

# Custom fitness bracelet design

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**Abstract** — This article investigates wireless communication technologies and the theoretical analysis of step measurement in the design of smart wearables. It examines various wireless technologies, including WiFi, Bluetooth, NFC, RFID, mobile networks, and satellite communication. The importance of measuring steps using accelerometers and gyroscopes is emphasized, underscoring the necessity of integrating these sensors for accurate motion tracking. The solution analysis section evaluates critical metrics for activity trackers, detailing both software and hardware requirements. The hardware design focuses on development boards, heart rate sensors, and accelerometers, with 3D printing identified as the preferred method for case design. The article concludes by summarizing the design approach for a user-friendly activity tracker tailored to user needs.

**Keywords** — ESP32, Fitness bracelet, Sensors

## I. INTRODUCTION

As the demand for smart wearable devices continues to rise, their design and implementation require a comprehensive understanding of wireless communication technologies and measurement techniques. This article aims to provide insights into the theoretical aspects of wireless communication and step tracking, offering a solution analysis for developing an efficient and user-friendly smart wearable. The focus is on selecting appropriate components, including development boards, sensors, and batteries, and designing a suitable case using 3D printing technology.

## II. WIRELESS COMMUNICATION TECHNOLOGIES

New chapters have been added as part of the theoretical analysis, including an in-depth exploration of wireless communication.

Wireless communication is a technology that enables data transmission between devices without the need for physical connections such as cables or other physical media. Various wireless communication technologies are globally utilized for different purposes. Here, we explore some of the most prevalent wireless communication technologies in use today:

WiFi is a technology that facilitates internet or local network connectivity. It allows devices to connect wirelessly, providing high-speed data transfer and enabling seamless access to the internet.

Bluetooth is a short-range communication technology designed for interactions between devices in close proximity. Widely used for tasks such as file sharing, audio streaming, and connecting peripherals, Bluetooth has become integral in the realm of wireless connectivity.

NFC (Near Field Communication) is a short-range communication technology that operates over very small distances. Primarily used for contactless transactions and data exchange between compatible devices, NFC finds applications in payment systems and data sharing.

RFID (Radio-Frequency Identification) utilizes radio waves for the identification of objects. This technology is employed for tracking and managing inventory, enabling efficient identification and monitoring of items equipped with RFID tags.

Mobile Networks technologies such as 3G, 4G, and 5G provide wireless access to the internet and facilitate communication between smartphones. These networks support high-speed data transfer, enabling a broad range of applications, including video streaming and online gaming.

Satellite communication involves the transmission of data between devices and satellites orbiting in space. Offering global coverage, satellite communication ensures connectivity in remote areas and plays a crucial role in various industries, including telecommunications and navigation .

### III. MEASURING NUMBER OF STEPS

Another chapter added as part of the theoretical analysis covers the measurement of steps. An accelerometer measures linear acceleration, allowing the detection of movements along individual axes (x, y, z). During walking, regular acceleration and deceleration patterns can be detected using the accelerometer. Step tracking algorithms analyze changes in linear acceleration to identify characteristic patterns corresponding to individual steps.

A gyroscope measures angular velocity, representing rotation or movement around a specific axis. During walking, the rotation of the arm can be detected using the gyroscope. The gyroscope is used to estimate the angular motion of the arm, providing information about the direction of the step. Combining both sensors allows for more precise motion tracking. The accelerometer is effective for monitoring linear movements, while the gyroscope helps detect rotation and angular changes. Calibration and data filtering from both sensors are crucial for achieving accurate results.

### IV. SOLUTION ANALYSIS – FUNCTIONALITIES REQUIREMENTS

Activity trackers capture various metrics, with some being more practical than others. Essential metrics like heart rate and calorie tracking are vital, while additional metrics such as blood oxygen levels and sleep tracking offer valuable insights.

Essential Metrics:

- Heart Rate Monitoring: crucial for assessing activity intensity and fitness levels, aiding in personalized training plans.
- Calorie Tracking: essential for weight management and fitness goals, guiding calorie intake and expenditure.
- Time Tracking: basic yet universal, serving various purposes in daily activities and exercises.

Additional Metrics:

- Blood Oxygen Level (SpO<sub>2</sub>) Monitoring: useful for endurance enthusiasts, providing insights into overall physiological well-being.
- Distance/Step Tracking: key for monitoring progress, setting goals, and optimizing training plans, especially for runners and cyclists.
- Sleep Quality Monitoring: vital for health and performance, helping users understand sleep patterns and improve sleep quality.

### V. SOLUTION ANALYSIS – SOFTWARE AND HARDWARE REQUIREMENTS

The software interface processes requests from the tracker, featuring user-friendly functionalities like data logging, graphical representation, goal-setting, and alerts.

Mandatory Software Requirements:

- Wireless communication
- Data storage
- Graphical representation

Additional Software Requirements:

- User-friendly design
- Customization options

The microcontroller manages sensors, optimizing communication stability, addressing errors, and minimizing energy consumption.

**Mandatory Hardware Requirements:**

- Wireless communication
- Sensor data recording
- Communication optimization

**Additional Hardware Requirements:**

- Energy-efficient programming
- Code optimization

Careful component selection is crucial. The development board should support Bluetooth and WiFi, sensors should be energy-efficient, and the battery should offer long life.

**Mandatory Component Requirements:**

- Suitable components
- Battery protection
- Rechargeable battery

**Additional Component Requirements:**

- Visual display
- Long battery life
- Compact casing
- Power-saving mode

In conclusion, thorough analysis ensures a user-friendly activity tracker system, aligning components and functionalities with user needs for a seamless tracking experience.

## VI. DESIGN OF HARDWARE PART SOLUTION

Choosing the right components is crucial for achieving functionality and performance while meeting project specifications. Efficient component selection significantly impacts energy consumption, especially in battery-powered or energy-efficient systems. Size, weight, and cost considerations play essential roles in creating compact, lightweight, and affordable devices. Balancing quality and price is vital during the design phase.

Development boards cater to specific functionalities, with some designed for IoT, sensors, or embedded systems. Selecting a board tailored to the device's purpose simplifies development and enhances performance. Crucial requirements include support for wireless communication, GPIO pins, and necessary interfaces.

As wireless communication is vital, choosing a development board with built-in support, like the ESP32 series, is recommended. The LilyGO TTGO T-Display, powered by ESP32, exemplifies a compact and feature-rich board for small smart devices. With WiFi, Bluetooth, and a color TFT display, it meets diverse requirements, including visual output. Its USB-C port facilitates programming, and the board supports battery charging, making it suitable for wearable applications.

In summary, the LilyGO TTGO T-Display showcases an ideal development board, meeting hardware requirements and tailored for wearable smart devices.

Heart rate sensors come in various types, with PPG sensors being popular for wearables. MAX30102 and MAX30105 are common choices for heart rate monitoring projects. The MAX30105, with an integrated 4-channel LED driver and 18-bit ADC, provides precise measurements at a higher cost (around €15). In contrast, the MAX30102 offers a more economical option, priced at approximately €4. It's designed for pulse and oxygen saturation (SpO<sub>2</sub>) measurements, utilizing infrared and red LED sources. Communication with the microprocessor occurs through I2C, and the sensor boasts low power consumption (max 1.2 mA) and compact dimensions. Widely used in healthcare applications like fitness trackers and smartwatches, the MAX30102 provides an affordable yet effective solution for heart rate monitoring.

For step counting, the ADXL series by Analog Devices offers versatile choices. The ADXL335, a three-axis accelerometer, stands out with adjustable measurement ranges, catering to a broad acceleration spectrum. Operating at 1.8 V to 3.6 V, it provides analog outputs for each axis, ideal for

interfacing with microcontrollers. Its low power consumption makes it suitable for portable devices. While other sensors combine accelerometer and gyroscope functionalities, the ADXL335 is a costlier but more accurate choice, avoiding conflicts with the limited I2C pins on the development board.

Choosing the right battery for a smart wearable involves critical factors for optimal performance. Battery capacity (mAh) reflects energy storage, crucial for extended use. Balancing size, weight, and capacity is essential in space-constrained wearables. Li-ion and Li-pol batteries are preferred for their high energy density and low weight.

Estimating total current for active sensors and display involves summing ESP32, MAX30102, and ADXL335 current consumptions: Total Current = 61.55mA. Consideration of the largest component (TTGO board) dimensions (51.49x25.09mm) guides battery size. A Li-Poly 502050 model (5x20x50mm, 500mAh) aligns well, providing an estimated 8.13 hours of battery life.

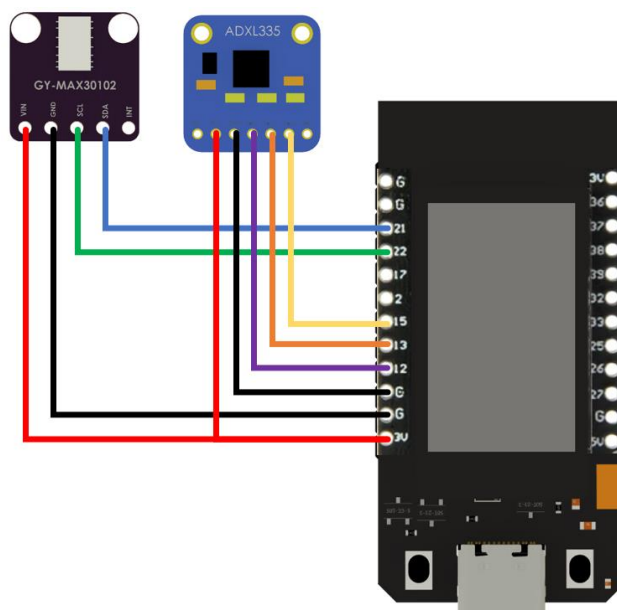


Fig. 1 Connection of sensors

## VII. CASE DESIGN

When creating a case for a wearable device, consider factors such as fit, protection, and aesthetics. Ensure the case fits precisely for proper protection and decide on its thickness based on the desired level of defense. Choose materials like silicone, plastic, or leather for durability against scratches and impacts. The case should provide easy access to controls and connectors, with well-designed openings for charging and button access. For prototypes, opt for a case that can be easily disassembled and reassembled.

After studying manufacturing technologies, 3D printing emerges as the optimal choice for cost-effective prototyping, providing skin-friendly plastics. Considering the intricate case design, 3D printing is preferred over CNC machining. An ideal filament for printing could be PETG, combining PLA and ABS benefits. Alternatively, TPU, commonly used in watch straps, could be suitable, though not all 3D printers support TPU printing.

The final Fusion 360 model consists of four parts connected through a bus and secured with screws. Straps, made of textile or leather, will be added separately. The case is designed to accommodate all chosen components – development board, battery, heart rate/oximeter sensor, and accelerometer. It includes tailored openings for wiring and a dedicated cover to isolate the battery. The case dimensions are 22.45x56.29x29.89mm.

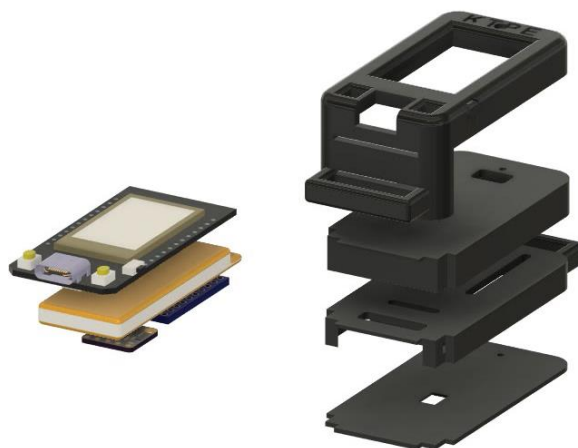


Fig. 2 Case model

### VIII. CONCLUSION

In conclusion, the design and development of a smart wearable device involve careful consideration of wireless communication technologies, motion tracking methods, and component selection. The integration of WiFi, Bluetooth, NFC, and other communication technologies ensures seamless connectivity, while accelerometers and gyroscopes play a crucial role in measuring the number of steps accurately. The solution analysis highlights essential and additional metrics that enhance the functionality of activity trackers. The hardware and software requirements, along with the choice of suitable components, contribute to the overall success of the project. The case design, utilizing 3D printing for prototyping, emphasizes the importance of a user-friendly and protective enclosure. The LilyGO TTGO T-Display development board, MAX30102 heart rate sensor, and ADXL335 accelerometer emerge as optimal choices for a compact and efficient smart wearable. This comprehensive approach ensures a well-rounded solution for individuals seeking a reliable and feature-rich activity tracker.

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