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Structonex: A Low-Cost ESP32-Based Vibration Detection and Alert System with Buzzer and Smartphone Notification

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Abstract: *Events at construction sites happening at unexpected time can have an adverse impact on temporary constructions like scaffolding, ladders or props installed on the site. Some vibration might be unnoticed because of the absence of the supervisor. Manual inspection cannot monitor the site all the time. Modern industrial vibration monitors can be too expensive. This paper presents Structonex, a low-cost Internet of Things IoT prototype that detects construction events and sends an alarm message. The SW-420 vibration sensor module sends its output signal to ESP32 microcontroller. As soon as a new event occurs, ESP32 sends a signal to a buzzer for a fixed period of time. Using built-in wireless interface, ESP32 sends a message to the user's smartphone through Blynk IoT app. There is a three-second gap between signals. Sensitivity is regulated with the help of potentiometer located on the module. Timing settings can be changed in firmware. The article presents a detailed account of design, the actual circuit and of the software code answering message*

Keywords: Vibration detection, ESP32, SW-420, Blynk, buzzer alert, Internet of Things

I. INTRODUCTION

Ladders, scaffolding, temporary platforms, and supports form a critical part of most construction schemes. During operation, these constructions can experience various vibrations caused by material handling operations, machines at work or by different conditions of the construction site. Some vibrations are harmless, but it is good to remember that a sudden vibration can be a good reason for checking up and a person who is given such a task might not always be present at the moment of vibration occurrence.

Although supervision plays a key role, regular monitoring should not be neglected, as the results of supervision, which are reliable yet intermittent, do not account for every vibration in between two visits. On the other hand, structural health monitoring systems (SHMS) offer reliable information about the state of the structure due to use of accelerometers, wireless sensor networks, and various analyses, but such approaches require specific types of sensors and specialists to install them.

The availability of affordable microcontrollers with integrated Wi-Fi, for instance, the ESP32 [3], enables the creation of a tiny awareness apparatus from minimal components. A threshold-based vibration sensor indicates a simple digital signal, which is verified by the microcontroller during each iteration of its operating cycle. Then, the IoT network transmits the notification through the application on the cellphone. The objective of this research is to present Structonex, an alerting device that consists of the ESP32 microcontroller, the SW-420 vibration sensor, and a buzzer. When a new vibration event occurs, the buzzer sounding in the local area, while a message appears on the smartphone of the user if the device is connected to Wi-Fi. The device was not developed for use as a certified safety device; instead, it is meant to be an early warning instrument for demonstration and monitoring purposes.

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The work makes three contributions: (i) a compact node that needs only a microcontroller, a vibration module and a buzzer; (ii) event-based alert logic in which the buzzer responds to every new event while notifications are rate-limited, so that rapid repeated events do not flood the phone; and (iii) a plain statement of what the threshold-based approach can and cannot tell the user. Section 2 reviews related work, Section 3 describes the proposed system, Section 4 covers the implementation, Section 5 discusses results and limitations, and Section 6 gives the conclusion and future scope.

II. LITERATURE REVIEW

Vibration-based monitoring of structures has long been an established research area. Pakzad et al. [4] Described the design and implementation of a wireless sensor network for structural monitoring and Sofi et al. [1] Gave an overview of smart sensor networks for vibration-based monitoring. Mustapha et al. [2] Reviewed sensor placement, implementation and challenges. I observe that the reliability of a measurement depends on where and how sensor is mounted as well as on sensor itself. Zanelli et al. [5] Designed a low-power wireless sensor node. Validated it in the field while Ha et al. [6] Built a wireless MEMS-based inclinometer node, which shows that sensor has to be chosen to match the quantity being observed.

Several authors have pursued IoT-based variants of vibration-based monitoring. Ribeiro et al. [7] Developed a low-cost multinode vibration monitoring system on the Arduino platform and compared it with a high grade system; in impulse tests vibration-based monitoring estimated natural frequencies within 2 % of the reference but it could not produce usable data in ambient vibration tests. Rehman et al. [8] Proposed a vibration-based IoT approach, for real-time structural health monitoring. I see that both works show the potential of hardware and the first also shows that affordable hardware has to be checked under realistic conditions.

The ESP32 and the SW-420 module have already been used together in systems that give alerts. Ariyanto and colleagues [9] linked an ESP32 to DHT22, MQ135 SW-420 and KY-037 sensors. They sent the sensor data to a server and a mobile app. Sent early-warning alerts when the measured values crossed set limits. Hercog and colleagues [3] talked about designing and building IoT devices that use the ESP32. Their work shows that the ESP32 can serve as the heart of a sensing node.

Most of the projects use accelerometers, nodes or process data, on a server. Those methods produce information but also increase cost and make the system more complex. For a student project or a small location a simpler set-up can give basic notice. One can use a vibration sensor that triggers at a set threshold, a buzzer and a ready-made notification service. Structonex follows this approach. It keeps clear that the module does not promise to measure amplitude, tilt or the exact structural state.

III. PROPOSED SYSTEM

3.1 System Overview

Structonex has three parts: a sensing unit, a processing and control unit, and an alert path. The SW-420 module senses mechanical vibration and gives a digital output to one input pin of the ESP32. The ESP32 polls this pin, detects the start of a new event, drives the buzzer and, when the timing rule permits, sends a notification through the Wi-Fi network to the Blynk server, which delivers it to the user's smartphone. The block diagram is shown in Fig. 1 and the components are listed in Table 1.

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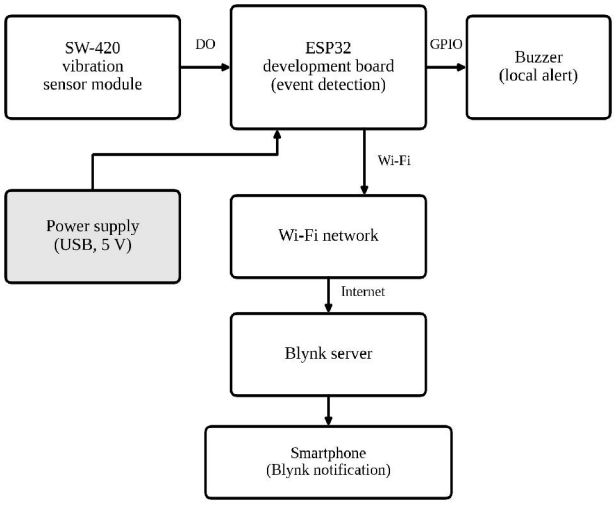


Fig -1: Block diagram of the proposed Structonex system

Table -1: Components of the Structonex system

Component	Function
ESP32 development board	Main controller and Wi-Fi communication
SW-420 vibration sensor module	Vibration sensing with adjustable sensitivity
Buzzer (active, low current)	Local audible warning
Jumper wires	Circuit connections
USB cable and 5 V source	Power supply and programming
Wi-Fi network	Wireless link to the internet
Blynk IoT platform	Relay of the notification to the phone
Smartphone	Receives the vibration notification

3.2 Hardware Description

The ESP32 is a Wi-Fi and Bluetooth system on chip from Espressif Systems [10]. It comes with a core 32-bit processor that can run at speeds up to 240 MHz. It has 520 KB of random access memory or SRAM. It supports IEEE 802.11 b/g/n Wi-Fi at the 2.4 GHz frequency band. The chip also includes a number of general purpose input/output pins that use 3.3 V logic. Since Wi-Fi is built into the chip there is no need for an external communication module.

The SW-420 is a vibration sensor module that works based on a threshold. It has a vibration- switching element and some electronics on the board. When a disturbance is stronger than the set sensitivity level the module gives an output. This output only tells that an event has happened. It does not provide details, like how strong the vibration was, how fast it was or what the acceleration was. Most SW-420 modules pull the output signal when vibration is detected. The firmware used in this project assumes this behavior. It is important to test the module during setup to confirm how it actually behaves. The pin connections used in this project are listed in Table 2.

Table -2: Pin connections of the Structonex circuit

Connection	ESP32 pin / supply
SW-420 VCC	3V3
SW-420 GND	GND
SW-420 DO (output)	GPIO 27
Buzzer (+)	GPIO 26
Buzzer (−)	GND

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USB port	5 V USB source

The buzzer is a type that is connected directly to GPIO 26. The buzzer does not need current than a GPIO pin can provide; if the buzzer requires more current the buzzer should be powered through a transistor. The board is powered via its USB connector from a computer or a 5 V adapter and the board shares a ground with all parts. The Wi-Fi network must be a 2.4 GHz access point with internet access and the user's smartphone runs the Blynk application.

3.3 Software Requirements

The firmware is written in C++ using the Arduino framework for the ESP32. The Wi-Fi library and the Blynk library handle the network connection and the link to the Blynk platform. The firmware uses a Blynk template named Structonex and an event with the code high_vibration, which produces the notification. The serial monitor at 115200 baud shows the sensor state, the vibration status and the Wi-Fi and Blynk connection status, per second and the serial monitor is used for testing.

3.4 Working Principle

After power-up the ESP32 configures the sensor pin as an input and the buzzer pin as an output, keeps the buzzer off, and starts Wi-Fi and the Blynk connection. In each pass of the main loop it reads the sensor pin and compares the level with the "vibration detected" level. When a detection starts, that is, when the sensor was quiet on the previous pass and is now active, the ESP32 sounds the buzzer for 500 ms. If at least three seconds have passed since the last notification, it also sends the Blynk event. The loop then waits 50 ms and repeats, so the unit watches the sensor without anyone operating it. The operation is summarised in the flowchart of Fig. 2.

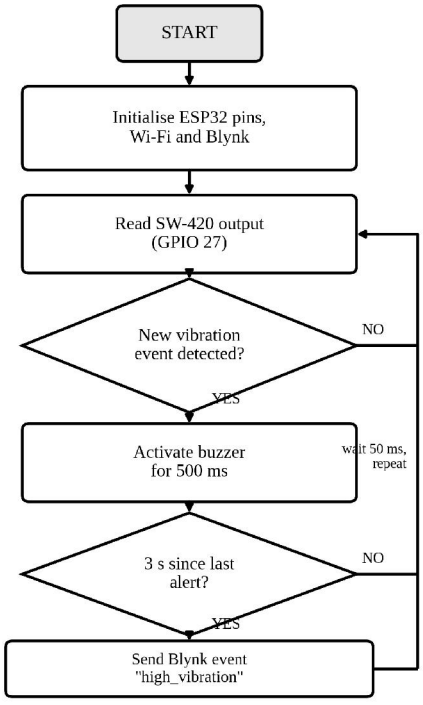


Fig -2: Flowchart of Structonex operation

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IV. IMPLEMENTATION

4.1 Circuit Connection

Fig. 3 shows the wiring. The SW-420 module is powered from the 3.3 V pin and the ground of the ESP32 board, and its digital output (DO) goes to GPIO 27. The buzzer signal is taken from GPIO 26, and its other terminal goes to the common ground. The board is powered from its USB port with a 5 V supply. Jumper wires are enough for all connections, so no soldering is needed.

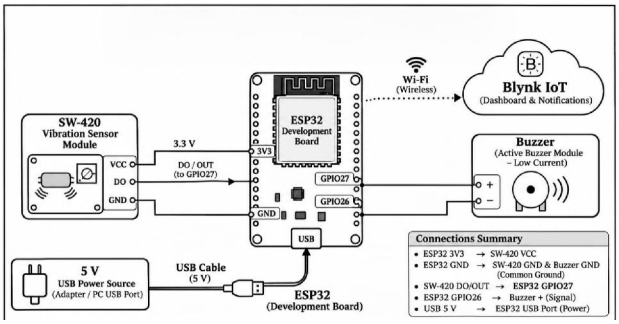


Fig -3: Circuit connection of the SW-420 module and the buzzer with the ESP32 board

4.2 Vibration Detection and Alert Logic

The detection is done using the firmware, above the threshold set on the module. The sensor pin is read using the digitalRead function, and a vibration is detected when the level becomes equal to the VIBRATION_DETECTED constant, whose value is set to LOW. The program takes into account the state in the previous pass and reacts only when there is a vibration at this moment but no vibration in the previous one; otherwise, an always active sensor signal will cause the buzz again during each pass. There are three timing-related constants – the duration of the buzzer signal (500 ms), the minimum period between detections (3000 ms), and the period of the status output (1000 ms). The buzzer itself is turned on and off using a blocking delay routine; thus, the program pauses while beeping. The program does not apply debouncing other than a delay of 50 ms inside the loop; thus, the sensitivity settings and the way the module is mounted will affect the frequency of the event reporting.

4.3 Blynk Notification

The ESP32 connects to the Wi-Fi network and logs into the Blynk server using the template ID and token for the particular device. Upon the triggering of an event where the notification should be sent and when the connection is active, the firmware triggers the Blynk event function, with arguments of “high_vibration” and “over load: alert high vibration”. This event is then pushed to the mobile phone by Blynk as a push notification. If Blynk connection fails, then the firmware only displays a message on the serial monitor. Hence, remote notification requires a functional Wi-Fi, internet, and a properly configured Blynk system. The message wording is simply a label for an event detected.

V. RESULTS AND DISCUSSION

5.1 Operation of the System

The Blynk notification containing the text “over load: alert high vibration” has been received on the mobile phone screen (Fig. 4). It means that notification transmission between the ESP32 module, Blynk server and the phone is working. While running, the firmware displays the value received from the sensor, vibration status and connection status of the Wi-Fi and Blynk app every second on the serial monitor, and the program sounds a buzzer during 500 ms for each new event. The fact that the sensor is being monitored at every cycle makes it unnecessary to observe the program in order to detect the vibration, as it can happen any time, and will be detected at once. The demonstration performed had a functional purpose only, timing and other parameters were not tested..

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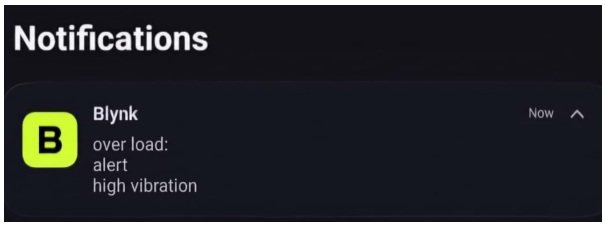


Fig -4: Blynk notification received on the smartphone

5.2 Comparison with Manual Inspection

Table 3 sets Structonex against periodic manual inspection on the points that matter most to small sites. Industrial SHM systems [1], [2] give quantitative data that Structonex does not attempt to provide.

Table -3: Structonex compared with manual inspection

Aspect	Manual inspection	Structonex
Detection	Periodic visual check	Sensor read on every loop pass
Observer	Must be nearby	Not needed for detection
Local warning	None unless noticed	Buzzer for 500 ms
Remote alert	None	Blynk notification (needs Wi-Fi)
Records	Written notes	Serial monitor status only
Measurement	Judgement of the inspector	Event only; no amplitude or tilt
Hardware	Visual aids	ESP32, SW-420, buzzer

5.3 Advantages and Limitations

Structonex is simple and affordable to build. It runs on USB power. It gives local alerts without needing a screen. It also sends alerts using an existing service. The sensitivity can be changed with a potentiometer. Timing settings are adjustable, in the firmware. This lets the device be adapted to mounting needs without changing hardware.

The SW-420 does not provide amplitude, frequency or acceleration data. The prototype does not include a tilt sensor. Detecting vibration is not enough to say a building is safe or dangerous. Sensitivity and how the device is mounted both play a role in the results [2]. Remote alerts depend on Wi-Fi, internet access and a working Blynk setup. In the firmware the Blynk start-up function waits until it connects to the network. That means the network must be ready when the device turns on.There is one measurement point. There is no record of events. Because the device runs on USB it has no battery. The alert message says "over load " which is confusing and should be changed. Far response time, false alarm rate and how reliable the notifications are have not been tested or measured.

VI. CONCLUSIONS AND FUTURE SCOPE

A low-cost vibration detection and alert prototype, Structonex, has been designed with an ESP32 microcontroller, an SW-420 vibration sensor module and a buzzer. The ESP32 reads the sensor, sounds the buzzer when a new vibration event begins and, with a minimum gap of three seconds, sends a notification to the user's smartphone through the Blynk IoT platform. The design uses common components and open tools, and it offers a simple way to be alerted to vibration events without continuous manual observation. It is an educational and preliminary monitoring aid, not a certified safety device.

Several improvements are possible. An accelerometer would give vibration intensity instead of a bare event, and a tilt sensor would add inclination, subject to proper testing and validation. Event logging with time stamps and a Blynk dashboard would let recurring disturbances be reviewed. Non-blocking buzzer timing, a battery backup, further alert channels such as e-mail or short message service (SMS) and a reworded notification message would make the device more reliable. Finally, controlled tests of detection sensitivity, response time, false triggering and notification

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reliability, in the manner of the validation reported in [7] and the performance evaluation in [9], are needed before any conclusion about practical performance is drawn.

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