

# Smart Early Detection of Diabetic Foot Ulcers Using Temperature and Pressure Sensors

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**Abstract:** Diabetic Foot Ulcer (DFU) is one of the most serious complications faced by diabetic patients and is a major cause of infection, hospitalization, and lower limb amputation. Early detection of abnormal conditions in the foot can significantly reduce the risk of ulcer formation. This project proposes a smart and low-cost system for the early detection of diabetic foot ulcer risk by analyzing foot temperature and plantar pressure. The system uses pressure sensors to measure the distribution of body weight on different regions of the foot and an infrared temperature sensor to monitor foot surface temperature. These sensors are interfaced with a microcontroller that continuously collects and processes the data in real time. The measured values are compared with predefined threshold levels to detect abnormal pressure concentration and temperature rise, which are considered early indicators of inflammation and tissue damage. Based on the analysis, the system classifies the risk level and provides immediate alerts through a display unit and buzzer to inform the user. The proposed device is non-invasive, portable, and cost-effective, making it suitable for regular home monitoring as well as clinical support systems. By providing early warning signals, the system helps diabetic patients take preventive actions before the development of severe ulcers. The implementation demonstrates that integrating temperature and pressure monitoring can improve the reliability of early diabetic foot ulcer detection and contribute to better preventive healthcare management.

**Keywords:** Diabetic Foot Ulcer, Arduino UNO, Force Resistive Sensor, Temperature Sensor.

## I. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder that affects millions of people worldwide. One of the most serious complications associated with diabetes is Diabetic Foot Ulcer (DFU), which occurs due to nerve damage (neuropathy), poor blood circulation, and prolonged pressure on certain areas of the foot. These conditions reduce the patient's ability to feel pain or discomfort, allowing small injuries or pressure points to develop into severe ulcers without early notice. If not detected in time, diabetic foot ulcers can lead to infections, hospitalization, and even lower limb amputation. Early detection and continuous monitoring of foot conditions are essential to prevent ulcer formation. Studies have shown that localized temperature increase and abnormal plantar pressure distribution are two important indicators that appear before the visible formation of ulcers. Monitoring these parameters can help identify high-risk conditions at an early stage and allow preventive action. Traditional diagnostic methods for diabetic foot complications often require clinical examination and specialized medical equipment, which may not be easily accessible for continuous monitoring. Therefore, there is a need for a low-cost, portable, and non-invasive monitoring system that can detect early warning signs of diabetic foot ulcers. This project proposes a smart early detection system that uses temperature and pressure sensors to monitor foot conditions in real time. The collected sensor data is processed using a microcontroller to identify abnormal pressure or temperature variations. When risky conditions are detected, the system provides alerts to the user, enabling timely preventive care. The proposed system aims to improve early detection, reduce complications, and support better management of diabetic foot health.

## II. LITERATURE SURVEY

[1] Chenetal.,2025 proposed a machine learning- based thermal analysis system for detecting diabetic foot ulcer risk. The system analyzes thermal images of the foot to identify abnormal temperature patterns.

This method improves early detection accuracy using artificial intelligence. [2] Liu et al., 2024 studied the use of temperature monitoring for diabetic foot ulcer management. Their research showed that continuous monitoring of wound temperature helps identify inflammation and infection at an early stage.[3] Khosa et al., 2023 developed an automatic diabetic foot ulcer detection system using thermo graphic images. The system analyzes temperature variations in foot image store cognize ulcer conditions effectively. [4] Duah et al., 2024 designed a self-powered wireless temperature monitoring platform for foot ulcer prevention. The system generates energy from foot movement and continuously measures foot temperature. [5] Billings et al., 2024 introduced a smart compression sock integrated with sensors to detect early diabetic foot ulcer risk. The wearable device monitors foot conditions and alerts the user about abnormal changes.[6]Martin and Davis, 2023 studied the effect of plantar pressure and shear stress on diabetic foot ulcers. Their research showed that high pressure on certain foot regions can cause tissue damage and ulcer formation.[7] Lee et al., 2022 developed a smart insole system with pressure sensors to measure plantar pressure distribution in diabetic patients. The system helps identify high-pressure areas that may lead to ulcer formation.[8] Wanget al., 2021 proposed a temperature monitoring approach for early detection of diabetic foot ulcers. The study showed that abnormal temperature increase in the foot can indicate inflammation before ulcers appear.[9] Nordin et al., 2024 designed an IoT-based system that uses both temperature and pressure sensors for diabetic foot monitoring. The system analyzes sensor data to detect abnormal foot conditions and provide alerts. [10] Sharma et al., 2023 analyzed diabetic plantar foot thermograms to identify severity levels of foot complications. Their research used temperature distribution patterns to detect potential ulcer risk.

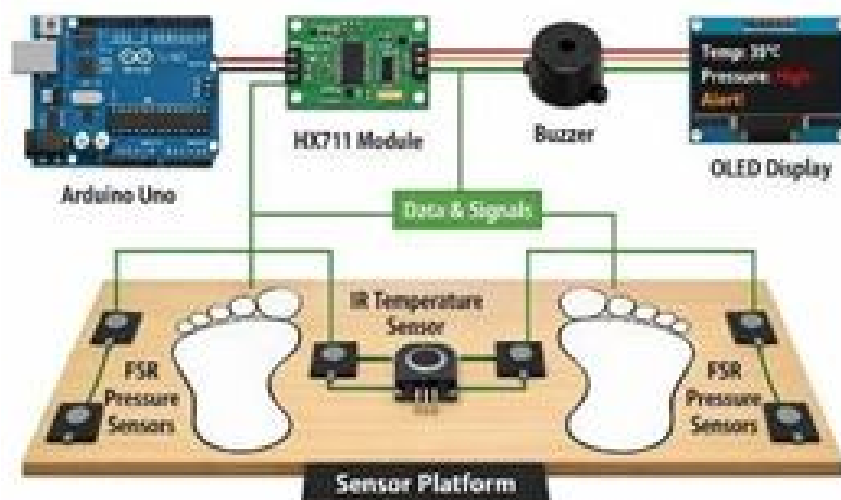
### III. METHODOLOGY

The methodology explains the step-by-step process used to design and implement the proposed Smart Early Detection of Diabetic Foot Ulcers using Temperature and Pressure Sensors. The system works by collecting foot temperature and pressure data, analyzing the data through a microcontroller, and providing alerts when abnormal conditions are detected. The proposed system consists of temperature sensors, pressure sensors, a microcontroller unit, and an alert/display system. The sensors are placed in a platform or foot mat where the user places both feet. The sensors continuously measure foot temperature and pressure distribution. The collected data is processed by the microcontroller to identify abnormal conditions that may indicate ulcer risk.

#### A. System Overview

The proposed system is designed to detect early signs of diabetic foot ulcer risk by monitoring foot temperature and plantar pressure. The system consists of temperature sensors, pressure sensors, a microcontroller unit, and an alert/display module. The sensors are placed on a platform where the user places both feet for measurement. The temperature sensor measures the surface temperature of the foot, while the pressure sensors detect the distribution of pressure across different regions of the foot. These sensors continuously send data to the microcontroller for processing. The microcontroller analyzes the sensor readings and compares them with predefined threshold values to identify abnormal conditions such as high pressure or increased temperature. If the system detects abnormal readings that may indicate a potential risk of ulcer formation, it generates a warning through a buzzer and display unit. This allows the user to take preventive action at an early stage. The overall system is designed to be non-invasive, portable, and low- cost, making it suitable for regular monitoring of diabetic patients.

#### B. Circuit diagram



**Fig1** Smart early Detection of Diabetic Foot Ulcers Using Temperature and Pressure Sensors

#### C. Hardware Components

The system consists of several essential components working together to perform sensing and monitoring functions. It uses an Arduino Uno as the main controller to process data from sensors. Force Sensitive Resistor (FSR) pressure sensors are used to measure pressure, while an Infrared Temperature Sensor (MLX90614) is used to detect temperature without contact. The HX711 amplifier module is connected to enhance the accuracy of pressure sensor readings.

An LCD display is used to show the measured values, and a buzzer provides alerts when necessary. The entire setup is powered by a suitable power supply, with connecting wires ensuring proper electrical connections between components. A sensor platform is used to properly place the sensors, and a breadboard helps in assembling and testing the circuit conveniently.

#### **D. System Integration**

System integration refers to the process of connecting all hardware and software components to work together as a single functional system. In the proposed project, the temperature sensor, pressure sensors, microcontroller, display unit, and alert system are integrated to monitor the condition of the user's feet. The pressure sensors and temperature sensor are placed on the foot platform to collect real-time data when the user stands on the device. These sensors are connected to the microcontroller, which acts as the main processing unit of the system. The microcontroller reads the sensor data, converts it into digital values, and analyzes the readings based on predefined threshold levels. The processed information is then sent to the display unit to show the measured temperature and pressure values. If the system detects abnormal pressure or increased temperature that may indicate a risk of diabetic foot ulcer formation, the buzzer is activated to alert the user. Through this integration of sensors, processing unit, and output devices, the system provides continuous monitoring and early warning for diabetic foot health. The first stage of integration involves connecting the temperature sensor and pressure sensors to the microcontroller unit. The temperature sensor is placed near the foot surface to measure the skin temperature, while the pressure sensors are embedded in the foot platform or mat to measure plantar pressure at different points of the foot. When the user places both feet on the platform, these sensors detect temperature and pressure values and convert the into electrical signals. These signals are then sent to the microcontroller (Arduino) through analog or digital input pins. The microcontroller acts as the central processing unit of the system. It reads the sensor signals, converts the min to digital data using the Analog-to- Digital Converter (ADC), and processes the information using the programmed algorithm. After collecting the sensor data, the microcontroller compares the measured temperature and pressure values with predefined threshold limits stored in the program. If the temperature exceeds the normal range or if excessive pressure is detected in certain areas of the foot, the system identifies it as a possible risk condition for diabetic foot ulcer development. Once the analysis is completed, the results are sent to the output modules, which include a display unit and a buzzer. The display shows the real-time values of temperature and pressure along with the system status. If abnormal conditions are detected, the buzzer generates an alert to notify the user about the potential risk. All components are powered through a stable power supply, ensuring continuous operation of the system. The integration of sensors, microcontroller, processing algorithm, and output devices allows the system to function as a real-time monitoring device for diabetic foot health. Thus, through proper system integration, the proposed device can continuously measure foot parameters, analyze the data, and provide early warning alerts, helping users take preventive measures before the formation of severe diabetic foot ulcers.

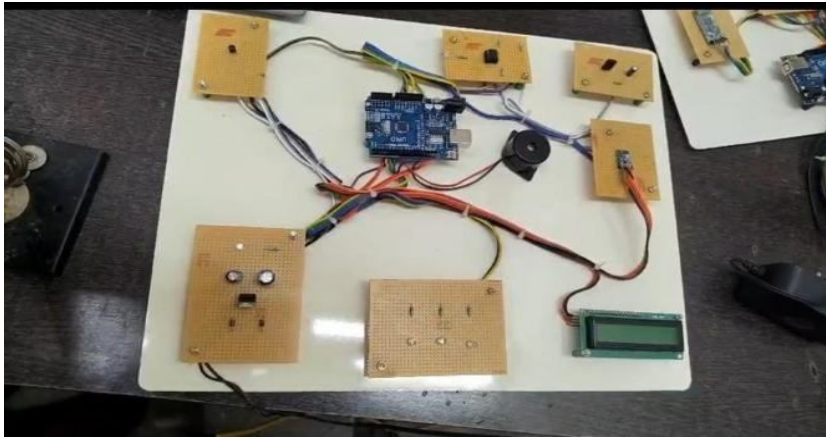
#### **E. Testing and Validation**

Testing and validation are performed to ensure that the proposed diabetic foot ulcer detection system works accurately and reliably. The process includes checking individual components, verifying sensor outputs, and validating the overall system performance under different conditions. Proper testing ensures that the system can correctly detect abnormal temperature and pressure levels that may indicate early risk of diabetic foot ulcers. During the testing phase, the temperature sensor and pressure sensors are checked individually to verify their proper functioning and accuracy. The sensors are connected to the microcontroller, and their outputs are observed through the display unit. First, individual component testing is carried out. Each hardware component such as the temperature sensor, pressure sensors, microcontroller, display unit, and buzzer is tested separately. The temperature sensor is checked by measuring known temperature values and verifying whether the readings displayed by the system match the expected values. Similarly, the pressure sensors are tested by applying different loads or weights on the sensor surface to confirm that the sensor output changes according to the applied pressure. Next, sensor calibration is performed to improve measurement accuracy. The temperature sensor readings are compared with a standard thermometer to ensure proper calibration. For pressure sensors, known weights are placed on the sensor platform to observe how the sensor values change. This helps determine the correct relationship between applied pressure and sensor output voltage. After calibration, system-level testing is conducted. In this stage, all components are connected together and tested as a complete system. The user places both feet on the sensor platform, and the system begins collecting temperature and pressure data in real time. The microcontroller reads the sensor values and processes them according to the programmed logic.

During validation, the measured values are compared with predefined threshold limits. For example, a significant increase in foot temperature or excessive pressure in a particular area of the foot may indicate possible tissue stress or inflammation. When these abnormal values are detected, the system activates the buzzer and displays a warning message. This confirms that the alert mechanism is functioning correctly. The system is also tested under different pressure conditions by placing different weights on the sensor platform. This helps verify that the sensors can accurately detect varying pressure levels. Similarly, the temperature sensor is tested in different environmental conditions to ensure consistent readings. Finally, result validation is carried out by observing whether the system correctly identifies normal and abnormal conditions. If the system consistently detects high pressure or abnormal temperature changes and generates alerts, it confirms that the system is functioning as intended. Through these testing and validation procedures, the proposed system demonstrates its ability to monitor foot temperature and pressure effectively and provide early warning alerts for potential diabetic foot ulcer risk. In the validation process, different pressure levels are applied on the sensor platform by placing varying weights to simulate foot pressure.

Similarly, the temperature sensor readings are tested by measuring different temperature conditions. The measured values are compared with expected values to confirm the accuracy of the system. The system is also tested to verify the alert mechanism. When the pressure or temperature exceeds the predefined threshold level, the buzzer and display alert are activated successfully. These tests confirm that the system can detect abnormal conditions and provide early warning for potential diabetic foot ulcer risk.

#### IV. RESULT AND DISCUSSION



**Fig2** Smart Early Detection of Diabetic Foot Ulcers Using Temperature and Pressure Sensors

Testing and validation are performed to ensure that the proposed system works correctly and provides reliable measurements. During the testing phase, the temperature sensor and pressure sensors are checked individually to verify their proper functioning and accuracy. The sensors are connected to the microcontroller, and their outputs are observed through the display unit. In the validation process, different pressure levels are applied on the sensor platform by placing varying weights to simulate foot pressure. Similarly, the temperature sensor readings are tested by measuring different temperature conditions. The measured values are compared with expected values to confirm the accuracy of the system. The system is also tested to verify the alert mechanism. When the pressure or temperature exceeds the predefined threshold level, the buzzer and display alert are activated successfully. These tests confirm that the system can detect abnormal conditions and provide early warning for potential diabetic foot ulcer risk.

#### V. CONCLUSION

The proposed system for Smart Early Detection of Diabetic Foot Ulcers using Temperature and Pressure Sensors provides a simple and effective approach for identifying early warning signs of foot complications in diabetic patients. Diabetic foot ulcers are a serious health problem that can lead to infection, hospitalization, and in severe cases, amputation. Early detection of abnormal pressure and temperature changes in the foot can help prevent these complications. Therefore, continuous monitoring of these parameters plays an important role in preventive healthcare. In this project, a monitoring system is designed using pressure sensors and a temperature sensor connected to a microcontroller. The sensors collect real-time data from the user's feet when they stand on the sensor platform. The microcontroller processes this data and compares it with predefined threshold values to detect abnormal pressure distribution or increased temperature levels. When such abnormal conditions are detected, the system generates an alert through a display unit and buzzer, informing the user about the possible risk. The proposed system is non-invasive, low-cost, portable, and easy to use, making it suitable for regular monitoring of diabetic patients at home or in healthcare centers. By providing early warning signals, the system helps users take preventive measures such as reducing pressure on affected areas or consulting medical professionals before the condition becomes severe. Overall, the implementation of this system demonstrates the potential of integrating simple sensors and embedded systems in medical monitoring applications. The project contributes to improving preventive healthcare by enabling early detection of diabetic foot ulcer risk. In future developments, the system can be enhanced by integrating wireless communication, mobile application monitoring, and advanced data analysis techniques to improve accuracy and remote healthcare support.

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