

SMART BABY ROOM MONITOR

IoT-Based Infant Cry Detection and Sound Analysis System

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1 Problem Statement

Parents are not always able to determine whether their baby is crying or if a detected sound in the room is potentially dangerous. Traditional baby monitors only transmit audio or video but do not intelligently analyze sound patterns or generate smart alerts.

There is a need for a low-cost intelligent monitoring system capable of detecting crying events and identifying potentially harmful noise levels in real time.

2 Proposed Solution

The Smart Baby Room Monitor is an Internet of Things (IoT) system designed to:

- Detect sound peaks in real time.
- Identify cry-like sound patterns using frequency and duration analysis.
- Trigger immediate alerts to a mobile device.
- Provide local visual and audible feedback.

Unlike a simple noise detector, this system incorporates basic signal processing techniques to differentiate between random noise and structured cry patterns.

3 System Architecture

The system follows a four-layer IoT architecture:

1. **Sensing Layer:** INMP441 digital I2S microphone.
2. **Processing Layer:** ESP32 microcontroller.
3. **Communication Layer:** WiFi + HTTP REST.
4. **Cloud Layer:** ThingSpeak for monitoring and alerts.

3.1 Data Flow

1. Audio is captured continuously by the digital microphone.
2. The ESP32 computes RMS and analyzes frequency characteristics.
3. Sound duration and peak repetition are evaluated.
4. If a cry-like pattern is detected, an alert event is generated.
5. Data is transmitted to the cloud dashboard.
6. Parents receive notification via mobile visualization platform.

4 Cry Detection Algorithm

The system does not rely on complex machine learning models in its initial version. Instead, it uses signal processing techniques:

4.1 Step 1: RMS Calculation

$$RMS = \sqrt{\frac{1}{N} \sum_{i=1}^N x_i^2}$$

Used to detect sound intensity peaks.

4.2 Step 2: Frequency Pattern Approximation

Baby crying typically exhibits:

- Repetitive frequency structure
- Sustained duration (several seconds)
- Consistent amplitude variation

The algorithm evaluates:

- Duration above threshold
- Number of consecutive peaks
- Approximate dominant frequency band

If conditions are satisfied, the event is classified as **Possible Cry Event**.

5 Hardware Design

5.1 Main Components

Component	Description
ESP32	WiFi-enabled microcontroller
INMP441	Digital I2S microphone
LED	Visual alert indicator
Active Buzzer	Audible alert system
Protoboard	Prototyping platform

Table 1: Hardware Components

The system operates entirely at 3.3V for safety and energy efficiency.

6 Internet Connectivity

The ESP32 connects to WiFi and transmits event data to ThingSpeak using HTTP requests.

Data fields include:

- Field 1: RMS Value
- Field 2: Sound Classification (Normal / Cry Detected)
- Field 3: Event Duration

Transmission intervals respect free-tier cloud limitations.

7 Smart Features

The Smart Baby Room Monitor qualifies as a Smart Thing because it:

- Continuously senses environmental sound.
- Processes signals locally.
- Makes autonomous decisions.
- Sends remote alerts.

It goes beyond simple monitoring by incorporating embedded signal analysis.

8 Future Improvements

Future development includes implementing a lightweight embedded classification model capable of distinguishing between:

- Baby crying
- Object impact (e.g., something falling)
- Ambient noise

This would introduce on-device machine learning, combining:

- IoT connectivity
- Real-time signal processing
- Edge AI inference

Possible techniques:

- TinyML model deployment
- Feature extraction (MFCC or spectral centroid)
- Lightweight neural networks optimized for ESP32

9 Innovation Aspect

The project is innovative because:

- It applies embedded signal processing in a real domestic scenario.
- It proposes scalable AI integration.
- It addresses a real parental safety concern.
- It remains low-cost and energy-efficient.

10 Evaluation Rubric Alignment

- **It Works** – Real-time cry detection and cloud alert system.
- **Smart Thing** – Autonomous signal processing and decision-making.
- **Internet Connected** – WiFi + ThingSpeak integration.
- **Innovative** – Edge signal processing with AI scalability.
- **Analytics** – Event-based monitoring dashboard.

11 Conclusion

The Smart Baby Room Monitor demonstrates the integration of IoT architecture, embedded systems, and real-time signal processing to solve a meaningful real-world problem.

By combining sound peak detection, duration analysis, and frequency-based pattern recognition, the system provides an intelligent monitoring solution that can evolve toward TinyML-based classification, making it a scalable and future-ready IoT device.