GlucoGuard: Smart Wearable Patch for Diabetes Monitoring

Team Stalkfish
B.M.S College of Engineering, Bangalore

Sensor Hackathon Proposal

1. Team Details

- **Team Name:** Stalkfish
- **Track:** Pulse Track
- **Institution/Organization:** B.M.S College of Engineering, Bangalore
- **Team Members:**
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2. Project Title

GlucoGuard: A Smart Wearable Patch for Continuous Diabetes Monitoring

3. Target Application Area

Continuous, minimally-invasive glucose monitoring for diabetic patients to detect and alert on hypoglycemia (<70 mg) and hyperglycemia (>180 mg), with future plans for automated emergency drug delivery to prevent life-threatening complications.

4. Overview of Proposed Solution

Problem: Diabetes affects 77 million people in India, projected to exceed 100 million by 2030 (WHO, 2021), contributing to 1.5 million global deaths annually. Conventional finger-prick tests are invasive and lack continuous monitoring, while commercial CGMs (INR 50,000–1,00,000) are inaccessible to most.
Scenario: A diabetic student in a hostel experiences a sudden glucose drop overnight, unnoticed until symptoms escalate, risking severe outcomes.
Monitoring Goal: GlucoGuard is a low-cost (~INR 3750) wearable patch using a microneedle-based glucose sensor (target MARD <10 %), a MCP9808 temperature sensor for environmental compensation, and an ESP32 S3 microcontroller for real-time processing and BLE alerts. Future plans include a PDMS-based thin-film actuator for insulin/glucagon delivery, addressing emergency needs. This prototype empowers patients with affordable, continuous monitoring. (Word count: 165)

5. Sensors and Compute Board

Component Type	Parts	Cost(INR)	Purpose
Glucose Sensor	Microneedle-based	2000	Glucose measurement
Temperature Sensor	MCP9808 (±0.5 °C)	250	Temperature compensation
Microcontroller	ESP32 S3	1500	processing and communication

Future Components:

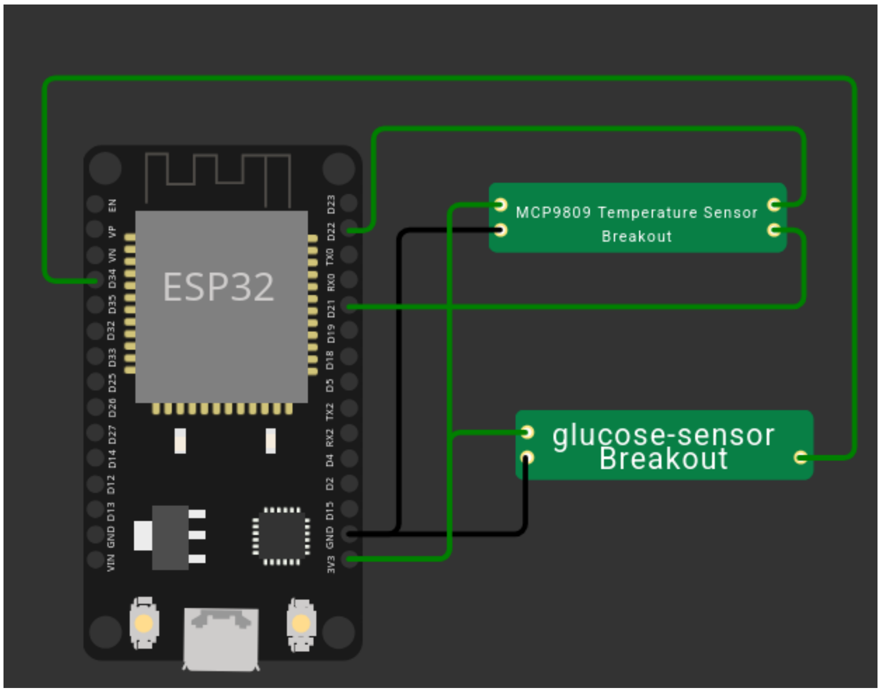
- Battery: Li-Po 3.7V, 1000mAh (INR 550) for 48-hour power.
- Charging Circuit: TP4056 (INR 200) for battery management.
- Accelerometer: MPU-6050 (INR 300) for motion detection.
- Enclosure: Biocompatible adhesive patch (INR 500) for wearability.
- Thin-Film Actuator: PDMS-based (TBD cost) for drug delivery.

6. Circuit Connection and Pinout Table

Sensor/Module	ESP32 S3 Pin	Function
Glucose Sensor OUT	IO34 (ADC1)	Analog signal (0 V–3.3 V)
MCP9808 SDA	IO21	I2C Data (4.7 kΩ pull-up)
MCP9808 SCL	IO22	I2C Clock (4.7 kΩ pull-up)
VCC (both sensors)	3V3	3.3 V power
GND (both sensors)	GND	Common ground

Textual Schematic: Glucose Sensor → IO34 (filtered with 10 kΩ, 100 nF); MCP9808 → I2C (IO21, IO22) with 4.7 kΩ pull-ups; ESP32 S3 powered via 3.3 V bench supply (future Li-Po/TP4056 integration); Enclosure → Future IP67-rated patch.

0.1 Circuit Diagram



7. Testing Plan (TRL-8 Readiness)

- **Accuracy:** Validate glucose sensor with solutions (50 mg per dL to 300mg per dL), targeting MARD <10 % (ISO 15197:2013).
- **Drift:** Test 24-hour stability for drift (<5 %).
- **Temperature Compensation:** Verify MCP9808 accuracy (±0.5 °C) under varying conditions.
- **BLE Transmission:** Test ESP32 S3 BLE with 99.9% packet delivery (manual logging for now).
- **Power Stability:** Ensure operation with bench power (future battery test).
- **Field Tests:** Trial with 5 non-diabetic volunteers for wearability.

8. Indian Sensor Substitution Plan

GlucoGuard's I2C and analog interfaces support Indian-made sensors. Current glucose sensor can be replaced with IIT Madras' GOx-coated prototypes, achieving MARDs of 10–12% in labs. The MCP9808 can be substituted with Indian alternatives (e.g., from CDAC or BEL) with similar I2C specs. Future collaborations with NemaCare and DiabetoCare will integrate local sensors, leveraging Make in India initiatives to reduce costs and enhance scalability.

9. Expected Output

- **Visualizations:** Real-time glucose trends via manual BLE data (future app integration).
- **Logs:** Paper-based logs with future secure cloud storage.
- **Alerts:** Manual BLE alerts (future SMS/vibration integration).

10. Declaration

We understand and agree to comply with cost constraints, TRL-8 goals, and sharing policies.

Signature:
N Nishchit

Additional Sections

Indian-Based CGM Development

India's CGM landscape is growing to address the 77 million diabetic population, where commercial devices (Dexcom, Abbott) cost INR 50,000–1,00,000. Indigenous efforts include:

- **Academic Research:** IIT Madras and IIT Bombay develop GOx-based electrochemical sensors, with MARDs of 10–12% and ongoing efforts to reach $<10\%$, supported by DBT funding.
- **Start-ups:** NemaCare and DiabetoCare prototype patch-based CGMs, targeting INR 5000–10,000, focusing on rural accessibility.
- **Industry:** Bharat Electronics Limited (BEL) and Semiconductor Laboratory (SCL) explore sensor manufacturing, aligning with Make in India.

GlucoGuard leverages these advancements, aiming for a INR 2000–3000 solution with local sensor integration.

Thin-Film Actuators for Drug Delivery

Thin-film actuators are a future innovation for wearable drug delivery in diabetes care:

- **Design:** A PDMS-based piezoelectric actuator (<0.5 mm thick) with micro-heaters will deform to release 50 µL of insulin/glucagon at $10\,\mu\mathrm{L\,min^{-1}}$.
- **Materials:** Biocompatible PDMS (FDA-approved) and gold electrodes; future use of Indian polymers (e.g., IIT Delhi research) is planned.
- **Control:** ESP32 S3 will use PWM signals to trigger actuation at glucose thresholds, with a pressure feedback loop.
- **Advantages:** Compact and flexible vs. insulin pumps (INR 20,000+), with an estimated cost of INR 1000–2000.
- **Challenges:** Requires calibration and biocompatibility testing, planned with CDSCO post-hackathon.
- **Indian Context:** Collaboration with IITs and CSIR labs will adapt this technology using local materials.

Risk Assessment

- **Sensor Drift:** Risk of glucose sensor drift over 24 hours. *Mitigation*: Two-point calibration every 12 hours.
- **BLE Reliability:** Potential packet loss with ESP32 S3. *Mitigation*: Optimize BLE intervals, test with manual logging.
- **Future Component Delays:** Actuator and battery delays. *Mitigation*: Focus on sensor prototype, secure local suppliers.

Future Scope

- Integrate Li-Po battery and TP4056 for 48-hour operation.
- Develop a mobile app with predictive analytics (LSTM-based).
- Implement thin-film actuator for insulin/glucagon delivery.
- Add accelerometer for context-aware monitoring.
- Expand to cloud-based caregiver monitoring via MQTT.
- Scale with Indian-made sensors and actuators.

References

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4. ISO 15197:2013. In vitro diagnostic test systems — Requirements for blood-glucose monitoring systems.
5. Department of Biotechnology, India. Biosensor Development Initiatives. 2023. `https://dbtindia.gov.in`