International Scientific-Electronic Journal “Pioneering Studies and Theories”
ISSN: 3060-5105
www.pstjournal.uz
№ 4
Volume 1
MARCH, 2025

APPLICATION OF THE HARDWARE-SOFTWARE COMPLEX "SALIVA" IN INTERNATIONAL DIGITAL INTEGRATION FOR THE DIAGNOSIS OF GASTROINTESTINAL DISEASES

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Abstract— This article examines the application of the hardware-software complex "Saliva" in the context of international digital integration for the diagnosis of gastrointestinal diseases. The relevance of this research is driven by the increasing demand for effective and innovative diagnostic methods that can be integrated into the digital healthcare systems of various countries.

The "Saliva" complex represents an advanced technology that enables precise analysis of the gastrointestinal tract's condition through non-invasive methods. The article provides a detailed description of the operating principles of the complex, its advantages over traditional diagnostic methods, and discusses the prospects for using "Saliva" within the framework of international cooperation in digital medicine.

The study analyzes the effectiveness of the complex in various clinical scenarios and evaluates the potential benefits of its implementation on an international level. Special attention is given to issues of data standardization and compatibility, which are key aspects for the successful integration of "Saliva" into global medical networks.

Keywords: Hardware-Software Complex SALIVA, Digital Economy, International Digital Integration, Diagnosis of Gastrointestinal Diseases, Non-Invasive Methods, Digital Medicine, Data Standardization.

INTRODUCTION

Modern healthcare is rapidly evolving towards digital transformation, opening new possibilities for the diagnosis and treatment of various diseases. In this context, hardware-software complexes play a key role in providing high accuracy and efficiency in medical research.

The President of the Republic of Uzbekistan, Sh. Mirziyoyev, has signed several decrees: "On measures to further support export activities" (dated 07.05.2020 No. PP-4707), "On additional measures to further increase the productive and export potential of the electrical engineering industry" (dated 10.01.2024 No. PP-15), and "On measures to support the training of qualified specialists in the field of IT service export" (dated 12.02.2024 No. 86) [1-3].

Based on the decrees of the President of the Republic of Uzbekistan, an innovative hardware-software complex "Saliva" was developed for the diagnosis of gastrointestinal diseases.

"Saliva" represents advanced technology that combines the advantages of non-invasive analysis methods and high-precision data processing algorithms. This not only reduces the time required for diagnosis but also significantly enhances its accuracy, which is particularly important given the increasing burden on healthcare systems.

International digital integration is a crucial aspect of modern medicine's development, facilitating the exchange of advanced technologies and standards between countries. The implementation of the "Saliva" complex into international medical practice opens new prospects for collaboration in digital medicine and improves the quality of medical services on a global scale.

This article examines the main operating principles of the "Saliva" complex, its advantages over traditional diagnostic methods, and the prospects for using this technology within the framework of international digital integration. Special attention is given to issues of data standardization and compatibility, which are key aspects for the successful integration of "Saliva" into global medical networks [4-6].

HARDWARE DEVELOPMENT

The Saliva device comprises essential components, including a sensor, analog-to-digital converter (ADC), microcontroller, universal asynchronous receiver-transmitter (UART), regulator, and Bluetooth module. Emphasis was placed on achieving cost-effectiveness and portability during the development process.

Accurate and efficient diagnosis of gastrointestinal tract diseases necessitates the utilization of specialized devices. This study introduces the Saliva device, specifically designed for primary diagnosis within this domain. Notably, the development process emphasized the device's affordability and ease of portability, enhancing its accessibility and practicality.

The Saliva device integrates multiple components critical for disease diagnosis. A sensor is incorporated to detect relevant biomarkers in saliva samples, enabling disease identification. Acquired signals undergo conversion through an analog-to-digital converter (ADC) to facilitate subsequent analysis. A microcontroller manages data processing and control functions, while a universal asynchronous receiver-transmitter (UART) facilitates seamless communication between the microcontroller and external devices. Furthermore, a regulator ensures a stable power supply, and the inclusion of a Bluetooth module allows for wireless data transmission.

The architecture of the Saliva system is structured into distinct functional blocks, each assigned specific tasks (as depicted in Figure 1). The Saliva system is composed of five main modules, which collectively constitute a comprehensive hardware-software complex designed for efficient disease diagnosis.

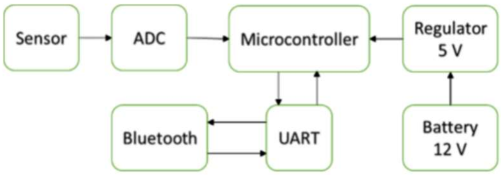

Fig 1. Functional module of the “Saliva” device

The development of the Saliva device marks a significant advancement in the primary diagnosis of gastrointestinal tract diseases. By integrating crucial hardware components and software modules, while considering cost-effectiveness and portability, the Saliva device demonstrates promise as a valuable tool for accurate and accessible disease diagnosis. Further research endeavors will focus on validating its performance through extensive clinical trials and refining its capabilities.

Sensors: A set of sensors for detecting protein, glucose, mucin, cholesterol, ammonium, and uric acid was assembled based on the selected parameters of the dataset.

ADS1298: The ADS1298, developed by Texas Instruments, is a low-power, multi-channel, 24-bit delta-sigma analog-to-digital converter (ADC). It simultaneously samples all channels. The gain parameters of the ADS1298 can be controlled using the programmable gain amplifier (PGA). This chip enables the measurement of patient saliva based on the selected parameters and can utilize the right leg drive (RLD) scheme. The chip's data transmission speed can reach up to 500-32 kbps (with a discrete frequency transmission rate of 103 seconds). The connection between the "Saliva" device and the computer is established through the UART interface [7-9].

The specifications of the ADS1298 ADC are as follows:

- 8 low-noise programmable gain amplifiers (PGA) and 8 high-precision analog reference channels (ARC)
- Channel power: 0.75 mW per channel
- Noise level: 4 µVpp (at a bandwidth of 150 Hz and gain of 6)
- Bias current: 200 pA
- Data rate: 250 SPS - 32 kSPS
- Common mode rejection: -115 dB

- Programmable gain options: 1, 2, 3, 4, 6, 8, or 12
- Compliance with ADC standards: AAMI EC11, EC13, IEC60601-1, IEC60601-2-27, and IEC60601-2-51
- Provides single polarity and bipolarity:
- AVDD: 2.7V - 5.25V
- DVDD: 1.65V - 3.6V
- Built-in features: RLD amplifier, trigger detection, WCT terminal, speed detection, and test signals
- Built-in breathing impedance measurement capability
- Digital speed measurement capability
- Built-in oscillator
- SPI interface

Atmega328 Microcontroller: The Atmega328 microcontroller plays a crucial role in the **Saliva** device by receiving primary processed signals from the ADS1298 microcircuits and performing secondary processing. It then transmits the processed signals to the Bluetooth module via the SPI interface. Additionally, the microcontroller controls the ADS1298 module, which is a 12-channel converter for discrete and analog-to-digital conversion of saliva sample signals, along with other peripheral devices [10-13].

The communication between the Atmega328 microcontroller and these peripherals is established using the SPI module. The block diagram of the Atmega328 microcontroller is shown in Figure 2.

Fig 2. Atmega328 microcontroller

The Atmega328 microcontroller is equipped with two SPI interfaces that support high-speed communication with the ADS1298 and NS-05 devices.

The ADS1298 module provides a serial communication timing system, ensuring synchronization in all communication processes at a minimal level. The Atmega328 microcontroller is distinguished by its low power consumption and high efficiency, characterized by the following features.

Specifications of the Atmega328 microcontroller:

- Operates with precise short commands
- AVR architecture with 40 pins
- 32 kB of flash memory
- 1 kB of EEPROM
- 2 kB of RAM
- 23 input/output pins
- Timer: two 8-bit and one 16-bit timers
- 10-bit 6-channel analog-to-digital converter
- 6-channel wide pulse modulator
- Separate oscillator
- Supports SPI master-slave and I²C modes
- External oscillator frequency: 20 MHz
- Universal synchronous-asynchronous receiver and transmitter (USART)

Bluetooth HC-05: The Bluetooth HC-05 module is a primary power supply module for the

Saliva device, enabling wireless data exchange between the device and a computer via the UART interface [14-16].

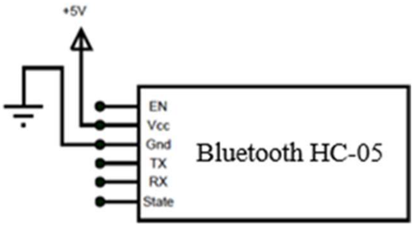

Fig 3. Block diagram of Bluetooth module HC-05

The HC-05 module operates within the ISM frequency range of 2.4 GHz, which is an internationally designated radio frequency range according to the regulations of the International Telecommunication Union. The block diagram of the Bluetooth HC-05 module is depicted in Figure 3.

The total information size from the 8 channels of the ADS1298 is calculated as follows: 224 ×8=224×23=227224×8=224×23=227, equivalent to 227×50/8=838,860,800227×50/8=838,860,800 or 838,860,800/1024=819,200838,860,800/1024=819,200 Kbps or 800 Mbps. In the hexadecimal number system, this value is 800/216=0.0122800/216=0.0122 MB. The selected NS05 Bluetooth device for the ECG design has a total bandwidth of 2.1 Mbps, which is approximately 10 times higher than the digital data (0.0122 Mbps) generated by the ADC device, thus meeting the current requirements [17-19].

The Bluetooth HC-05 operates in two distinct modes: command state and transmit/receive state, with data rates of 38,400 bps and 9,600 bps, respectively.

Technical specifications of the NS05 Bluetooth device:

- Bluetooth chip: HC-05 (BC417143)
- Radio frequency range: 2.4-2.48 GHz
- Transmission power: 0.25 - 2.5 mW
- Signal sensitivity: -80 dBm (0.1% BER)
- Supply voltage: 3.3-5V
- Current requirement: 50 mA
- Range: up to 10 meters
- Interface: serial port (UART)
- Modes: master, slave, master/slave
- Operating temperature: -25...75 °C
- Dimensions: 27 x 13 x 2.2 mm
- Standard: IEEE 802.15.1
- Transmission method: FHSS (Frequency Hopping Spread Spectrum) with modulation type
- Default baud rate: 38,400 bps, but supports 9,600, 19,200, 38,400, 57,600, 115,200, 230,400, and 460,800 bps.

Universal Asynchronous Receiver-Transmitter (UART): UART is a simple protocol that uses only two wires for bidirectional data transmission between a transmitter and receiver.

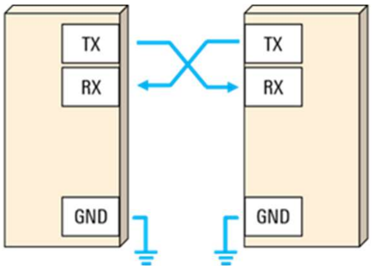

Fig 4. Data in the UART is transmitted in the form of frames

Communication in a UART can be simplex, half-duplex, or full-duplex. The UART protocol operates asynchronously, meaning the transmitter and receiver do not share a common clock signal. To ensure proper communication, both ends must transmit at the same predetermined rate and use the same frame structure and parameters.

The UART frame structure is illustrated in Figure 4. It consists of a start bit, data bits (typically 8 bits), an optional parity bit, and stop bit(s).

LM2596 Regulator: The LM2596 series regulators are monolithic integrated circuits (ICs) that encompass all active functions necessary for a buck switching regulator capable of controlling a 3-A load with excellent line and load regulation. These regulators are offered in fixed output voltages of 3.3V, 5V, 12V, as well as an adjustable output voltage option.

Designed to require minimal external components, the LM2596 regulators are user-friendly and feature internal frequency compensation and a fixed frequency oscillator. Operating at a switching frequency of 150 kHz, these regulators allow for the use of smaller filter components compared to low-frequency switching regulators.

The LM2596 regulators are available in a standard 5-pin TO-220 package, with various lead bending options, as well as a 5-pin TO-263 surface mount package [20-22].

Figure 5 illustrates the completed hardware-software complex Saliva.

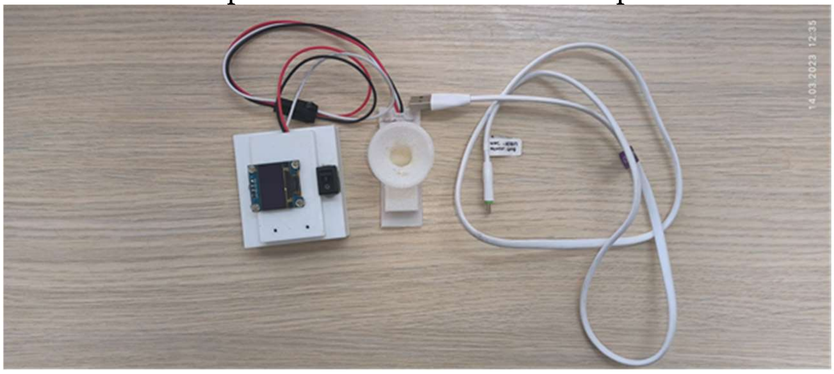

Fig 5. Hardware-software complex "Saliva"

ECONOMIC EFFICIENCY OF THE HARDWARE-SOFTWARE COMPLEX SALIVA

Figure 6 illustrates a histogram and line plot detailing medical equipment exports over different years. The histogram displays export volumes in thousands of US dollars, while the line plot shows the quantity of exported equipment. The data highlights a decline in both export volume and quantity from 2013 to 2019, followed by a minor recovery in 2023 [23-25].

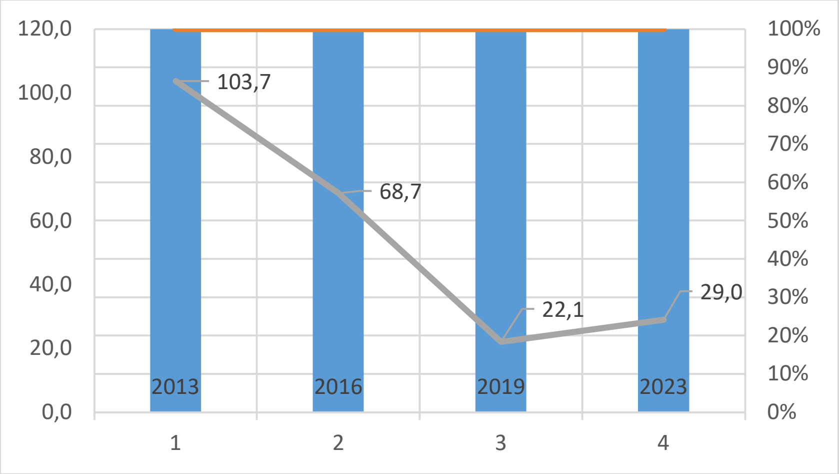

Figure 6. Export of Medical Equipment

Figure 7 presents a line graph depicting medical equipment imports as a percentage relative to quantity and cost from 2013 to 2023. The graph highlights fluctuations in the quantity ratio, with significant declines and peaks, while the cost ratio remains relatively stable around 100%. This suggests varying trends in import volumes alongside consistent costs [26-28].

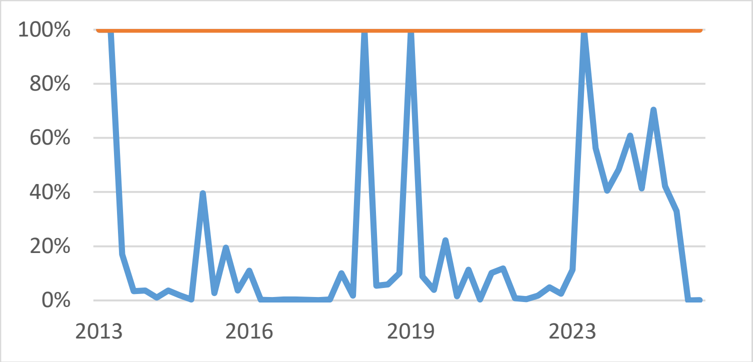

Figure 7. Import of Medical Equipment

Figure 8 displays a forecast graph of medical equipment imports, featuring four lines representing different datasets. The blue line shows actual imports from 2013 to 2019, indicating steady growth. The orange line depicts projected imports, suggesting a significant decline by 2026. The yellow and red lines represent low- and high-probability forecasts, respectively. The Y-axis measures values in thousands of dollars, with a negative range indicating a potential decrease in imports. The graph facilitates the analysis of import trends and the assessment of economic impacts on the medical technology sector over the forecasted periods [29-30].

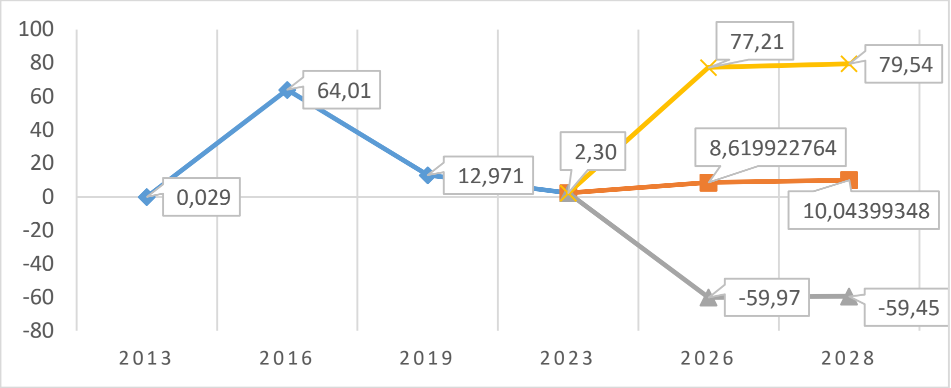

Figure 8. Forecast of Medical Equipment Import

Figure 9 shows a line graph of economic efficiency from 2022 to 2028, featuring four lines representing different datasets. The blue line displays actual efficiency, starting at $0.8 thousand in 2022 and reaching $0.9 thousand in 2023. The orange line depicts forecasted efficiency, gradually increasing from $1 thousand in 2024 to $1.4 thousand in 2028. The gray line represents a low-probability forecast, with values rising slightly from $1.1 thousand in 2025 to $1.2 thousand in 2026. The yellow line shows a high-probability forecast, with values climbing from $1.3 thousand in 2027 to $1.4 thousand in 2028. The X-axis indicates years, while the Y-axis measures economic efficiency in thousands of dollars. This graph enables the analysis and comparison of projected economic returns across different forecasting models.

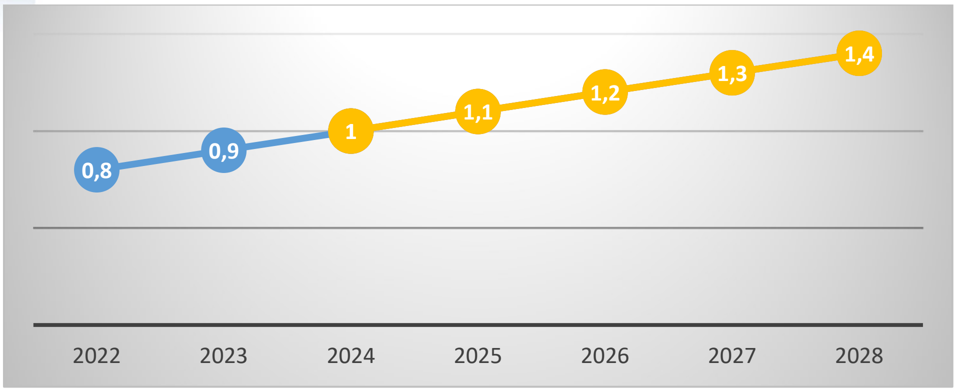

Figure 9. Economic Efficiency of the Saliva Hardware-Software Complex

CONCLUSION

The application of the hardware-software complex "Saliva" in international digital integration for the diagnosis of gastrointestinal diseases marks a significant advancement in the field of medical diagnostics. This study has highlighted the increasing demand for innovative and effective diagnostic methods that can be seamlessly integrated into the digital healthcare systems of various countries.

The "Saliva" complex represents a cutting-edge technology that facilitates precise and non-invasive analysis of the gastrointestinal tract's condition. By providing a detailed overview of its operating principles and advantages over traditional diagnostic methods, this article has demonstrated the potential of "Saliva" to revolutionize the diagnostic landscape.

Furthermore, the analysis of the complex's effectiveness across various clinical scenarios underscores its versatility and reliability. The potential benefits of implementing "Saliva" on an international scale are substantial, particularly in terms of enhancing diagnostic accuracy and efficiency.

Crucially, this study has emphasized the importance of data standardization and compatibility, which are vital for the successful integration of "Saliva" into global medical networks. Addressing these aspects will ensure that the "Saliva" complex can be effectively utilized in diverse healthcare settings worldwide, fostering international cooperation in digital medicine and ultimately improving the quality of healthcare services globally.

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