

Transformer Health Monitoring Using IoT Technology

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Abstract: *Power transformers are important parts of electrical power systems. Their reliable operation depends on temperature, loading, insulation and environmental conditions. Manual inspection at intervals may not identify an abnormal condition immediately.*

This project presents a laboratory-scale Transformer Health Monitoring System using an Arduino Uno, sensors, a character LCD, relay modules and GSM communication. The prototype demonstrates temperature measurement, approximate liquid-level measurement, flood detection, DC load voltage and current measurement, load switching, local alarms and remote alerts.

A DS18B20 sensor measures temperature. An HC-SR04 ultrasonic sensor measures distance to the surface of a demonstration liquid, which the Arduino converts to a percentage using configured empty and full distances. An ACS712 sensor measures demonstration-load current, while a voltage-divider circuit measures DC load voltage. The LCD shows operating values and status.

In the report design, a temperature reading above 48°C triggers a warning/protection sequence; the lower reset threshold is 47°C. Flood detection also activates an alarm and line-disconnection relay. The SIM800L module is intended to send an SMS and place a call for a high-temperature event.

The prototype demonstrates the relationship between sensing, controller logic, protection actions and communication. It is an educational model and must not be treated as certified protection equipment for a real power transformer..

Keywords: Transformer monitoring, Arduino Uno, IoT, DS18B20, ACS712, ultrasonic sensor, GSM, relay protection

I. INTRODUCTION

1.1 Introduction

A transformer transfers electrical energy between circuits by electromagnetic induction and is used to step voltage up or down. Distribution transformers supply electricity to domestic, commercial and industrial consumers. Their operation can be affected by overloading, overheating, abnormal voltage, low oil level and environmental hazards such as flooding.

Temperature, current and voltage readings help describe operating conditions. Oil level is relevant to oil-filled transformers because insulating oil supports insulation and cooling. A monitoring controller can collect sensor signals, compare values with configured limits, display readings and trigger an alarm when a condition needs attention.

1.2 Problem Statement

Traditional inspection may rely on periodic manual checks. An abnormal condition can arise between inspections, potentially delaying corrective action. The project therefore demonstrates a compact system that monitors selected parameters and provides local indication, automatic relay action for defined conditions, and GSM notification for high temperature.



1.3 Proposed Approach

Collect sensor readings with an Arduino Uno.

Display temperature, approximate oil-level percentage, voltage, current and load status on a 20×4 LCD.

Use programmed thresholds to demonstrate fault detection.

Operate a relay, buzzer and red indicator for selected abnormal conditions.

Use a SIM800L GSM module for SMS/call alerts, subject to adequate power and cellular service.

II. OBJECTIVES AND SCOPE

2.1 Objectives

Monitor temperature using a DS18B20 sensor.

Demonstrate non-contact liquid-level measurement using an HC-SR04 ultrasonic sensor.

Measure demonstration-load DC current using an ACS712 module.

Measure demonstration-load DC voltage using a voltage-divider circuit.

Detect water/flood conditions with a water-detection arrangement.

Display measurements and fault messages on a 20×4 LCD.

Demonstrate line disconnection and second-load control using relay modules.

Generate local alarms and GSM notifications for configured events.

2.2 Scope and Boundaries

The system is a laboratory prototype. The described voltage-divider and ACS712 arrangements are for the demonstration DC load, not direct measurement of a 230 V AC primary circuit. The ultrasonic sensor reports distance; the displayed percentage depends on the physical tank geometry and the empty/full calibration values.

III. LITERATURE SURVEY AND RESEARCH GAP

The supplied report describes four broad approaches: conventional manual inspection, microcontroller-based sensing, wireless monitoring and IoT-based monitoring. Conventional approaches can be simple but may require personnel at the equipment location. Microcontrollers automate reading and threshold comparison. Wireless links allow information to be sent to a remote receiver, while IoT dashboards can present readings remotely and may retain historical data.

The report identifies gaps in basic systems: limited continuous monitoring, lack of remote access, limited historical records, delayed alerts, integration complexity and insufficient handling of invalid sensor data or communication failure. This prototype combines several sensors, a controller, display, relay action and GSM alerting in one educational setup.

AI or predictive analytics are discussed as possible extensions in the original report, but should only be claimed as implemented if a trained model and validated analysis are actually part of the working prototype.

IV. SYSTEM OVERVIEW AND BLOCK DIAGRAM

The system can be understood as five connected sections: sensing, controller, display/alarms, relay outputs, and power/communication.



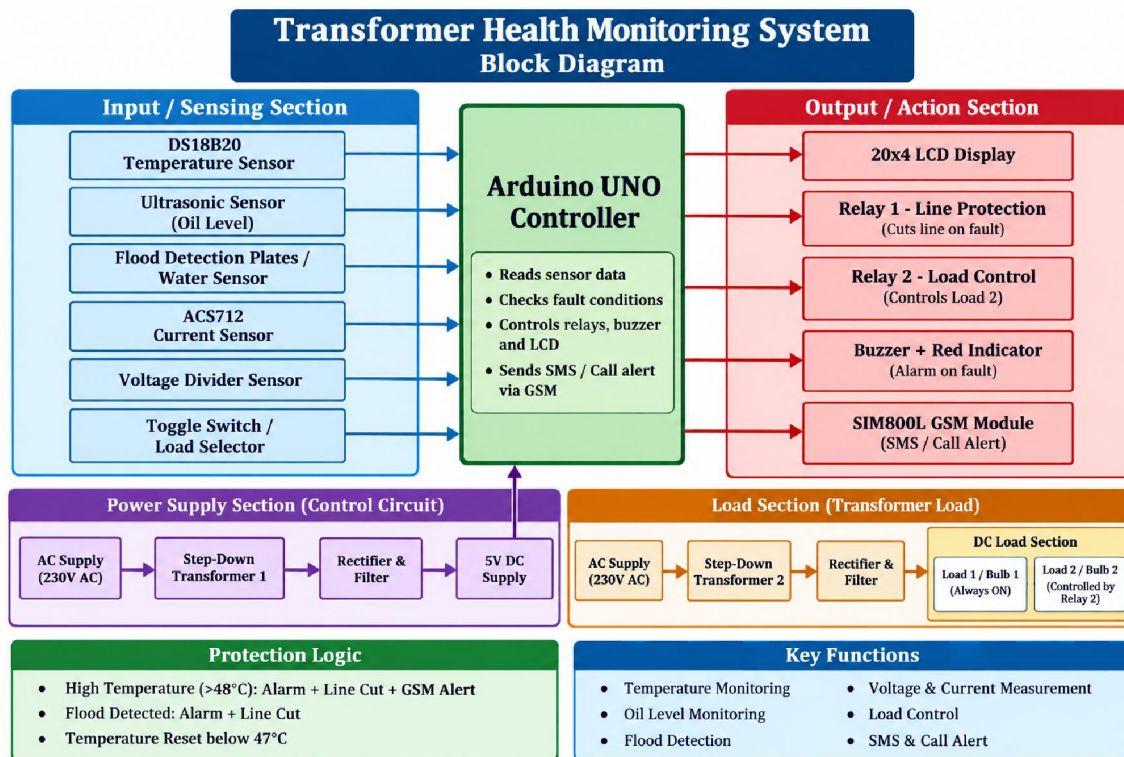


Figure 1. Block diagram reproduced from the supplied report.

4.1 Signal Flow

Sensors collect temperature, distance/liquid level, flood status, current and voltage information.

The Arduino reads sensor signals and calculates or interprets the measured values.

The controller compares the readings with programmed conditions, including high temperature and flood detection.

The LCD presents normal measurements or warning messages.

Relay outputs disconnect the demonstration transformer line or switch the second load; the buzzer and red indicator provide local warnings.

For a high-temperature event, the GSM module is commanded to send an SMS and initiate a call.



V. CIRCUIT DIAGRAM AND FUNCTIONAL CONNECTIONS

Transformer Health Monitoring System – Circuit Diagram

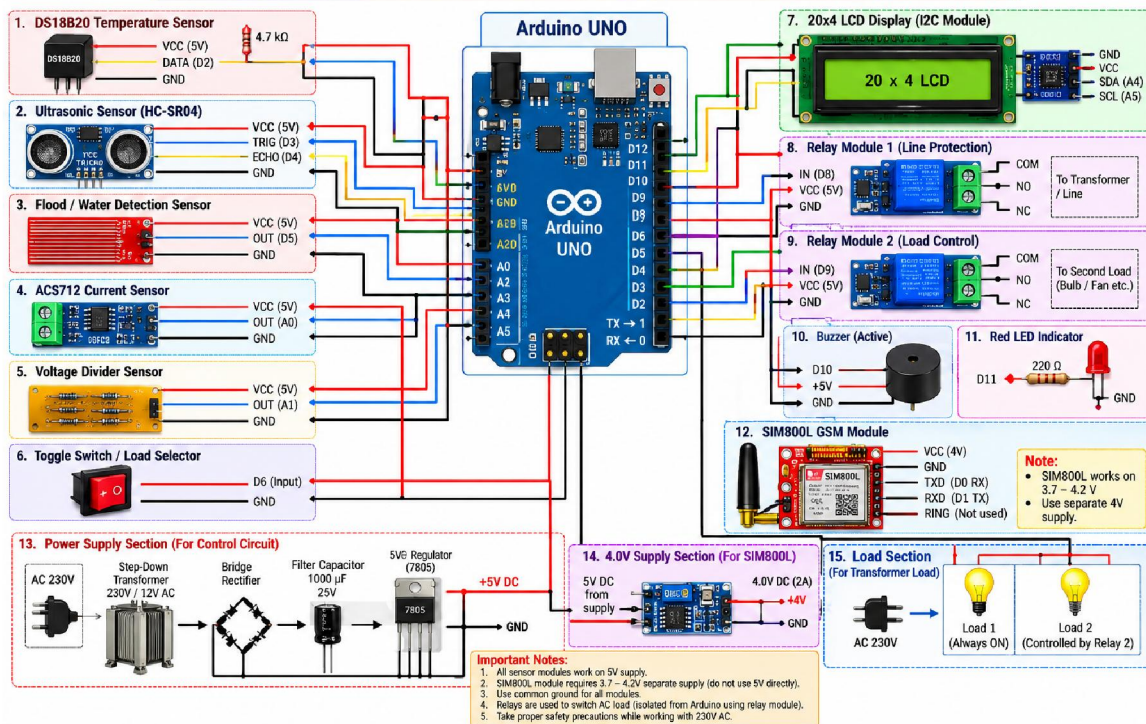


Figure 2. Circuit diagram reproduced from the supplied report. Use the actual pin assignments in the final working sketch and verify them against the assembled hardware.

5.1 Main Connection Groups

DS18B20: data line to a digital input, with the required pull-up resistor; VCC and GND to the suitable supply.

HC-SR04: VCC, GND, TRIG and ECHO connected to suitable Arduino pins.

Flood sensor: digital output connected to an Arduino input; verify whether the module output is active-LOW or active-HIGH.

ACS712: supply and ground connected correctly; analog output connected to an Arduino analog input.

Voltage divider: output connected to an analog input only after confirming the input stays within the Arduino's safe voltage range.

LCD and relay modules: connect control pins and supply/ground as required by the actual modules.

SIM800L: use a stable supply within its specified voltage range and a suitable logic interface; do not power it directly from an Arduino pin.

Safety: the diagram includes mains-powered sections. Mains wiring can cause fatal electric shock or fire. Assembly and testing of the 230 V section must be done only by a qualified supervisor using isolation, fusing, enclosure and appropriate protective practices. Never connect Arduino inputs directly to mains.



VI. HARDWARE COMPONENTS

6.1 Arduino Uno

The Arduino Uno is the central controller. It reads the sensor inputs, performs calculations and threshold checks, updates the LCD, and controls relay, buzzer, indicator and GSM commands.

6.2 DS18B20 Temperature Sensor

This digital sensor measures temperature and communicates using the OneWire interface. The supplied report specifies a high-temperature threshold of 48°C and a reset threshold of 47°C. These are prototype program settings, not universal safe limits for all transformers.

6.3 HC-SR04 Ultrasonic Sensor

The sensor sends an ultrasonic pulse and measures the time taken for its echo to return. The Arduino calculates distance from the echo time. To display a level percentage, the program uses calibrated empty and full distances. This measures distance to a surface; it does not directly measure oil quality or oil temperature.

6.4 Flood Detection Sensor

Two conductive sensing surfaces or a water-detection module provide a signal when water bridges the sensing area. The controller interprets the signal as a flood condition and activates the programmed alarm/protection response. Keep the sensing arrangement electrically isolated from hazardous circuits.

6.5 ACS712 Current Sensor

The ACS712 provides an analog output related to current through its conductor. The report identifies a 30 A variant for the demonstration load. Accurate readings require the correct sensor variant, zero-current calibration, sensitivity value and suitable wiring.

VII. HARDWARE COMPONENTS (CONTINUED)

7.1 Voltage-Divider Measurement Circuit

A resistor divider scales a DC voltage to a smaller value that the Arduino analog input can measure. The program reconstructs the input voltage using the divider ratio and ADC reference. The divider must be designed so the analog input never exceeds its permitted range.

7.2 20×4 LCD

The 20×4 character LCD provides four rows of twenty characters for live measurements and status messages. It can show temperature, level percentage, voltage, current, load status and warnings.

7.3 Relay Modules

Relay 1 is described as the demonstration line-protection relay. Relay 2 controls the second lamp/load. The actual contact arrangement and active logic must be confirmed on the installed modules. A relay module in this educational prototype is not a substitute for a certified transformer protection system.

7.4 Buzzer and Red LED

The buzzer gives an audible alarm and the red LED gives a visual warning when a programmed fault condition is active.

7.5 SIM800L GSM Module

The SIM800L communicates with the Arduino over serial communication and can send SMS messages or initiate calls. Reliable operation requires a supported cellular network, SIM service, correct antenna and a stable supply capable of handling current peaks.

7.6 Power Supply and Loads

The report describes separate power paths for the control electronics and demonstration transformer/load. A 230 V-to-12 V step-down transformer, rectifier, filter and regulator may be used in the supply path as designed. The prototype lamps illustrate how adding a second load changes the measured current.



VIII. SOFTWARE AND WORKING PRINCIPLE

8.1 Software

The report uses the Arduino IDE and Arduino C/C++. The listed libraries are LiquidCrystal for the LCD, OneWire and DallasTemperature for the DS18B20, and SoftwareSerial for the GSM module.

8.2 Operating Sequence

Power on the control circuit and initialize the LCD, sensors, relay outputs and GSM serial interface.

Read the temperature sensor, ultrasonic distance, flood input, current sensor and voltage-divider input.

Convert raw readings into engineering values using calibration constants.

Display the measurements and the current system status.

Compare readings with the programmed conditions.

If temperature exceeds the configured threshold, activate the local warning and protection response and request a GSM alert.

If flood detection is active, activate the flood warning and disconnect the demonstration line as programmed.

Return to normal only when the reset conditions in the program are satisfied.

8.3 Level Percentage Calculation

The ultrasonic sensor measures distance from the sensor to the liquid surface. A common calibration approach is: level height = tank reference height – measured distance; level percentage = (level height ÷ usable tank height) × 100. The actual code must use the prototype's calibrated empty/full distances and limit the result to 0–100%.

IX. FAULT RESPONSE, TESTING AND RESULTS

9.1 Programmed Fault Response

High temperature: the supplied report specifies trip above 48°C and reset below 47°C. This gap is hysteresis, used to reduce rapid relay switching near the threshold.

Flood detected: the controller activates the alarm and line-disconnection response. The report describes restoring operation only after the flood input remains clear for approximately four seconds, provided no temperature fault remains.

Load selection: a toggle switch requests the second load; the relay logic prevents the second load from remaining active during a system fault.

Voltage/current: readings are displayed to observe the demonstration load. The supplied report does not establish a validated overcurrent or overvoltage trip threshold, so do not claim those measurements independently trip protection unless the final code does so.

9.2 Testing Procedure

Compare temperature readings with a reference thermometer over a safe temperature range.

Check ultrasonic distance at known positions and calibrate the empty/full level values.

Compare current readings with a suitable meter at multiple safe DC load conditions.

Compare voltage-divider readings with a multimeter and verify the Arduino input voltage remains safe.

Test flood sensing using a controlled low-voltage demonstration arrangement.

Verify LCD warnings, relay states, buzzer/LED operation, and GSM SMS/call response.

9.3 Observation Table

Test condition	Expected indication	Observed result	Pass/Fail
Normal operation	Readings on LCD	Fill from actual test	—
Temperature > 48°C	Alarm/relay/GSM alert	Fill from actual test	—



Flood input active	Flood message and line cut	Fill from actual test	—
Second load selected	Current/load status changes	Fill from actual test	—

No measured experimental readings have been invented in this report. Enter the values observed on your own prototype and include dates/instrument details where available.

X. ADVANTAGES, LIMITATIONS AND APPLICATIONS

10.1 Advantages

Combines several monitoring functions in one educational prototype.
Provides local display and audible/visual warnings.
Demonstrates automatic relay action for selected conditions.
Demonstrates remote GSM notification for high-temperature events.
Supports practical learning about sensors, embedded control and electrical monitoring.

10.2 Limitations

The prototype does not provide certified industrial transformer protection.
Ultrasonic level percentage depends on tank geometry and calibration.
ACS712 and voltage-divider accuracy depend on calibration and circuit design.
GSM alerts depend on network coverage, SIM service and module power supply.
A basic threshold controller does not itself provide AI prediction or validated fault diagnosis.

10.3 Applications

The prototype is suitable for laboratory demonstrations, student projects and learning about condition monitoring. Industrial deployment would require engineered sensors, isolation, suitable protection devices, robust communications, validated thresholds and compliance with applicable standards.

XI. FUTURE SCOPE AND CONCLUSION

Future improvements could include calibrated isolated voltage/current sensing, sensor-fault detection, data logging, a cloud dashboard, communication-health monitoring, and validated trend analysis. Any AI-based prediction should be implemented with real labelled data and evaluated before it is described as a project capability.

The project demonstrates how sensors, an Arduino Uno, an LCD, relays and GSM communication can work together to monitor selected conditions of a laboratory transformer setup. It provides a useful learning model for temperature monitoring, approximate liquid-level measurement, flood detection, electrical measurement and fault notification. Its results should be reported from actual prototype tests, and the system should not be used as the sole protection for a real transformer.

REFERENCES

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