

UroBuddy: Enhancing Dignity And Comfort For Bedridden Geriatric Patients Through Smart Diaper Technology

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ABSTRACT: Many older people suffer from urinary incontinence, a prevalent illness that causes both physical and emotional anguish. To give caretakers real-time notifications, we created "UroBuddy," a clever, non-invasive moisture monitoring technology built inside diapers. An ESP32 microcontroller and a moisture sensor based on copper tape are part of the hardware, and the system uses Firebase Cloud Messaging to sync data with a mobile app. When moisture levels are above 50%, family members and caregivers are notified so that prompt action can be taken. The gadget is inexpensive, reusable, and simple to attach with magnets. The companion Flutter app facilitates user interactions and the logging of health data. This method uses useful, reasonably priced technology to address issues in elder care.

KEYWORDS: Biomedical and Health Sciences, Geriatric Monitoring, Smart Diapers, Moisture Detection, Real-Time Alerts.

■ Introduction

Although aging is a normal part of life, many older people find it extremely difficult to perform even basic tasks, particularly if they are bedridden or have long-term conditions like Parkinson's disease. Urinary incontinence, which affects more than 50% of residents in long-term care facilities worldwide, is one such problem.¹⁻⁵ In addition to discomfort and health hazards such as skin and urinary tract infections, it has a significant emotional cost. It frequently results in feelings of shame, worry, and diminished self-worth.

Urinary incontinence (UI), particularly in immobile elderly people, is a social and emotional problem in addition to a medical one.⁴ Between 2015 and 2050, the proportion of the world's population over 60 years will nearly double from 12% to 22%.⁵ Many bladder health management applications and devices are too clinical or require manual data entry, making them inconvenient for older adults to use.⁶ This study presents UroBuddy, a smart diaper system that combines mobile notifications and real-time sensing to provide effective and respectful senior care. The device is compact and easy to use, with copper conductive tape for improved moisture detection coverage and magnets for a smooth connection. The system is enhanced with a mobile app built with Flutter that provides family members and caregivers with specific interfaces, as shown in Figure 5. The software includes a history tab that allows caregivers to track moisture and pH levels over time. For pH monitoring, a litmus paper is used, and the caregiver simply observes the colour change and manually enters the pH value into the app. A built-in chat feature facilitates communication between caregivers and family members, ensuring coordinated care.

For dependable notification delivery, real-time synchronization, and safe data storage, Firebase Realtime Database and Firebase Cloud Messaging (FCM) are used. At a 50% saturation threshold, experimental results show reliable and accurate detection. The system is an economical and efficient way to

care for the elderly because it is reusable after cleaning and costs less than ₹2000.

■ Methods

Hardware Components:

The UroBuddy project's hardware device is based on a small, effective electronic setup intended for incontinence monitoring in real time. The central processing unit is an ESP32 microcontroller, which was chosen for its tiny size, low power consumption, and integrated Bluetooth and Wi-Fi. It receives information from a moisture sensor that uses conductivity changes to detect wetness and is based on flexible copper tape. After using the diaper, the device can be easily removed and reused. However, the copper tape acts as a one-time sensor layer and should be replaced with a fresh strip for the next use. When moisture reaches a predetermined threshold, the signal is conditioned using an LM393 comparator to provide a dependable digital output.

Power is supplied by a 3.7V, 850mAh Li-ion rechargeable battery, managed by a TP4056 charging and protection module, which allows safe recharging and extended usage of up to six hours per charge. And the battery required around 50 minutes to charge fully. To ensure convenience and portability, the entire circuitry is housed in a 3D-printed enclosure with openings for charging, a power switch, and a slot for a small 0.91-inch OLED display that shows real-time readings, as shown in Figures 2 and 3.

For ease of integration with diapers, the system incorporates neodymium magnets that allow the enclosure to be attached and detached outside the diaper without causing discomfort or exposure of the electronics to moisture. The lightweight and skin-safe enclosure ensures comfort for prolonged use, while smooth edges prevent irritation.

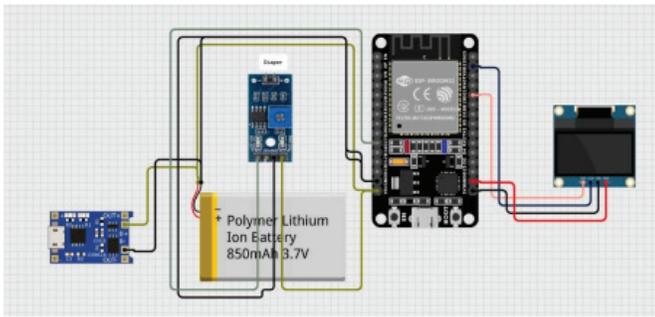


Figure 1: Circuit Diagram.

- **ESP32 Microcontroller:** Wi-Fi enabled for real-time data transmission.
- **Moisture Sensor:** Built with copper conductive tape and LM393 comparator.
- **OLED Display:** A 0.91" screen connected via I2C interface.

This sensor is composed of parallel copper strips that are secured within the diaper to function as electrodes. The other side is connected to LM393. When liquid penetrates the diaper, the resistance between these strips diminishes, resulting in a change in the sensor's output. UroBuddy system operates at a 3.3V logic level and draws minimal current (typically below 150 mA), which poses no risk of electric shock or discomfort to the user. All conductive parts are fully enclosed within the casing, and the diaper-integrated copper strips carry only low-signal sensing current (<1 mA).

To process this signal, the sensor was connected to an LM393 comparator module, which transformed the variable resistance into a clear analog voltage signal that the ESP32 can interpret.^{6,7} The LM393 facilitated threshold adjustments through an on-board potentiometer,⁷ enhancing the stability of the readings and minimizing noise compared to relying solely on raw copper tape, as shown in Figure 1.

Experimental Setup:

- Fluids tested: water and honey at volumes of 50 ml and 100 ml.
- Procedure: Each liquid was introduced into the diaper, and the sensor's response was documented in both analog (percentage moisture) and digital (wet/dry threshold crossing) formats.

Moisture Calculation:

The analog output from the LM393 module (spanning from 0–3.3V) was sampled by the ADC of the ESP32.⁷ A dry baseline (0%) and a fully saturated reference (100%) were established. The percentage moisture was computed using:

$$\text{Moisture \%} = ((\text{Sensor Value} - \text{Dry Value}) / (\text{Wet Value} - \text{Dry Value})) \times 100$$

The estimated moisture content in ml was then calculated as:

$$\text{Moisture Content (ml)} = (\text{Moisture \%} / 100) \times \text{Fluid Volume (ml)}^{11}$$

Table 1: Moisture content calculation across fluids.

| Sample | Volume (ml) | Moisture (%) | Moisture Content (ml) |
|--------|-------------|--------------|-----------------------|
| Water | 50 | 63 | 31.5 |
| Water | 100 | 70 | 70 |
| Honey | 50 | 5 | 2.5 |
| Honey | 100 | 6 | 6 |

Tests were carried out throughout the UroBuddy project's experimental phase to assess the moisture sensing system's accuracy and reactivity in various scenarios. To test the ESP32 microcontroller's sensitivity and dependability, the moisture sensor was subjected to a range of fluid types and quantities. Parameters, including the fluid type, sample volume in millilitres (ml), system-detected moisture percentage, and associated computed moisture content, are all listed in Table 1. The ability of the copper tape-based sensor to discriminate between pertinent fluids—such as urine, which has a conductivity similar to that of water—and irrelevant ones—such as thicker, low-conductivity liquids—was validated with the aid of this structured data in Table 1.

With 100 ml of water yielding a near-saturation value of 70%, the findings in the table amply illustrated the sensor's strong sensitivity to conductive liquids like water, where bigger volumes correlated with higher moisture percentages. Conversely, even at higher volumes, viscous and less conductive materials like honey showed extremely low moisture percentages (5–6%). This demonstrates how the technology can prevent false alarms from non-urinary fluids, guaranteeing precise incontinence detection. As a result, the experimental Table 1 confirms the sensor's appropriateness for actual aged care applications in addition to highlighting its accuracy.

The device has not yet been tested on human subjects. All evaluations were conducted in a controlled environment under normal conditions. The testing process involved manually applying measured amounts of water and honey onto the diaper to observe the sensor's response and verify the device's functionality.

Data Transmission:

The ESP32 transmitted the processed values to Firebase,⁸ and the UroBuddy Flutter app provided real-time alerts when the moisture surpassed the designated threshold ($\geq 50\%$) as shown in Figure 4. This mechanism ensured prompt notifications for caregivers while differentiating between various fluid types.

CAD Design:

The system housing is modelled in SolidWorks, featuring a 0.91-inch OLED display in a rectangular slot that lets developers or caregivers see the device's moisture information. The device enclosure was 3D printed using PLA (Polylactic Acid) material, which is biocompatible, non-toxic, and skin-safe. Additionally, it has specific apertures for programming and charging, making it simple to access the ESP32. The shell included a push-on power button that allowed for easy on/off.

The enclosure's measurements were roughly 55 mm × 40 mm × 30 mm. The design of UroBuddy prioritizes comfort and ergonomics. The sensor strip is flexible and thin, seamlessly integrating into the diaper lining without adding noticeable bulk. And the device position is easily adjustable using magnets, so that it won't affect sleep.



Figure 3: CAD design.



Figure 4: Compact design for user comfort.

Mobile Application (Flutter):



Figure 4: Real-time alerts.



Figure 5: Logging features for pH and moisture.

Results and Discussion

When the moisture level rises beyond 50%, the ESP32 uses Firebase Functions to start a real-time notification, as shown in Figure 4. These serverless features provide the basis for communication without the need for a dedicated backend server, ensuring automated and seamless alert delivery. Authentication tokens, which Firebase Functions manage, verify, and authorize each request, guaranteeing secure and reliable access. Additionally, unique device tokens are maintained under the unique patient ID, allowing notifications to be sent to the right family member or caregiver. This systematic strategy ensures timely alarms, secure data handling, and personalized communication for effective senior care management.

Notifications were sent within 10–15 seconds of moisture detection. Firebase synchronization updated app data within 5–10 seconds. While the UroBuddy system proved effective, certain limitations were identified during testing. The durability of the copper tape-based sensor may be reduced over extended use or repeated washing, potentially affecting long-term reliability. Additionally, the system is susceptible to occasional false alerts triggered by factors such as sweat, high humidity, or accidental spills of water, which can mimic urinary moisture. Another limitation is its dependency on Wi-Fi

connectivity, as the current version does not support offline operation or Bluetooth Low Energy (BLE), restricting its usability in areas with poor internet access.

Conclusion

The UroBuddy project successfully demonstrated that an affordable, reusable smart diaper system can enhance dignity, hygiene, and comfort for bedridden geriatric patients while easing the burden on caregivers. By integrating a copper tape moisture sensor with an ESP32 microcontroller and a Flutter mobile app, the system reliably provided real-time alerts and data logging. UroBuddy addressed the project's original aim of creating a low-cost, user-friendly, reusable system that improves quality of life for patients and simplifies caregiving. Beyond its technical achievements, it highlights how empathetic, user-centered design can transform eldercare. Future work should involve direct caregiver and patient trials and improved sensor durability.

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References

- Pizzol, D.; Demurtas, J.; Celotto, S.; Maggi, S.; Smith, L.; Angiolielli, G.; Trott, M.; Yang, L.; Veronese, N. Urinary Incontinence and Quality of Life: A Systematic Review and Meta-Analysis. *Ageing Clin. Exp. Res.* **2021**, *33*(1), 25–35. <https://doi.org/10.1007/s40520-020-01712-y>.
- AlQuaiz, A. M.; Kazi, A.; Almuneef, M.; AlShehri, F.; AlKhamis, N.; Alenezi, A. Urinary Incontinence Affects the Quality of Life and Increases Psychological Distress and Low Self-Esteem. *Healthcare* **2023**, *11*(12), 1772. <https://doi.org/10.3390/healthcare11121772>.
- Jerez-Roig, J.; Santos, M. M.; Souza, D. L. B.; Lima, K. C.; et al. Prevalence of Urinary Incontinence and Associated Factors in Nursing Homes: A Multicentre Cross-Sectional Study. *BMC Geriatr.* **2024**, *24*, 169. <https://doi.org/10.1186/s12877-024-04748-1>.
- Javanmardifard, S.; Gheibzadeh, M.; Shirazi, F.; Zarea, K.; Ghodsbin, F. Psychosocial Experiences of Older Women in the Management of Urinary Incontinence: A Qualitative Study. *Front. Psychol.* **2022**, *13*, 785446. <https://doi.org/10.3389/fpsyg.2022.785446>.
- World Health Organization. Ageing and Health [Online]; WHO: Geneva, **2023** [accessed 2025-09-26]. Available from: <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health>.

6. Almeida, J.; de Souza, R.; Pereira, T.; et al. Wearable Sensor Technologies for Health Monitoring: A Review. *Sensors* **2023**, *23*, 1279158. Available from: <https://www.frontiersin.org/journals/sensors/articles/10.3389/fsens.2023.1279158/full>.
7. Hardianto, F.; Shofani, M. S.; Kusuma, H. H. Utilization of IP LM393 Sensor Module as an Automation System for a Portable Gallon Pump. *Phys. Educ. Res. J.* **2023**, *5*(2), 91–96. <https://doi.org/10.21580/perj.2023.5.2.11099>.
8. Camargo, M.; et al. ESP32 Communication System Connected to Google Firebase Realtime Database in Real-Time via LoRa. A Smart Real-Time Monitoring System for Upgrading Biogas and Biomethane, Figure 6, **2025**. <https://doi.org/10.13140/RG.2.2.35899.94243>.

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