Chirp Charm

A Discreet, Hands-Free Safety Device Powered by Your Steps

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Abstract

Chirp Charm is a discreet personal safety device powered by piezoelectric energy harvesting and a rechargeable lithium-polymer battery—eliminating the need for manual charging. An IMU detects a double stomp to trigger an alarm, enabling hands-free activation in high-stress situations. We developed and tested a compact prototype with >99% stomp detection accuracy and sound levels up to 104 dB. The system fits into a thin shoe liner, with a small charm mounted on the laces.

Introduction

Personal safety fears are at a 30-year high—especially for women under 25 [1]

Traditional devices like pepper spray and alarms often go unused in emergencies because they:

- Require manual activation
- Are not easily accessible in high-stress moments
- Risk escalating a situation unnecessarily
- Feel unfamiliar or intimidating to use

Using your voice to call for help is one of the most effective deterrents—but in panic, many freeze and stay silent [2].

Our solution, Chirp Charm, is a hands-free alarm in your shoe that activates with two stomps—powered by your steps, always on, and ready to call for help when you need it most.

Methods

Triggering Mechanism
- An IMU detects a double-stomp motion using derivative accelerometer data and DMP-based gravity compensation

Power System
- A LiPo battery is supplemented by piezo electrics embedded under the sole

Microcontroller Logic
- An ATMega1284P processes IMU data and controls alarm activation

Alarm System
- A small speaker emits a 104 dB siren using a single transistor amplifier

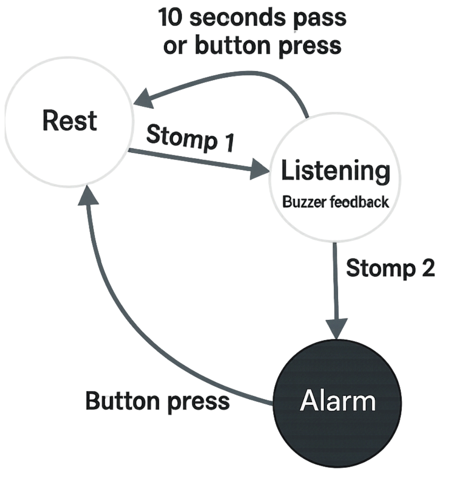

Figure 1. Trigger Mechanism Finite State Machine

Results and Validation

Stomp Detection

We implemented a detection algorithm using the ICM20948 IMU with DMP-based gravity filtering to distinguish intentional double-stomp gestures from normal motion. The system successfully distinguished stomp gestures from walking, standing, and kicking using data collected via ESP32.

- >99% stomp detection accuracy across real-world testing scenarios.
- Latency between stomp event and alarm activation was under 200 ms.

Acoustic Alarm System

Alarm output was generated using a PWM-driven speaker with BJT amplification.

- A custom square-wave tone between 800 Hz and 1200 Hz to mimic emergency sirens.
- Measured up to 104 dB, equivalent to a rock concert

Piezo Electric Energy Harvesting

The harvesting subsystem uses a ceramic piezo array embedded in an insole placed in the shoe.

- Output filtered with a full-bridge rectifier and smoothing capacitor to recharge a LiPo battery.
- Simulated charge rate of 1mAH for 5000 steps

Microcontroller

The microcontroller interfaces with the ICM20948 IMU via I²C and drives both the speaker and buzzer via PWM outputs. An external interrupt pin handles deactivation via a button input.

Stomp Detection:
- The IMU captures real-time derivative acceleration data.
- Stomp registered when acceleration exceeds a defined threshold after gravity compensation.

Trigger Sequence:
- First stomp: Activates haptic feedback buzzer, confirmation that the device is armed.
- Second stomp (within a time window): Triggers the speaker alarm (~104 dB).

Deactivation:
- At any point, pressing the external button cancels the alarm or buzzer and resets the system to the default listening state as a manual shut off

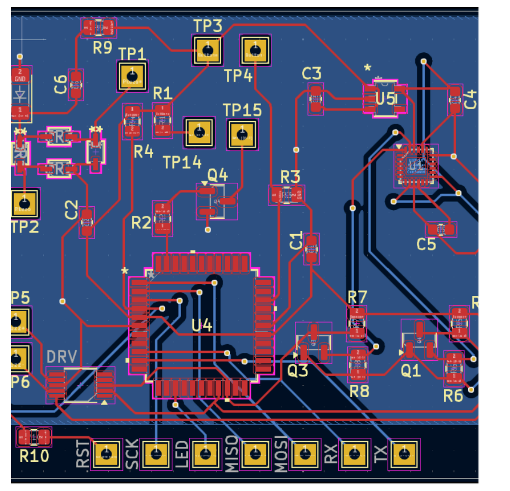

Figure 3: Custom PCB for compact, wearable integration.

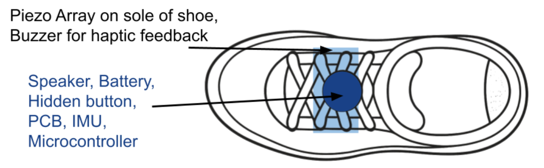

Figure 4: Consumer Application and Mounted Device

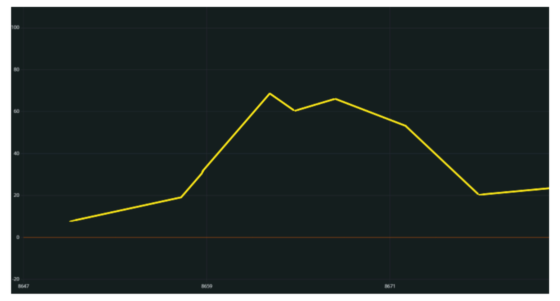

Figure 5: IMU Stomp Detection

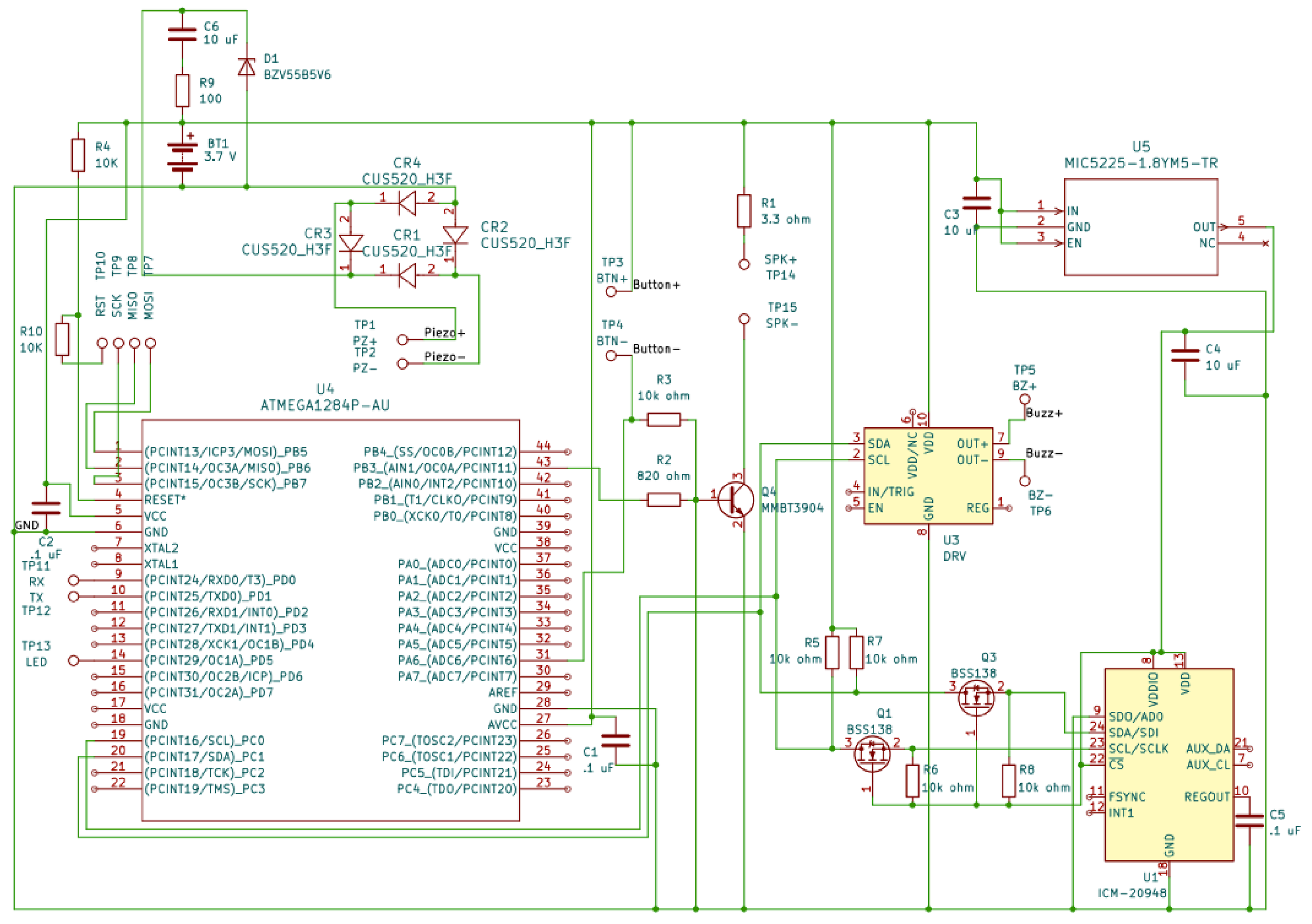

Figure 2. Full Circuit Schematic

All components were integrated into a 3 mm flexible shoe liner and a lace-mounted charm.

- The liner houses the piezoelectric array positioned under the foot.
- The charm contains the microcontroller, IMU, speaker, LiPo battery, off button, and amplification circuitry, enclosed in a compact 3D-printed housing.
- The full system was tested across a range of daily activities including walking, running, and stairs.

Findings:
- Prototype remained fully functional during extended wear across real-world college scenarios
- No measurable discomfort

Figure 6: Lace mounted charm

Conclusions

Chirp Charm is a discreet, stomp-activated safety device designed for hands-free, always-available protection.

- Combines a piezoelectric shoe liner with a lace-mounted charm
- Charm includes IMU, microcontroller, speaker, and an off button
- Double-stomp algorithm triggers a 104 dB alarm
- Energy harvested from steps supplements a rechargeable LiPo battery
- Comfortable, compact, and effective in daily wear

Next Steps:
- Add GPS and emergency contact notifications
- Partner with universities for large-scale deployment

Figure 7: CAD of ideal final prototype

References & Acknowledgements

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Additional Questions?

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