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Portable ECG Monitoring System

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ABSTRACT—

The core of the system includes low-power ECG signal acquisition modules integrated with an energy-efficient signal processing unit. The acquired ECG signals are converted into audio signals and transmitted through a standard wired audio connection to a receiving device, such as a smart phone or computer, where they are decoded and analyzed. This approach not only simplifies the hardware requirements but also ensures reliable data transmission with minimal interference, leveraging existing audio processing capabilities of consumer devices. Experimental results demonstrate the system's effectiveness in capturing and transmitting high-fidelity ECG signals without significant loss of data quality. The paper discusses the design considerations, implementation challenges, and potential applications of this innovative ECG monitoring system, highlighting its feasibility as a low-cost, sustainable solution for continuous cardiac health monitoring.

INTRODUCTION

The introduction of this battery-less ECG monitoring system has significant implications for both patients and healthcare providers. It offers a practical, cost-effective solution for continuous cardiac monitoring, particularly beneficial for patients with chronic heart conditions who require ongoing surveillance. Moreover the simplicity and reliability of wired audio transmission present a compelling alternative to wireless methods, ensuring consistent and high-quality data transfer. The design of the system focuses on low-power ECG signal acquisition and processing, ensuring efficient energy use. The ECG signals are converted into audio signals, which are transmitted through wired audio connection to a receiving device such as a smart phone or a computer. The method leverages the ubiquitous nature and processing capabilities of consumer audio devices, providing a robust and interference-free communication channel. In the following sections, we will delve into the technical details of the system, including its design considerations, implementation challenges, and potential applications. The aim is to demonstrate the feasibility and advantages of this innovative approach, paving the way for more sustainable and user-friendly health monitoring solutions.

LITERATURE SURVEY

Lei He : His research interests include bio-signal acquisition frontend circuits design and RF circuits design.

Lianxi Liu : His research interests include high-speed CMOS data converters, mixed-signal integrated circuits design, and low-voltage low-power analog circuits design.

Yi Zhang: His research interests include low-noise analog integrated circuits design and bio-signal acquisition front-end systems design.

Tianyuan Hua: His areas of interest in research are high-precision SAR ADC design and front-end systems design for bio signal acquisition.

H. Chandrakumar and D. Markovi´c: Their areas of interest include data converters, implantable neural sensor structures for closed-loop neuro-modulation, mixed-signal, analog, and radiofrequency integrated circuits, and applications of circuits in medicine, diagnostics, and therapy.
Behzad Razavi: Razavi specializes in telecommunications circuitry and his research involves work with data receivers, frequency synthesizers, and phase-locking and clock recovery for high-speed data communications.

Pradeep and Medioni G describes that it provides a comprehensive review of blindness and not a proper vision to blind people and describes the sight and any object to be visualized by blind people. The paper reviews the standards and regulations of brain port vision technology.

SYSTEM OVERVIEW AND DESIGN

The creation of a headphone cable-based ECG signal monitoring system. System overview, chopper/AM combo scheme design, power management unit (PMU) theory, and signal processing in smart devices comprise the four main components of the overall system design.

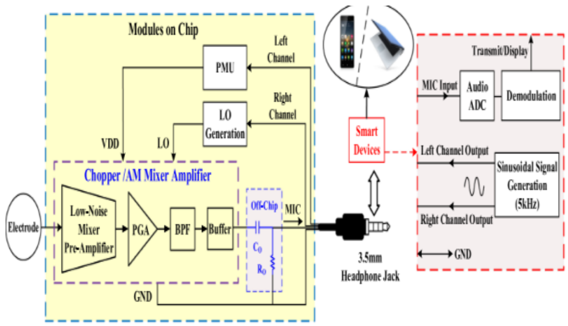

Fig 1: Block diagram of proposed system

SYSTEM OVERVIEW:

The modulated ECG signal is sent to the headphone jack's microphone input via a 3.5 mm headphone cable, which serves as the signal transmission medium in the suggested design. The smart device's high-precision audio ADC samples the signal, which the internal software then demodulates. This system has the advantage that the smart device can perform the functions of high power consumption and complex structure modules like DSP and ADC, negating the requirement for a wireless transceiver module. Three components make up the designed ECG signal acquisition and processing chip: a local oscillator (LO) signal generating circuit, a power management unit, and a chopper/AM mixer amplifier.

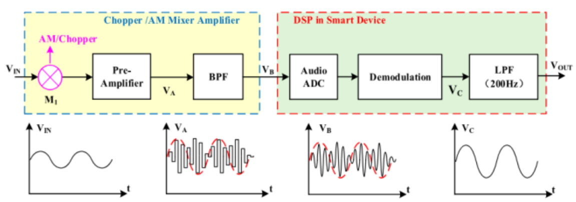

Fig 2: Principle of proposed scheme.

HOPPER/AM COMBINATION SCHEME DESIGN

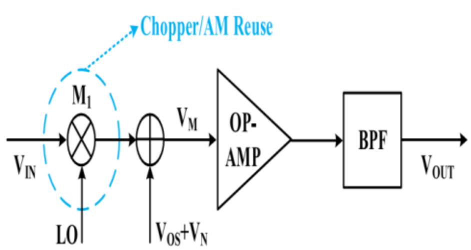

Fig 3: Simplified scheme for paper.

To separate the signal for chopper and AM modulation, an audio modulation circuit is installed behind the instrumentation amplifier. The frequency of sounds the plan that follows the conventional notion of modulation separation and amplification. The local oscillator signal used in both AM and chopping modulation is 5 kHz in order to avoid adding extra clock signals.AM modulation and amplification have been applied to the input signal. The input signal passes via one amplification, one filtering, and two modulations (M1, M2) at the first stage, which is a standard chopper stabilization amplifier structure (LPF1). Following two modulations, the input signal returns to its original frequency band, and the low-pass filter (LPF1) filters out the modulated noise and offset. The multiplier M3 modulates V3 to the odd harmonics of the carrier frequency fC in the second stage, which is the AM modulation stage. LPF2's job is to filter away higher harmonics while maintaining the first harmonic signal and, thus, the cutoff frequency. Three multipliers are used by the audio transmission amplifier to carry out AM modulation and amplification tasks. Two redundant modulations are applied to the input signal during a modulation-demodulation-demodulation process. Furthermore, it is necessary to have two low-pass filters with distinct cutoff frequencies (fF1 < fC < fF2).

POWER MANAGEMENT UNIT

The power management unit's schematic design shows how the system receives and stores the energy output from the left channel of the headphones. The software on the smart device regulates the left channel to produce a fixed frequency sinusoidal signal (e.g., 5 kHz). A charge pump rectifier with a voltage-multiplying function subsequently converts the signal into a DC signal. To provide a steady DC voltage that other circuits can use as their power supply voltage, an LDO is connected to the rectifier output. To stop excessive voltage from breaking down transistors, the rectifier output maximum voltage is limited by the Over-Voltage safety circuit. The reference voltages for the LDO and the Over-Voltage protection circuit are produced by the band gap reference (BGR) circuit. The band gap reference circuit activates when the rectifier's output voltage reaches 0.8 V. The 0.6 V reference voltage that is produced thereafter serves as the reference voltage for the LDO (VREF2) and the over-voltage protection circuit (VREF1). The voltage is ultimately restricted at 1.8 V by the Over-Voltage protection circuit, but the LDO won't work until the rectifier's output voltage is higher than 1.5 V.

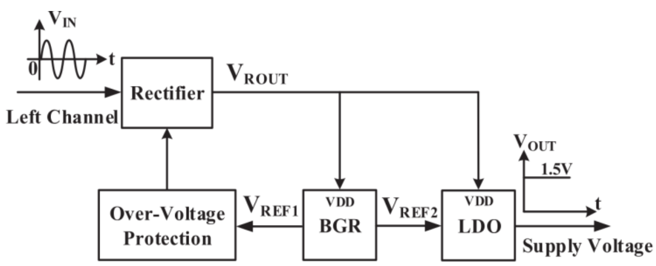

Fig 4: Schematic diagram for power management unit

SIGNLE PROCESSING IN SMART DEVICE

The smart device mentioned above is a PC, and Mat lab is used to implement the software's function in the PC to enable verification. Smart device sound cards often provide sample rates of 8000, 11025, 22050, 44100, 48000, or 96000 Hz, with 16 or 24 bit sampling precision. While gathering the signal from the microphone device is comparable to the recording process, outputting a set frequency signal from the channel is similar to playing an audio signal. The "audio recording" function in Mat lab may control the audio ADC to sample the input signal, which is similar to the realization of the recording process. Channel output can be done by invoking the "sound" function in Mat lab. The strong computational capabilities of Mat lab are necessary to realize signal demodulation. The quadrature demodulation approach, which can resolve the phase-difference problem, is employed to demodulate the modulated signal since it is challenging to produce a local restored carrier signal with the same phase as the input modulated signal. The demodulation principle is applied as the figure below illustrates.

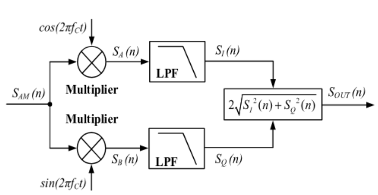

Fig 5: Schematic for demodulation principle.

WORKING

We develop a chopper/AM mixer amplifier based on the condensed method of mixing chopping with AM. The input signal is amplified and modulated by the low-noise mixer pre-amplifier. Through the automated gain control circuit, the programmable gain amplifier (PGA) may automatically modify the gain. The higher frequency harmonics that the modulation produces, as well as the low frequency noise and offset, are filtered out using the band-pass filter (BPF). The power management circuit uses a two-stage charge pump rectifier, and the LDO's 1.5 V DC voltage output powers every other circuit. In addition, a circuit for over-voltage protection is included to keep the rectifier's output voltage from rising to the point where the transistors in the circuit's next stage fail. An ideal diode has a turn-on voltage drop of zero, however in real-world applications; this drop is usually 0.7 V. To produce a clock signal, a conventional biomedical front-end system must incorporate an oscillator into the chip. In order to shape the sinusoidal signal from the right channel to the clock signal—which is needed by the modulation and control circuit—we created a LO signal generation circuit in this design. Two clock signals are needed for this scheme: the control clock signal, which is a square wave signal of 5 kHz from the chopper switches, and the control clock signal, which has a period of 1.6 s from the automated gain control circuit.

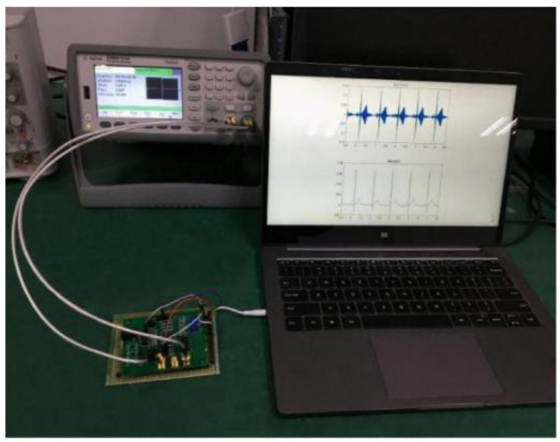

Fig 6: Result

III CONCLUSION

By harnessing ambient energy sources, the proposed system eliminates the need for frequent battery replacement, enhancing the device's portability and sustainability. The conversion of ECG signals into audio signals for transmission through a standard wired audio connection leverages the widespread availability and processing capabilities of consumer audio devices, ensuring reliable and interference-free data transfer. Future work will focus on optimizing the energy harvesting mechanisms, improving the signal processing algorithms, and conducting extensive clinical trials to validate the system's performance in real world scenarios. The battery-less ECG monitoring system with wired audio transmission represents a promising step toward more accessible and enduring health monitoring solutions, with the potential to significantly impact the management of cardiac health.

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