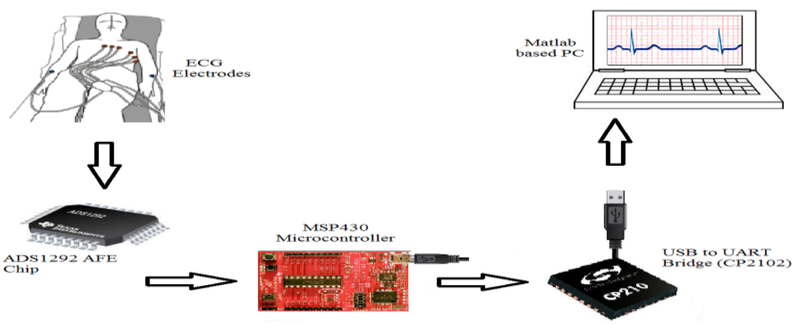

Figure 2. Flow Diagram of ECG System Design

4. Results and Discussion

The ECG data acquisition system successfully designed with using MSP430 controller and ADS1292 chip which having low power consumption, cost-effective and compact size also. The ECG data successfully received on the Mat lab window. Ideally the Simulator ECG Signals available at MATLAB-window on the PC should look like as shown in the Figure 3.

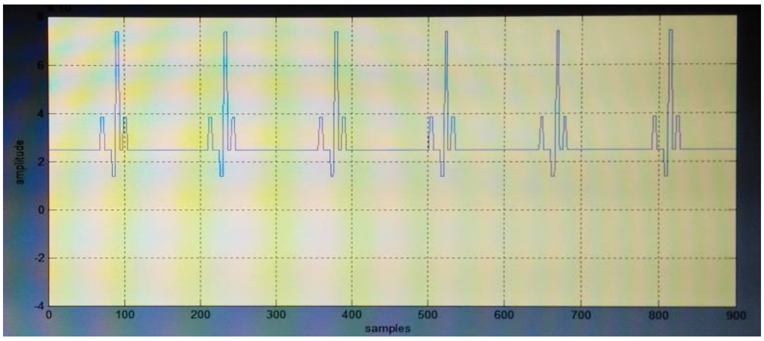

Figure 3. Output Waveform on MATLAB Window

We have done the comparative analysis between present work and previous works are given below.

4.1. Comparison of Power Consumption with Related Work

The Design of the ECG system presented in this work can be evaluated by comparing its performance, power consumption with similar works discussed previously in the literature review section.

Sr. no	Research Paper	Author	Year
1.	Design and Development of ECG data Acquisition system using integrated analog front end [3]	Ira Mahajan and Mandeep Singh (C-Dac, Mohali)	2013
2.	Design and Implementation of Real Time Embedded Tele-Health Monitoring System[5]	Suhas Kale and C. S.Khandelwal (B.A.M University Jawaharlal Nehru Engineering College, Aurangabad)	2013
3.	Wearable ECG Recording and Monitoring System based on MSP430 Microcontroller[6]	Asifiqbal Thakor, Prof. Rahul Kher and Prof. Dipak Patel (A.P., EC-deptt., A.D. Patel Institute of Technology, Gujarat)	2012
4.	ECG system design by Medicaid Pvt. Ltd, Chandigarh. [58]		2015

4.1.1. Comparison of Power Consumption with Reference Work ‘1’

Table 1. Power Consumption: Present Work Vs Reference Work 1

Present work		Reference work ‘1’	
Components	Power consumption	Components used	Power consumption
MSP430G2553	990µW	P89V51RD2FBC	57.5mW
ADS1292 chip	840µW	ADS1292 chip	840µW
DAC	33mW	DAC	33mW
Total	34.830mW	Total	91.340mW

Our design consumes 61.86 % less power as compared to reference work ‘1’. The graphical representation is shown below.

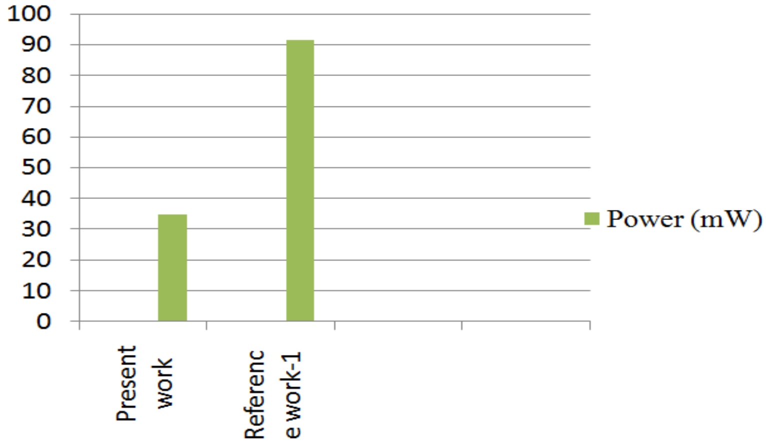

Figure 4. Comparison of Power Consumption with Reference Work ‘1’

4.1.2. Comparison of Power Consumption with Reference Work ‘2’

Table 2. Power Consumption: Present work Vs. Reference Work 2, 4

Present work		Reference work ‘2,4’	
Components	Power consumption	Components used	Power consumption
MSP430G2553 controller	990µW	LPC2138, 16bit ARM Cortex	30mW
ADS1292 chip	840µW	INA 321	30mW
Display	400mW	Display	400mW
Total	401.830mW	Total	460mW

Our design consumes 12.64 % less power as compared to reference work ‘2’ as shown below.

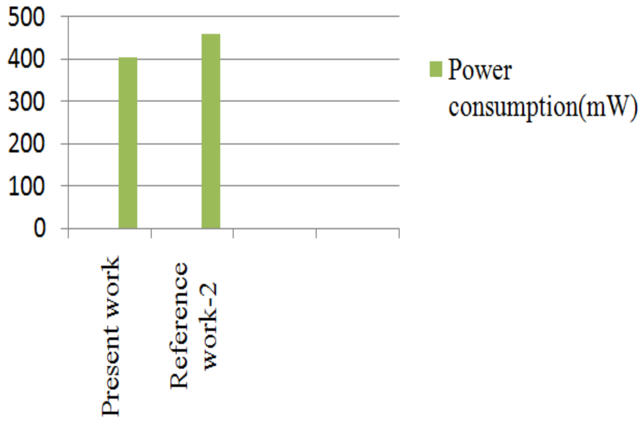

Figure 5. Comparison of Power Consumption with Reference Work ‘2’

4.1.3. Comparison of Power Consumption with Reference Work '3'

Table 3. Power Consumption: Present work Vs Reference Work 3

Present work		Reference work '3'	
Components	Power consumption	Components	Power consumption
MSP430G2553	990µW	MSP 430FG439	1.41mW
ADS1292 chip	840µW	INA 321	30mW
Accelerometer	8.510mW	Accelerometer	8.510mW
Micro SD card	330µW	Micro SD card	330mW
Total	340.340mW	Total	369.92mW

Our design consumes 5.26 % less power as compared to reference work '3'. The graphical representation is shown below.

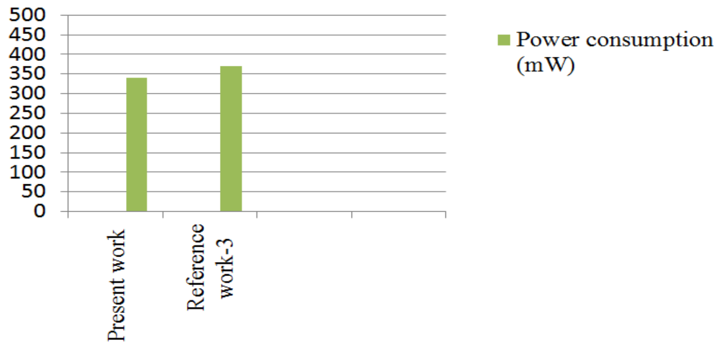

Figure 6. Comparison of Power Consumption with Reference Work '3'

4.1.4. Comparison of Power Consumption with Reference Work '4'

Table 4. Power Consumption: Present work Vs Reference Work 4

Present work		Reference work '4'	
Components	Power consumption	Components	Power consumption
MSP430G2553 controller	990µW	ATxmega192A3 (AVR) controller	2091 µW
ADS1292 chip	840µW	INA 321	30mW
Display	400mW	Display	400mW
Total	401.830mW	Total	432.09mW

Our design consumes 7 % less power as compared to reference work '4'. The graphical representation is shown below.

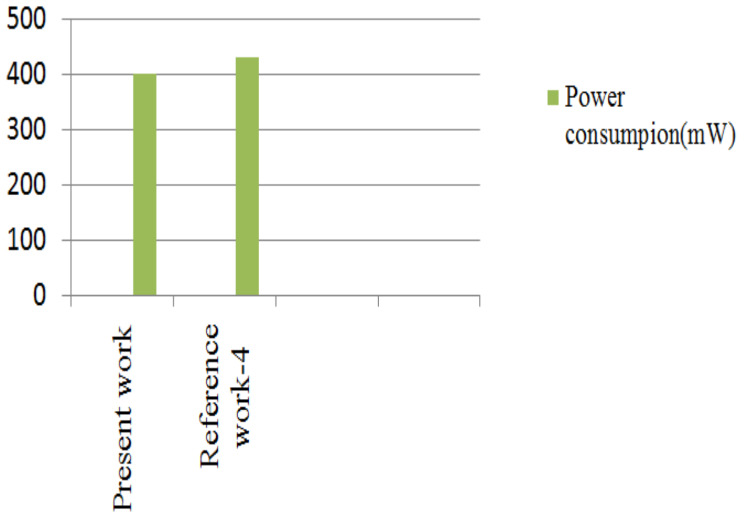

Figure 7. Comparison of Power Consumption with Reference Work '4'

We can also calculate the life-time of Lithium coin 240 mah battery for these machines [18]. The graphical representation of life-time of Lithium coin 240 mah battery is shown below.

Life-Time of 240 mah Battery		
Compared with Reference	Previous design(hrs)	Present design(hrs)
Reference work-1	13.05	33.28
Reference work-2,4	2.5	2.97
Reference work-3	2.2	2.33
Reference work-4	2.76	2.97

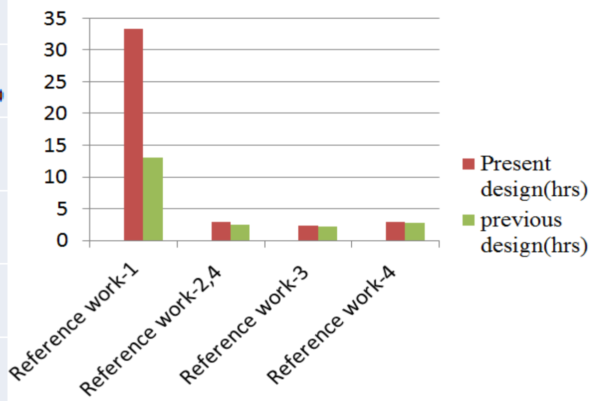

Figure 8. Life-time of Lithium Coin 240 mah Battery

Also it has very less size reduce the components in the system by 99% when we compare with INA321 instrumentation amplifier. The dimension of INA321 instrumentation amplifier has 210x185mm whenever the ADS1292 analog front end chip has only 5x5mm.

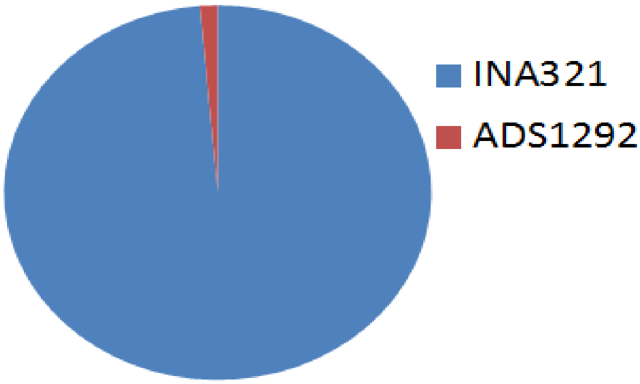

Figure 8. Size of INA321 & ADS1292 Chip

5. Conclusion

There is a growing demand for affordable, portable/handheld ECG machine. The remote monitoring of the patients proposes to tackle this problem, by using portable/handheld monitoring systems. So by choosing the appropriate components suitable for portable applications, portable/handheld ECG machine can be developed. We compared with other system designs, present works provides reliable measurements, extended power autonomy, and also they are generic enough for reducing the costs over them.

6. Future Scope

In future, we can use MSP430 processor in another medical instruments likes Ultrasound machine, CT scan, BP machine *etc.*

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