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Analysis of the development of an STM32-based smartwatch

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Abstract. Sensors and microcontrollers are well-functioning and inexpensive, and the smartwatch industry continues to grow. In response to the problems of traditional smartwatches, which are not fully functional, have poor computing effectiveness and are not suitable for wearing, this thesis designs a smartwatch based on the STMicroelectronics NUCLEO-L476RG microcontroller, using Altium Designer 17 software to draw The schematic diagram and Printed Circuit Board are drawn using Altium Designer 17 software, the driver code of the sensor is compiled and integrated using MBED software, the signal is processed by the STMicroelectronics NUCLEO-L476RG microcontroller and displayed in the Organic Light-Emitting Diode with Bluetooth debugger The measured parameters, such as heart rate, ambient temperature, number of steps, latitude and longitude, are displayed in the Organic Light-Emitting Diode with Bluetooth debugger. The results of the study show that the transmission of the signals in the STMicroelectronics NUCLEO-L476RG microcontroller and the display of the signals in the Organic Light-Emitting Diode and Bluetooth debugger have the advantages of small size, perfect functionality and low energy consumption, making it convenient for the user's daily use.

Keywords: STM32, embedded, smartwatches, sensors, communication protocols.

1. Introduction

A new generation of small, powerful, and effective computing devices, such as smart wearables, also known as smart wearable technology or wearable devices, which offer the ability to access data anywhere, anytime, and are being hailed as the next generation of ubiquitous technology after smartphones, has emerged thanks to advancements in electronics, especially microprocessors[1]. For the continued development and use of testing devices like smartwatches, good accuracy is a crucial guarantee[2]. Traditional smartwatches have low measurement accuracy and are unable to make judgements on a wide range of environmental factors.

The smartwatch designed in this thesis is a device for users to make accurate measurements of their biometric characteristics in everyday life. MAX30102, DS18B20, MPU6050 and other sensors are compiled in code based on the MBED development environment. After using the serial output Terminal to observe whether the measured parameters are accurate, the measurement is correct, the schematic is drawn using Altium Designer 17 (AD17) software, the schematic is encapsulated and imported into Printed Circuit Board (PCB), and the wireless module is used to simplify it and complete the design of the smartwatch.

The main significance of this thesis research is to design an embedded system for the user that provides accurate measurements of the user's biometric characteristics and provides a health assessment for the users.

2. Methodology

As shown in figure 1, the smartwatch designed in this thesis applies the microcontroller STMicroelectronics NUCLEO-L476RG (stm32l476rg) with several sensors to measure biometric features, including MAX30102, DS18B20, MPU6050, HC-05, Buzzer. Organic Light-Emitting Diode (OLED), Global Positioning System (GPS), the smartwatch pre-work for the sensor development environment for the MBED software, select the MBED library to compile the sensor driver code, the test period using Terminal output serial debugging, for each After observing the measured values of each sensor to ensure they are correct, the driver code is integrated in the MBED software and downloaded to the microcontroller stm32l476rg via ST-LINK to achieve the sensor driver porting, the schematic of the sensor and the PCB of the smartwatch are completed with the AD17 software to achieve the design of the smartwatch in the end.

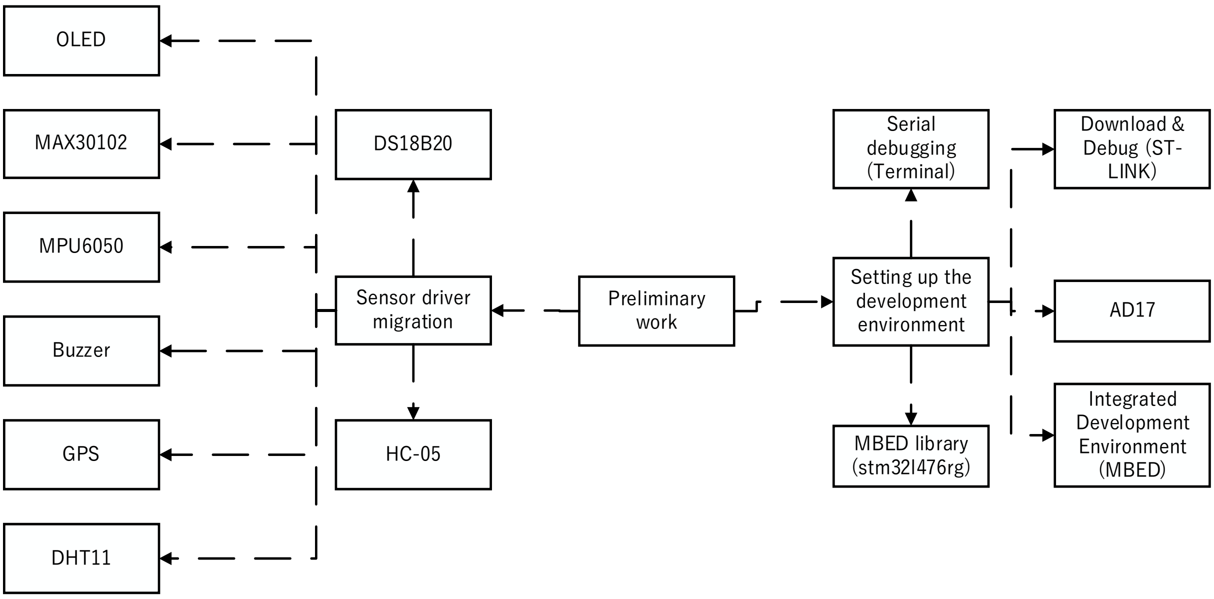

Figure 1. Smartwatch pre-build.

2.1. Hardware design

As shown in Figure 2, the measurement system of the smartwatch is divided into heart rate and blood oxygen collection system, ambient temperature, humidity and skin temperature collection system, acceleration and step collection system, latitude, longitude and time collection system, display system and warning system. Depending on the set number of systems, the heart rate and oxygen collection system is the MAX30102, the ambient and skin temperature collection system is the DS18B20 and DHT11, the acceleration and time collection system is the MPU6050, the latitude, longitude and time collection system is the GPS, the display system is the HC-05 The above measurement parameters can be displayed on the OLED and the HC-05 Bluetooth tuner to provide the user with accurate body values.

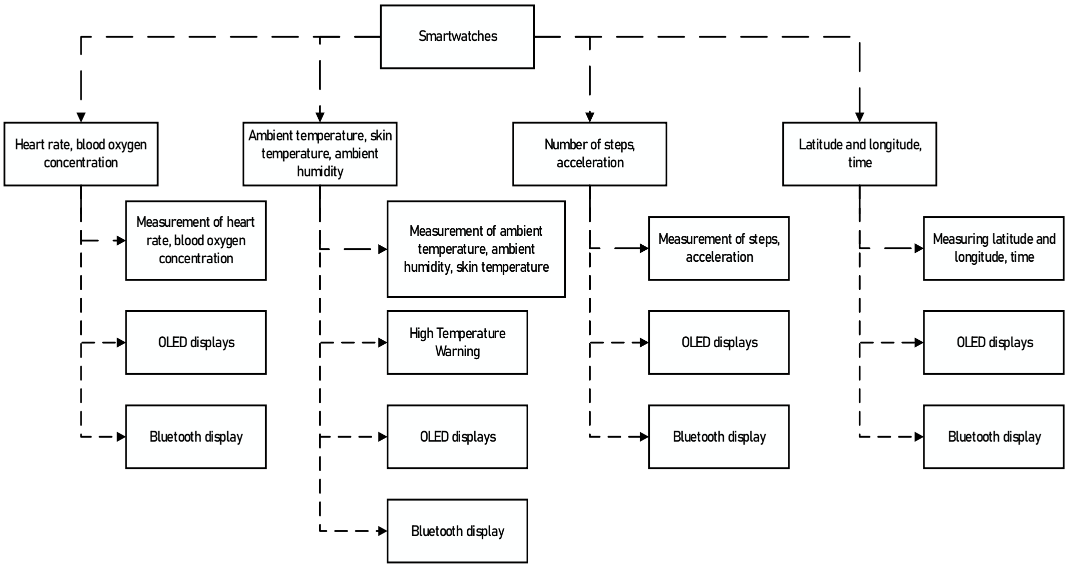

Figure 2. Smartwatch measurement function classification.

2.1.1. Sensor design. (1)MAX30102: As shown in Figure 3(a), the MAX30102 is a high-sensitivity blood oxygen and heart rate biosensor that has an operating temperature range of minus 40 degrees Celsius to plus 55 degrees Celsius. It has internal LEDs, photodetectors, optics, and low-noise electronics for suppressing ambient light, a single 1.8-volt power supply, an internal LED power supply at 5.0 volts, and an Inter-Integrated Circuit (IIC) interface operation for communication protocol standards[3]. The principle of operation is the non-invasive detection of physiological parameters such as blood oxygen saturation and heart rate through infrared light and infrared light reflection.

(2)DS18B20: As shown in Figure 3(b), the DS18B20 has a voltage operating range of 3 to 5.5 volts and a temperature measuring range of -55 to +125 degrees Celsius. It has four temperature sensing resolutions that can be internally programmed: 9, 10, 11, or 12 bits, with an accuracy of up to 0.0625 degrees Celsius[4]. The data is output in binary form for easy handling and storage.

(3)MPU6050: As shown in Figure 3(c), the MPU6050 contains a 3-axis gyroscope and 3-axis accelerometer that are internally integrated. They are coupled to the STM32L476RG via an IIC interface with programmable control, which removes the sensitivity between the acceleration axis and the gyroscope and lowers setup effects and sensor drift[5]. Using digital signal processing technology, the MPU6050 can measure parameters such as tilt angle, angular velocity and acceleration of objects in space, and has a temperature compensation function to improve data accuracy and stability.

(4)Active Buzzer: As shown in Figure 3(d), the active buzzer is an active buzzer with an integrated internal oscillation circuit and driver that generates sound by inputting a specific voltage signal on, only a digital Pulse Width Modulation (PWM) signal is required to control the sound generation, and the frequency of the buzzer generation can be changed by adjusting the input frequency.

(5)Organic Light-Emitting Diode: As shown in Figure 3(e), OLED is a new display technology that uses organic materials as the light emitting material and emits light under the action of an electric field. With higher contrast and more vibrant colours, a larger viewing angle range, no problems such as colour inversion and the ability to turn off unwanted pixels in black scenes, thus saving energy, it is an environmentally sustainable display technology.

(6)DHT11: As shown in Figure 3(f), the DHT11 is a low cost digital temperature and humidity sensor that requires only one digital I/O port for measurement when in use, with an operating voltage of 3 to 5 volts and an operating temperature range of 0 to 50 degrees C. The DHT11 has an output data accuracy of 1% C and 1% RH and a fast response time. The DHT11 works by using a built-in capacitive sensor to detect the ambient relative humidity and uses a thermistor to detect the ambient temperature. The sensor converts the ambient temperature and humidity collected in real time into a digital signal and outputs it via the IIC protocol.

(7)HC-05: As shown in Figure 3(g), the HC-05 is a Bluetooth serial module that enables serial data and wireless Bluetooth communication, usually consisting of a master control chip, Bluetooth baseband chip, RF front-end transceiver and related circuitry, eliminating the need to use traditional serial cables for data transmission and enabling data communication between devices that move relatively close to each other freely, the HC-05 Bluetooth sensor supports a maximum serial bit rate of 230400bps, which can provide higher communication speeds, and uses a standard serial communication protocol, the HC-05 sensor is well compatible with various serial devices.

(8)Global Positioning System(h): As shown in Figure 3, GPS is a sensor that uses satellite positioning technology to obtain location information, it can determine the user's precise location on earth by receiving signals sent by the global satellite navigation system, including longitude, latitude, etc. The GPS sensor mainly consists of a receiving antenna, a receiver and a processor. The receiver calculates the position based on the signals received, while the processor processes and analyses the data received and outputs the final positioning results. GPS sensors can achieve accurate position information measurement, and their positioning accuracy is usually between a few metres and ten metres, and GPS sensors are compact, lightweight and have simple circuitry, making them easy to integrate and use in a variety of applications.

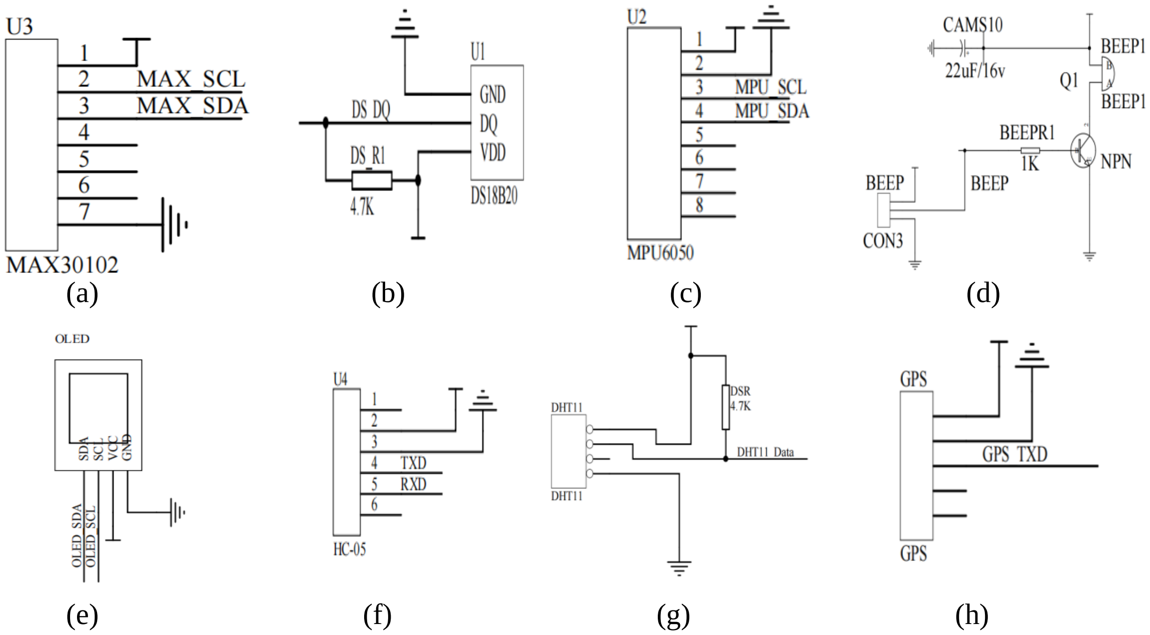

Figure 3. Sensor Collection, (a)MAX30102 sensors, (b)DS18B20 sensors, (c)MPU6050 sensors, (d)Buzzer sensors, (e)OLED sensors. (f)HC-05 sensors, (g)DHT11 sensors, (h)GPS sensors.

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2.1.2. Printed circuit board layout. As shown in Figure 4, signal integrity, current drive, heat dissipation, solderability, etcetera. should all be taken into account during the PCB project's design[6]. In the component layout section, the Arduino plugs and plugs, the spacing between the plugs and components is fixed, the spacing between the two groups of Arduino plugs on the left is 200mile, the spacing between the two groups of Arduino plugs on the right is 160mile, the spacing between the plugs on the left and right is 1900mile, the spacing between the pads between the Arduino plugs is In the wiring project, the power and earth wires are 40mile wide and the signal wires are all 20mile wide, with no overlap between wires and no overlap between wires and sensors. The layout of components should pay attention to the sensors used to measure the user's body parameters are placed on the outside of the PCB to facilitate the user's measurement, and the OLEDs are placed in the middle of the PCB to facilitate the user's observation of the data, so as to reasonably arrange the location of the sensors and save layout area and cost.

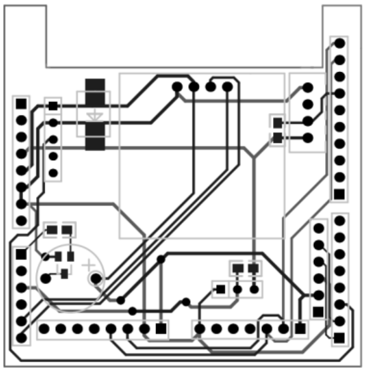

Figure 4. PCB layout.

2.2. Communication protocols

(1)1-wire: As shown in figure 5, the 1-wire single bus offers the advantages of simple structure, low cost, easy bus expansion and maintenance, bidirectional data transmission, and the use of a single signal line for both clock and data transfer. The 1-wire bus is primarily utilised in single-host systems that can operate one or more slave devices. The host can be a microcontroller, while the slave could be a 1-wire The data between them is delivered and received just through a control line, and the slave may be a 1-wire device while the host may be a microcontroller[7]. By using a single data pin and a ground pin for communication, the protocol can provide a unique address code to each device and supports multiple devices sharing the same bus, with each device having a unique address when multiple 1-wire devices are linked on the same bus.

(2)Inter-Integrated Circuit: As shown in figure 5, the clock signal (SCL) and the serial data (SDL), which are the two signal lines that make up the IIC bus, convey the respective signals in opposite directions[8]. IIC communication involves a master device and a slave device. The master device initiates a transmission process and controls the timing, while the slave device receives commands from the master device and answers the data sent by the master device. The master device sends commands to the slave device, which include the address of the data to be read or written, the address of the register, etc. The slave device responds to the command in the correct manner and sends the data or status information to the master device.

(3)Pulse Width Modulation: As shown in figure 5, the PWM communication protocol is a variable pulse width regulation technology that can be used to control the load in a circuit by varying the width and period of the pulse to achieve regulation of the output signal. PWM communication protocols can be used to control a variety of peripherals and circuit systems. When using PWM, parameters such as the period and duty cycle of the PWM signal need to be determined and controlled and regulated accordingly according to specific needs to achieve different output effects.

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(4)Universal Asynchronous Receiver/Transmitter: As shown in Figure 5, universal Asynchronous Receiver /Transmitter (UART) is a common serial communication protocol used to transfer data between a computer and an external device. The same way as microcontrollers, memory, and CPUs send data, UART serial communication does the same thing by using two unidirectional lines[9]. One is used to send data and the other to receive data. The UART is capable of supporting different baud rates to quickly transmit large amounts of data in a short period of time. When using the UART serial communication, the transmitted data needs to be compiled and decoded, and the compiled data is transmitted to the receiver via the TX pin, and after the receiver receives the data, the data is decoded via the RX pin and processed accordingly.

(5)General Purpose I/O: As shown in Figure 5, the connection and communication with external devices is achieved by configuring the General Purpose I/O (GPIO) into input or output mode and setting the corresponding level states.GPIOs typically comprise of pins, pinouts, and other components, and each GPIO pin is assigned a specific number. The pins' arrangement is quite versatile; they can be used either as input or output pins separately, and their status is adjustable[10]. GPIOs rely on configuration and review status in hardware to connect and communicate with external devices, ensuring that GPIO parameters such as voltage, current, etc. are available. to ensure the stability of the communication.

(6)National Marine Electronics Association: As shown in Figure 5, the National Marine Electronics Association (NMEA) communication protocol is a standard protocol for marine navigation and GPS positioning applications, which defines the data format and syntax for transmitting GPS positioning information and other marine electronics, commonly used in serial communications. The most common are the Generalised Gradient Approximation (GGA) and Router manager centre (RMC) data types, where GGA is the GPS position data used to describe information such as position, time and horizontal altitude, and RMC is the recommended best path data used to determine information such as speed and direction when When using the NMEA protocol, it is necessary to follow the data format and syntax rules defined by it, and to implement the corresponding procedures to parse, process and transform the received data in order to obtain useful information for the development of relevant applications.

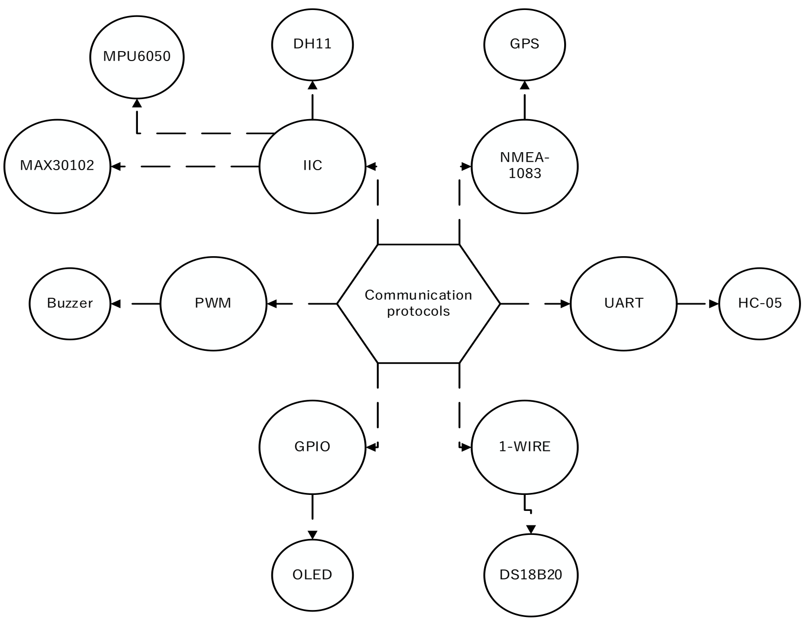

Figure 5. Classification of communications protocols.

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3. Function display

3.1. Measurement

As shown in Figure 6, after the smartwatch is reset, the OLED screen displays heart rate, temperature, steps, latitude and longitude, etc. In order to obtain accurate measurements, the user needs to press his finger on the sensor MAX30102 and wait a few moments. The smartwatch will restart when the black button on the stm32l479rg microcontroller is pressed, the measurement data on the OLED screen will be cleared, the measurement data will be re-measured, the measurement data will be re-obtained, the HC-05 sensor will work normally when the reset is carried out, the smartwatch will not be disconnected from the Bluetooth, the Bluetooth data will not be cleared, the Bluetooth debugger will stop, the user will re-measure and the Bluetooth will continue to appear. After the measurement, the Bluetooth will continue to appear with the corresponding data.

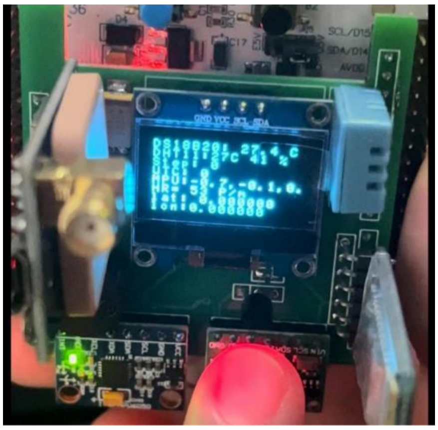

Figure 6. Smartwatch physical demonstration.

3.2. Bluetooth

As shown in Figure 7, the Bluetooth function of the smartwatch enables the transfer of the measured values to the user's mobile phone via the Bluetooth function of the sensor HC-05, recording and observing the user's physical characteristics at every moment. To use this function it is necessary to download the software called Bluetooth debugger in the mobile phone, which matches the Bluetooth name of the smartwatch HC-05 in the Bluetooth debugger. The user can adjust the Bluetooth transmission time according to his personal needs and the Bluetooth debugger can adjust the data reception, merging and interval, in order to protect the data from garbled reception in batches.

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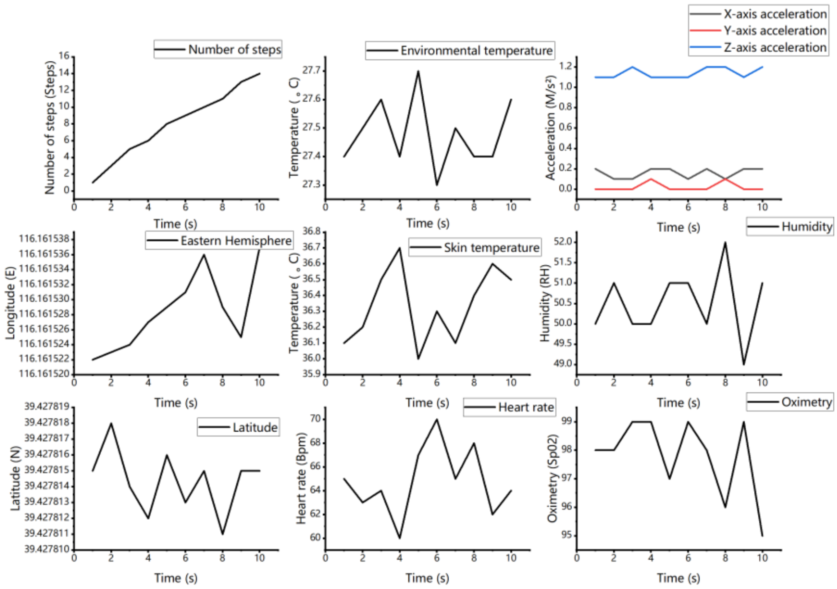

Figure 7. HC-05 transmission data form.

4. Conclusion

This thesis focuses on the design of a smartwatch based on the stm32l476rg microcontroller to measure various body parameters of the human body. The testing of the data shows that the smartwatch designed in this project is highly efficient, accurate and stable in monitoring the body parameters of the user. The smartwatch project still has many areas of optimisation. The construction of the watch is not reasonable, it is not realistic to wear, the OLED display is not aesthetically pleasing, there is no detailed division of functions, the logic of the warning function is not perfect, the GPS reception signal takes too long and many other issues need to be improved. Future research in this project will focus on noise removal in order to reduce the impact of interference and noise. Where possible, multiple users' body values will be analysed, rather than limiting the analysis to one user, and greater efforts will be made to build predictive models to safeguard the health of users.

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