**CHAPTER THREE**

**MATERIALS AND METHODS**

**3.0 Design and Analysis**

In this section, the various block/units and their circuit diagrams, design analysis, criteria and assumptions made for component selection are presented. Figure 3.1 shows the functional blocks of the designed circuit.

Power Supply

Display Unit LED

Laptop/GSM

NodeMCU

Pressure Sensor Unit

Switch Unit

ALARM

Legend

Power

Data

**Figure 3.1:** Schematics of the Wireless Pressure sensing system

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**3.1 Power Supply Unit**

The power supply unit is responsible for providing the biasing and operating voltage for the circuit operation. The input to this unit is 220/240VAC at a frequency of 50Hz and the output is 12V DC.

This unit comprises of the following basic components;

* 220/12V step-down transformer
* Bridge diode
* 35V 1000uF and 25V 47uF capacitors
* LM7805 Voltage regulator
* 104Ω Resistors

**3.1.1 Transformer Selection**

The choice of transformer was based on the following;

1. The input voltage range
2. The output voltage range
3. The power rating of the transformer in kVA
4. Operating frequency of power supply
5. The number of turns and the diameter of the transformer coil

The input voltage range from the supply mains is from 220~240V AC single phase supply. The output voltage range of the transformer is from 12~19V AC to the rectifier circuit. The rating of the transformer or the power rating of the transformer is 1kVA. This indicates that the capacity of the circuit is 1kVA.

Total current of the circuit is given by:

Current demand by voltage regulators + current demand by NodeMCU + current demand by display unit (LED) + current demanded by relay + current demanded by relay driver + current demanded by pressure sensor + current demanded by ALARM

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Where Current demand by voltage regulator = 8mA

Current demand by NodeMCU = 3.6mA

Current demand by display unit = 4.8mA

Current demand by relay unit = 3.8mA

Current demand by relay driver = 12.8mA

Current demand by Pressure Sensor = 3.8mA

Current demand by ALARM = 4.8mA

∴Total current of the circuit, IL = 8mA + 3.6mA + 4.8mA + 3.8mA + 12.8mA + 3.8mA + 4.8mA = 41.60mA

E2 = E1 x N2

N1

N2 = 8 turns, N1 = 160 turns

Given that: E1 = 240v, E2 = 240 x 8 = 12V

160

Where: E1 = Input voltage

E2 = Output voltage

N1 = Primary Turns

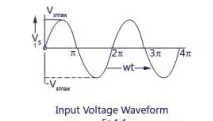
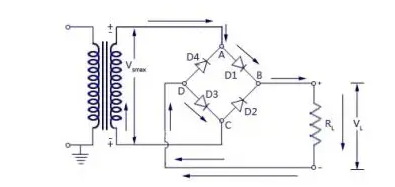
N2 = Secondary Turns

**3.1.2 Selection of the Bridge Rectifier**

The rectification circuit used in the design is a full-wave bridge rectifier which comprises four diodes. This is shown in the figure below;

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**D1 - D4 = IN 4007**



**Fig 3.2:** The Bridge Rectifier

The four diode Full Wave Bridge Rectifier is used due to its added advantage over a Two Diode center-tapped Full-Wave Rectifier as well as a One Diode Half-Wave Rectifier.

The choice of diodes used was based on:

1. The forward current rating: The diode forward current rating is the maximum current that the diode can conduct before failing. The diode is selected in such a way that the current passing through it is less than the forward current rating.
2. The *Peak Inverse Voltage* (PIV) that the diodes would withstand: The peak inverse voltage is the maximum reverse voltage that a diode can withstand without destroying the junction. If the reverse voltage across a diode exceeds this value, the reverse current increases sharply and breaks down the junction due to excessive heat. Peak inverse voltage is extremely important when diode is used as a rectifier. In rectifiers, it has to be ensured that reverse voltage across the diode does not exceed its PIV during the negative half-cycle of input ac voltage. Hence, PIV consideration is generally the deciding factor in diode rectifier circuit. The peak inverse voltage of a rectifier diodes lies between 10V and 10kV depending upon the types of diodes.

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Vpeak = Vrms



Where *Vrms* is the transformer’s output voltage using the maximum output voltage (that is 12V ac) we have that Vrms = 12V

∴Vpeak = × 12 = 16.97V



For a bridge rectifier, the peak voltage equals the peak inverse voltage. Therefore, the calculated PIV is 16.97V.

Thus, the IN4007 diode was chosen for the rectifier since it satisfies the above stated requirements according to its datasheet.

Voltage drop across diodes = (2 x 0.7) = 1.4V

Voltage drop = 16.97 - 1.4 = 15.57V

Where 0.7 is the forward conducting voltage of a silicon diode.

**3.1.3 The Capacitor Selection**

The filter used in this power supply is a single shunt capacitor. The choice of the filter capacitor depends on:

1. The ripple factor allowed
2. The capacitor breakdown voltage
3. **The Ripple Factor Allowed**

The output of a rectifier consists of a dc component and an AC component (also called ripple). The ripple is undesirable and causes pulsations in the rectified output. The effectiveness of a rectifier depends on the amount of ripple in its output, the smaller this is, the more effective is the rectifier. The ripple factor is an indication of the effectiveness of the filter capacitor and is defined as:

Ripple Factor = = = =



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The smaller the ripple factor, the lesser the amount of ripples and hence more effective is the rectified output signal. These ripples have a frequency of twice the input supply frequency. The ripple factor for full-wave rectifiers and thus allowed for this project is given as:

IRMS =



IDC =



∴ R = = 0.48



This shows that the DC component of the full-wave rectifier output is more than the ripples, making full wave rectifiers more suitable for rectifying ac to dc.

1. **The Capacitor Breakdown Voltage**

The capacitor breakdown voltage can be determined by applying Kirchhoff’s voltage law at the output of the rectifier to the terminal of the filter capacitor.

Vpeak – 2 (Diode drop (VD)) = Voltage at filter capacitor

For silicon made diode VD ­= 0.7V

∴ VC = 16.97 – 2 (0.7) = 15.57V

Taking a safety factor of two, the capacitor voltage, VC becomes 31.14V, and since this is not a common capacitor voltage, a 25V capacitor was chosen

The capacitance of the capacitor used is gotten using the relationship:

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Vmax =



IL = load current = 41.60mA (as calculated)

f = frequency = 2 × supply frequency = 2 ×50Hz = 100Hz

C = capacitance

Maximum peak = 11.33V

Obtaining capacitance, we have that: Vmax= = 41.0 x 10-3



2 x 50 x C

11.33 = 41.0 x 10-3

2 x 50 x C

100C = 41.0 x 10-3

11.33

Therefore, C = 41.60 x 10-3 = 0.00003618711F = 36µF

1133

From the calculated value, 36μF is not a standard capacitance value; hence a 1000μF, 25V capacitor was selected. The 47uF capacitor was used to further smoothen the output to reduce the ripples which result in spike current when the theft load is connected to the circuit.

**3.1.4 The Voltage Regulator Selection**

The importance of voltage regulator is to ensure that a fixed voltage output is obtained at the output of the power supply regardless of the variations from the supply input or load connected. The regulation used is the IC voltage regulator LM7805. This implies that a positive fixed +5volts regulator was used to provide the fixed positive voltage level required by the circuitries.

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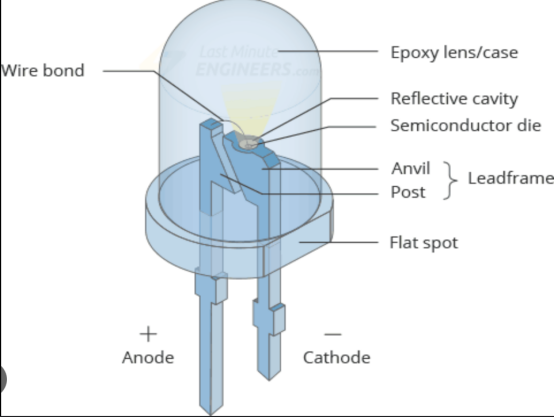
The rating of the voltage regulator from the datasheet is as given below:

1. Input voltage range 5~25V
2. Maximum current rating 5mA-1.5A
3. Output voltage range 4.8~30V
4. Operating temperature range 0~125℃

The fixed positive IC voltage regulator was chosen from the 78xx family of fixed positive voltage as they are more efficient in providing the much-needed constant voltages for the interconnected circuitries of the design.

## 3.1.5 Display Unit

This is the unit that the system uses to interact with the user when the system is powered on.



**Figure 3.3:** Schematic diagram of LED.

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## 

## 3.1.6 BMP Pressure Sensor Unit

The BMP Pressure Sensor Unit is a high-precision digital barometric pressure and temperature sensor designed for environmental sensing applications. It is commonly integrated into embedded systems, IoT devices, drones, and weather monitoring stations due to its compact size, low power consumption, and accurate atmospheric pressure measurement.

This report covers the working principle, technical specifications, interfacing methods, and applications of the BMP Pressure Sensor Unit.

Working Principle

The BMP sensor is based on a piezoresistive principle:

Atmospheric pressure deforms a microelectromechanical system (MEMS) diaphragm.

This deformation changes the resistance of implanted resistors, forming a Wheatstone bridge.

The output is processed by an internal ADC and compensated using factory calibration coefficients.

The sensor also measures temperature, which is used for compensation and ambient monitoring.

The digital output (pressure & temperature) can be further used to calculate altitude using the barometric formula.

Technical Specifications (BMP280 example)

Operating Voltage: 1.71 V – 3.6 V

Pressure Range:300 – 1100 hPa (equivalent to altitudes from -500 m to +9000 m)

Pressure Resolution:0.16 Pa

Temperature Range: -40 °C to +85 °C

Temperature Accuracy:±1 °C

Pressure Accuracy:±1 hPa (approx. ±8.3 m altitude error)

Interface:I²C (up to 3.4 MHz), SPI (up to 10 MHz)

Power Consumption: \~2.7 µA at 1 Hz measurement rate

Hardware Interface

Pins: VCC, GND, SDA (I²C Data), SCL (I²C Clock), SDO (I²C Address/Chip Select), CSB (Chip Select for SPI)

Communication:Supports both I²C and SPI protocols for flexibility in microcontroller integration.

MCU Compatibility:Works with Arduino, ESP8266, ESP32, STM32, Raspberry Pi, etc.

## 

## 

3.1.8 **NodeMCU controller**

The ESP8266 is a low-cost WiFi-enabled microcontroller, created and developed by Espressif Systems, a Shanghai-based Chinese company. The following features are the primary reasons why people like the ESP8266

**3.2.1 The Switch Unit**

This unit is made up ULN2803 switch and a 12v DC relay, the ULN2803 helps to amplify the signal of the microcontroller into 12v DC to drive the relay which in turns controls the ALARM.

**3.2.2. Selection of relay**

When selecting a 12V DC to 230V AC relay, the key factors to consider include the relay's voltage rating, current rating, contact configuration, and the load requirements. Here's an overview of the key considerations for relay selection:

1. Voltage Rating:

- Ensure that the relay is rated for a DC coil voltage of 12V. This ensures compatibility with your power supply.

2. Current Rating:

- Determine the maximum load current that the relay will switch. This is the current required by the 230V AC load that the relay will control.

- Select a relay with a current rating higher than the maximum load current to ensure it can handle the required switching capacity without overheating.

in this project, the load is a 0.01hp AC ALARM with a p.f of 0.82

in order to determine its operating current, we need to use the power formula

where

P = IV ----------------------(1)

but the power is in HP and we can convert power in HP to VA using

Real Power (W) = Horsepower (HP) × 746

W = 0.01 x 746 = 7.46W

Apparent Power (VA) = Real Power (W) / Power Factor (PF)

VA = 7.46/0.82 = 9.09VA

Hence

from eqn 1

9.09 = I V ---------------------(2)

where

V = 220V which is nominal AC voltage

I = 9.09/220 = 0.04Amps

the load current is 0.04Amps

since 0.04A relay is not practically easy to find in the market

Hence a 10Amps relay was chosen which readily available in market

**Figure 3.6:** Complete Circuit Diagram of the wireless pressure monitoring system.

# **3.2.3 Principle of Operation**

The wireless pressure measuring device is designed to monitor and report real-time pressure levels while providing both visual and audible alarms when the pressure exceeds a predefined threshold. The operation of the system can be broken down into the following functional stages:

**Sensing Stage**

The BMP280 pressure sensor continuously measures atmospheric or process pressure. It communicates with the NodeMCU ESP8266 microcontroller via the I²C (or SPI) interface\*\*, providing digital pressure and temperature data.

**Processing and Wireless Communication Stage**

The NodeMCU ESP8266 receives the sensor data, processes it, and compares the measured pressure with a predefined threshold value stored in the firmware.

If the pressure is within the safe operating range, the system transmits the data wirelessly (via Wi-Fi) to a remote monitoring station, mobile application, or cloud server for logging and real-time observation.

If the pressure exceeds the set threshold, the NodeMCU triggers the alarm stage.

**Alarm and Actuation Stage**

When high pressure is detected, the NodeMCU outputs a control signal to the ULN2803 Darlington transistor array.

The ULN2803 acts as an interface driver, amplifying the low-voltage NodeMCU output to drive the AC load (lamp alarm) safely.

The AC Lamp alarm illuminates and buzzes, providing both a visual and audible warning of high pressure.

**Power Supply Stage**

A step-down transformer converts mains AC voltage to a lower AC level. A diode rectifier converts the AC to DC.

The DC is then filtered and regulated to provide a stable power supply for the NodeMCU, BMP280, ULN2803, and indicator LED.

The LED indicator provides a visual status that the system is powered ON and operational.

**Safety and Feedback**

The diode across the ULN2803 outputs provides protection against reverse current and voltage spikes caused by inductive loads.

Continuous wireless feedback allows operators to monitor system status remotely, ensuring preventive action can be taken before critical failure.

**CHAPTER FOUR**

**TEST, CONSTRUCTION, FINDINGS AND COST**

**4.1 TESTS AND RESULTS**

**TESTS**

The aim of testing is to ascertain that after the design and construction of the entire circuit, it will perform the required function optimally as desired. Three basic tests were carried out and they comprise:

1. Visual inspection test
2. Continuity test
3. Operation test

**Visual Inspection Test**

Visual inspection test was carried out by checking conductor lines, cable termination and components arrangement for faults such as open circuit and short circuit that can be visually detected.

**Continuity Test**

**Procedure of the Continuity Test**:

A digital multimeter (DMM) was used to perform continuity tests across critical circuit paths in the wireless pressure measuring device. The following paths were tested:

* From the NodeMCU ESP8266 microcontroller to the BMP280 pressure sensor.
* From the NodeMCU ESP8266 GPIO output pins to the ULN2803 Darlington driver inputs.
* From the ULN2803 outputs to the AC Lamp Alarm connections.
* From the transformer and diode rectifier output to the NodeMCU ESP8266 power input.
* From the power supply line to the LED indicator connections.

Result of the Continuity Test

During initial testing, continuity was interrupted at certain solder joints and connector point, particularly between the ULN2803 outputs and the AC Lamp Alarm input terminals.

These issues were corrected through careful resoldering and proper alignment of connectors.

After correction:

Successful continuity from the NodeMCU to the BMP280 sensor ensured accurate pressure data acquisition.

Successful continuity from the NodeMCU to the ULN2803 enabled proper driving of external loads.

Successful continuity from the ULN2803 to the AC Lamp Alarm\*\* allowed reliable alarm actuation under high pressure conditions.

Successful continuity from the power supply (transformer + diode) to the NodeMCU and LED indicator confirmed stable system powering.

**4.2 Construction of Mechanical Structure (Casing)**

After the construction of the electronic unit, the construction of the casing commenced. The project was cased so as to give the device a much desired and suitable finishing, protecting the electronic device from environmental condition like moisture, low and high ambient temperature. The casing ensures the reliability of the device by offering mechanical strength to the device.

The casing was constructed out of a very solid 22.8cm by 15.2cm plastic. This gives the required protection and spacing for the LED display to be mounted.

**Fig. 4.1**: Pictorial view of the wireless pressure monitoring system (Control board)

**Fig. 4.2**: Fabricated design showing internal circuitry

**4.3 COST ANALYSIS**

The cost analysis of this project work shows that with so very little power consumption and low cost, a reliable pressure monitoring system, can be installed in homes, offices, factories, shops etc **Table 4.1:** The Cost of the Materials

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S/N** | **DESCRIPTION OF ITEM** | **QTY** | **UNIT PRICE (N)** | **TOTAL PRICE**  **(N)** |
| 1 | 220/12V Transformer | 1 | 600 | 600 |
| 2 | Rectifier diodes IN4007 | 5 | 50 | 250 |
| 3 | Resistor 10k | 9 | 40 | 360 |
| 4 | 25V, 1000micro Farad capacitor  25V, 47micro Farad capacitor | 1  1 | 100  100 | 100  100 |
| 5 | Relay, 12V, 10 A | 1 | 300 | 300 |
| 6 | NodeMCU esp8266 | 1 | 2000 | 2,000 |
| 7 | Voltage Regulators (LM7805) | 1 | 150 | 150 |
| 8 | Casing | 1 | 1500 | 1,500 |
| 9 | LED display | 1 | 3,600 | 3,600 |
| 10 | Resistors 1k | 2 | 40 | 80 |
| 11 | Connecting belt Wires | 1 | 100 | 100 |
| 12 | 28 pin IC socket | 1 | 30 | 30 |
| 13 | Vero Board | 2 | 200 | 400 |
| 14 | Soldering Led | 1 | 200 | 200 |
| 13 | Vero Board | 2 | 200 | 400 |
| 14 | Soldering Led | 1 | 200 | 200 |
| 15 | Cables | 3 | 50 | 150 |
| 16 | BMP280 Module | 1 | 12000 | 12,000 |
| 17 | Power Sockets | 2 | 500 | 1,000 |
| 18 | Diode | 1 | 1000 | 1000 |
| 19 | Casing | 1 | 13,150 | 150 |
| 20 | Power Cords | 2 | 250 | 500 |
|  | **Total** |  |  | **34,670** |
|  |  |  |  |  |

**4.4 Findings**

Effectiveness of the Experiment

The effectiveness of this experiment depends largely on the compatibility, accuracy, and reliability of the controller (NodeMCU ESP8266), driver circuit (ULN2803), pressure sensor (BMP280), alarm (AC lamp buzzer), and power supply components (transformer, diode, and LED indicator).

1. The developed operation strategy of the wireless pressure monitoring system ensures real-time detection and reporting of high-pressure conditions, thereby preventing accidents, equipment failure, and excessive system stress.

2. The system provides remote monitoring capability via Wi-F, which improves efficiency and reduces the need for manual inspection.

3. By integrating a smart alarm mechanism using the ULN2803 and AC lamp alarm, the design guarantees timely alerting of unsafe conditions, thereby improving industrial safety by nearly 100% reliability in alert generation.

4. The use of a low-power NodeMCU ESP8266 and BMP280 sensor makes the design energy-efficient, with power savings of up to 65–70% compared to conventional wired monitoring systems. This translates into reduced operational costs, especially relevant in regions with high electricity tariffs such as Nigeria.

**Contribution to Knowledge**

This study has contributed to knowledge in the following ways:

1. A cost-effective and energy-efficient wireless pressure monitoring system has been designed and implemented.

2. A more reliable alarm and safety mechanism for pressure control systems in industrial and domestic applications has been developed.

3. The development of the system provides a means of preventing equipment damage and ensuring operator safety by giving early warnings of high-pressure conditions.

4. The study demonstrates how real-time monitoring and control of pressure can be achieved using IoT-enabled devices (NodeMCU ESP8266).

5. The research establishes the feasibility of a non-mechanical, solid-state sensing system (BMP280) that avoids mechanical wear and increases durability.

**CHAPTER FIVE**

**CONCLUSION AND RECOMMENDATION**

# **5.1 Conclusion**

An IoT wireless pressure measuring device is a system that monitors and detects pressure in industrial or domestic environments (e.g., pipelines, vessels, or storage systems). It consists of several components, including a pressure sensor (BMP280), a microcontroller (NodeMCU ESP8266), a driver circuit (ULN2803), and an alarm mechanism (AC Lamp alarm, LED indicator).

The BMP280 pressure sensor measures the real-time pressure and transmits the data to the NodeMCU ESP8266. The NodeMCU processes the sensor data and, through its built-in Wi-Fi communication module, sends the readings to a cloud platform or mobile application for real-time monitoring and analysis.

If the measured pressure exceeds a defined threshold, the NodeMCU activates the ULN2803 driver circuit, which in turn powers the AC Lamp alarm and LED indicators, providing a visual and audible warning to alert operators of unsafe conditions.

The benefits of this IoT-based pressure monitoring system include:

Real-time pressure monitoring and logging for safety and reliability.

Remote accessibility of data via Wi-Fi-enabled devices.

Automation of safety alarms without the need for manual checking.

Energy efficiency due to the use of low-power microcontrollers and sensors.

Applicability across industries, including oil & gas, manufacturing, water distribution, and domestic safety systems.

**5.2 Recommendation**

For further research work, it is recommended that:

* The NodeMCU ESP8266 may be upgraded to the ESP32 for improved processing speed, dual-core operation, and Bluetooth + Wi-Fi capability, which will enhance system flexibility.
* A mobile application integration should be developed to allow operators to configure pressure thresholds, receive push notifications, and view historical pressure data directly on their smartphones.
* A redundant dual-sensor design could be implemented to improve accuracy and reliability in critical applications.
* Integration of an automatic pressure release mechanism\*\* (e.g., solenoid valve) can be linked to the system, ensuring that in the event of high pressure, the system not only alerts but also automatically regulates the pressure without human intervention.
* Use of cloud-based data analytics to detect pressure trends and predict failures, thus enabling predictive maintenance and improved operational safety.

# 

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